Lac Qui Parle Yellow Bank Bacteria, Turbidity, and Low Dissolved Oxygen TMDL Assessment Report

Prepared for:

Lac qui Parle Yellow Bank Watershed District
600 6th Street, Suite 7
Madison, Minnesota 56256
(320) 598-3319

Prepared by:

WENCK ASSOCIATES, INC.
1800 Pioneer Creek Center
P.O. Box 249
Maple Plain, Minnesota 55359-0249
(763) 479-4200

January 2013

Wenck
Engineers • Scientists

wq-iw7-24e

Acknowledgements:

This Lac qui Parle Yellow Bank Watershed District TMDL study was conducted by Wenck Associates, Inc., Maple Plain, MN, in conjunction with the Lac qui Parle-Yellow Bank Clean Water Partnership (LQPYBCWP) organization and in cooperation with the Minnesota Pollution Control Agency (MPCA). Special thanks go to the LQPYBCWP's Mary Homan, whose local efforts with citizens and stakeholders gave the project strong impetus, and to the MPCA's Katherine Perkarek-Scott, whose project management kept things rolling. We have very much appreciated assistance from MPCA staff Nick Gervino, Marco Graziani, Lee Ganske, Emily Schnick, Anna Kerr, Kelli Nerem, Mark Hanson, and Gregory Johnson. Additional thanks to Chris Domeier and Shane Rustin with the Department on Natural Resources. Wenck's project staff consisted primarily of Pamela Kiel Massaro, Rich Brasch, Jeff Strom, and Wes Boll. This report was prepared mainly by Ms. Massaro.

Table of Contents

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

TABLES

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

FIGURES

Table of Contents (Continued)

Table of Contents (Continued)

APPENDICES

TMDL Summary

EPA/MPCA Required Elements	Summary	TMDL Page Number
Location	Minnesota River basin; Western Minnesota and Eastern South Dakota	Executive Summary p.xv Section 1.2 p1-1
303(d) Listing Information	Total of 19 listings for bacteria, turbidity and low dissolved oxygen (DO) in eleven assessment unit IDs: *See Table 1.5 p1-9*	Table 1.5 p1-9 Table 1.6 p1-10
Applicable Water Quality Standards/ Numeric Targets	*See Section 1.6* Bacteria: *See Section 2.1* Turbidity: *See Section 3.1* Low DO: *See Section 4.1*	Bacteria Section 2.1 p2-1 Turbidity Section 3.1 p3-1 Low DO Section 4.1 p4-1
Loading Capacity (expressed as daily load)	Bacteria: *See Section 2.4* Turbidity: *See Section 3.4* Low DO: *See Section 4.4*	TMDL Table (p.xiii) **Critical Conditions** Bacteria Section 2.6 p2-41 Turbidity Section 3.6 p3-35 Low DO Section 4.6 p4-24
Wasteload Allocation	Bacteria: *See Section 2.4* Turbidity: *See Section 3.4* Low DO: *See Section 4.4* The general permit numbers for construction and industrial stormwater are as follows: Construction: MN R100001 Industrial: MN R050000	TMDL Table (p.xiii) **Reserve Capacity** Bacteria Section 2.7 p2-42 Turbidity Section 3.7 p3-35 Low DO Section 4.7 p4-24
Load Allocation	Bacteria: *See Section 2.4* Turbidity: *See Section 3.4* Low DO: *See Section 4.4*	TMDL Table (p.xiii)

EPA/MPCA Required Elements	Summary	TMDL Page Number
Margin of Safety	Bacteria: An explicit 10% MOS was used. *See Section 2.3.2* Turbidity: An explicit 10% MOS was used. *See Section 3.3.2* Low DO: An explicit 10% MOS was used, in addition to an implicit MOS. The MOS is implicit by incorporating conservative model assumptions; *See Section 4.3.5*	TMDL Table (p.xiii) **MOS** Bacteria Section 2.3.2 p2-10 Turbidity Section 3.3.2 p3-10 Low DO Section 4.3.3.5 p4-21

TMDL Table – TMDL Page Number for LC, WLA, LA and MOS

Assessment Unit ID (AUID)	Bacteria Impairments	Turbidity Impairments	Low Dissolved Oxygen Impairment
07020003-521	Table 2.15, p 2-15	Table 3.14, p 3-17	~not listed~
07020003-508	Table 2.19, p 2-17	Table 3.18, p 3-18	~not listed~
07020003-512	Table 2.24, p 2-18	~not listed~	~not listed~
07020003-516	Table 2.28, p 2-20	Table 3.22, p 3-20	~not listed~
07020003-505	Table 2.33, p 2-21	Table 3.27, p 3-21	~not listed~
07020003-506	Table 2.37, p 2-22	Table 3.31, p 3-23	~not listed~
07020003-501	Table 2.42, p 2-24	Table 3.36, p 3-25	Table 4.10, p4-23
07020003-511	Table 2.46, p 2-26	~not listed~	~not listed~
07020001-510	Table 2.49, p 2-27	~not listed~	~not listed~
07020001-526	Table 2.52, p 2-28	~not listed~	~not listed~
07020001-525	Table 2.56, p 2-29	Table 3.40, p 3-26	~not listed~

EPA/MPCA Required Elements	Summary	TMDL Page Number
Seasonal Variation	Bacteria: Load duration curve methodology accounts for seasonal variations; *See Section 2.6* Turbidity: Load duration curve methodology accounts for seasonal variations; *See Section 3.6* Low DO: TMDL was developed to target the critical conditions, i.e., late summer low flow period after a storm event; *See Section 4.5*	Bacteria Section 2.6 p2-41 Turbidity Section 3.6 p3-35 Low DO Section 4.5 p4-23
Reasonable Assurance	Information is presented regarding BMPs to address impairments of bacteria, turbidity and low DO. Since they have several sources and some common delivery pathways, most of the strategies have multiple water quality benefits in terms of load reductions though implementation. NPDES permits provide assurances for permitted sources to comply with WLAs; *See Section 6.1*	Section 6.0 p6-1
Monitoring	A general overview of follow-up monitoring is included; *see Section 5.2*	Section 5.2 p5-6

EPA/MPCA Required Elements	Summary	TMDL Page Number
Implementation	This report sets forth an implementation framework and general load reduction strategies, as well as a rough approximation of the overall implementation cost to achieve the TMDL. (A separate more detailed implementation plan will be developed within one year after of EPA's approval of this TMDL report.) *See Section 5.0*	Section 5.0 p5-1
Public Participation	· Public Comment Period (May 29, 2012 – June 27, 2012) · Comments received · Summary of other key elements of public participation process	Section 7.0 p7-1

Executive Summary

This Total Maximum Daily Load (TMDL) report addresses the 19 impairments on eight reaches of the Lac qui Parle River and three reaches of the Yellow Bank River. All these impairments are located within the Lac qui Parle – Yellow Bank Watershed District (LQPYBWD). Eleven of the impairments are for bacteria, seven impairments are for turbidity and one impairment is for low dissolved oxygen. These reaches are listed on Minnesota's final 2008 and draft 2010 303(d) lists as being impaired due to not supporting their designated aquatic life and aquatic recreation uses. The goal of this TMDL report is to quantify the pollutant reductions needed to meet State water quality standards as required by the Clean Water Act.

The LQPYBWD is located in west central Minnesota, on the southwest side of the Minnesota River. Portions of the watersheds are located in South Dakota and Minnesota. The watersheds have a drainage area of approximately 1,538 square miles in western Minnesota (824 square miles) and eastern South Dakota (714 square miles). The Lac qui Parle starts at Lake Hendricks in Lincoln County and flows north through Yellow Medicine and Lac qui Parle Counties. Coming off the Coteau, a high glacial landform occupying southwestern Minnesota, southeastern South Dakota, and northwestern Iowa, there is a 1,070-foot drop in elevation in the first 60 river miles. The Yellow Bank River is located in the northern portion of Lac qui Parle County. In Minnesota, the watershed includes the cities of Bellingham, Boyd, Dawson, Louisburg, Madison, Marietta, Nassau, Canby and Hendricks. Land use is dominated by agricultural cropping. Point sources (permitted municipal and industrial dischargers) and a small number of unsewered communities also exist in the watershed. The portion of Lac qui Parle and Yellow Bank watersheds located within Minnesota are predominately comprised of two agroecoregions, the Coteau and the Dryer Blue Earth Till.

Fecal coliform and *Escherichia coli* (*E. coli*) **bacteria** are "indicator organisms," meaning that not all the species of bacteria of this category are harmful, but they are usually associated with harmful organisms transmitted by fecal contamination. They are found in the intestines of warm-blooded animals, including humans and livestock. The presence of indicator organisms in water suggests the presence of fecal matter and associated bacteria (i.e. some strains of fecal coliform and *E. coli*), viruses, and protozoa (i.e. Giardia and *Cryptosporidium*) that are pathogenic to humans when ingested (USEPA 2001a). The TMDLs reported in this report are based on meeting the 2008 state chronic standard for *E. coli* of 126 colony-forming unit (cfu) /100 ml. The TMDLs were established using a load duration analysis as described by Cleland (2002) which integrates flow and the bacteria standard to provide loading capacities and allocations across the full range of flows. While it is known that bacteria levels are affected by seasonal weather, water temperature, stream flow, distance from pollution sources, livestock management, wildlife activity, age of fecal material, sewage overflows, and rainfall, bacteria also die-off, hibernate and multiply in soils, beaches and stream sediments. Thus, from a pragmatic standpoint, there may be a fraction of bacteria that will exist in streams and rivers regardless of most traditional implementation strategies to control bacteria sources. Among sources that could be controlled through traditional implementation practices, the ones deemed most significant in this TMDL report, based on the data available, were over-grazed riparian pasture and noncompliant septic systems (including "straight pipe" septics) during dry conditions, and surface applied manure, over-grazed pasture, and feedlots without runoff controls during wet conditions. The primary contributing sources to bacteria in this TMDL report, based on the data available, were attributed to over-grazed riparian pasture and noncompliant septic systems (including "straight pipe" septics) during dry conditions, and surface applied manure, over-grazed pastures, and feedlots without runoff controls during wet conditions.

Turbidity in water is caused by suspended sediment, organic material, dissolved salts, and stains that scatter light in the water column, making the water appear cloudy. Excess turbidity can degrade aesthetic qualities of water bodies, increase the cost of treatment for drinking water or food processing uses, and harm aquatic life. Adverse ecological impacts caused by excessive turbidity include hampering the ability of aquatic organisms to visually locate food, negative effects on gill function, and smothering of spawning beds and benthic organism habitat. Since turbidity is a measure of light scatter and adsorption, loads need to be developed for a surrogate parameter. Total suspended solids (TSS) is a measurement of the amount of sediment and organic matter suspended in water and is often used as a turbidity surrogate to define allocations and capacities in terms of daily mass loads. The TMDLs reported in this report are based on meeting the turbidity standard of 25 nephelometric turbidity units (NTU) corresponding to a surrogate TSS concentration of 45 mg/L, a level based on paired data collected in the watershed. The TMDLs were established using a load duration analysis as described by Cleland (2002) which integrates flow and the turbidity standard to provide loading capacities and allocations across the full range of flows. The primary contributing sources to the turbidity impairments on the Lac qui Parle River and Yellow Bank River sites were found to be runoff-driven mechanisms, such as delivery of sediment to the river from upstream areas and/or bank instability under higher flow conditions during significant storm events during the spring and summer months. Sources on Florida Creek and Lazarus Creek include runoff driven processes that deliver sediment, bank instability, livestock access to the stream, and/or point source inputs such as from noncompliant septic systems. West Branch Lac qui Parle River (Lost Creek to Florida Creek) data suggest a variety of causes, which could include runoff driven processes that deliver sediment, bank instability, livestock access to the stream, and/or point source inputs such as biosolids from noncompliant septic systems.

Dissolved oxygen (DO) is an important water quality parameter for the protection and management of aquatic life. All higher life forms, including fish and aquatic macroinvertebrates, are dependent on minimum levels of oxygen for critical life cycle functions such as growth, maintenance, and reproduction. Problems with low dissolved oxygen in river systems are often the result of excessive loadings of carbonaceous biochemical oxygen demand (CBOD) and nitrogenous biochemical oxygen demand (NBOD), particularly in combination with high temperatures and low flow conditions. The breakdown of organic compounds in the water column and/or sediment consumes water column DO. Organic matter loading to streams can come from both natural (plant, leaf and periphyton debris, in-situ primary production) and anthropogenic (wastewater effluent, agricultural animal feces) sources. The amount of oxygen that a given volume of water can hold is a function of atmospheric pressure, water temperature, and the amount of other substances dissolved in the water. The TMDLs were based on meeting the dissolved oxygen standard of 5.0 mg/L as a daily minimum. The TMDLs were established using hydraulic and water quality models developed to assess the conditions resulting in persistent low dissolved oxygen in Lac qui Parle River. A scenario assessment determined that the likely causes were low-oxygen discharge from headwater and diffuse source detritus loading resulting in excessive sediment oxygen demand.

A general strategy for implementation of diffuse source-related actions to address the impairments is provided in this document (a more specific implementation plan will be developed within one year of EPA's approval of this report and will be available as a separate report). Diffuse contributions are not regulated and, therefore, reductions will need to proceed on a voluntary basis. Point sources are regulated through the MPCA's National Pollutant Discharge Elimination System (NPDES) permit programs.

1.0 Introduction

1.1 PURPOSE

Section 303(d) of the Clean Water Act establishes a directive for developing Total Maximum Daily Loads (TMDLs) to achieve Minnesota water quality standards established for designated uses of State waterbodies. Under this directive, the State of Minnesota has directed that a TMDL be prepared to address bacteria and turbidity exceedances in both the Lac qui Parle River and Yellow Bank River systems, as well as, low dissolved oxygen in the lower reach of the Lac qui Parle River. The goal of the TMDL study is to quantify the pollutant reductions needed to meet State water quality standards. This report presents the results of the study.

A TMDL is defined as the maximum quantity of a pollutant that a water body can receive and continue to meet water quality standards for designated beneficial uses. Thus, a TMDL is simply the sum of point sources and diffuse sources in a watershed. A TMDL can be represented in a simple equation as follows:

$$\begin{aligned} TMDL = &\ \Sigma \text{ Wasteload Allocation (WLA; Point Sources)} \\ &+ \Sigma \text{ Load Allocation (LA; diffuse sources)} \\ &+ \text{Margin of Safety (MOS)} \end{aligned}$$

The wasteload allocation is the sum of the loads from all permitted sources and the load allocation is the sum of the load from all non-permitted sources. The Margin of Safety represents a load allocation to account for variability in environmental data sets and uncertainty in the assessment of the system. Other factors that must be addressed in a TMDL include seasonal variation, reserve capacity (which is an allocation for future growth), critical conditions, and stakeholder participation.

This TMDL report provides waste load allocations (WLAs), load allocations (LAs) and Margin of Safety (MOS) needed to achieve the state standard for each parameter in each impaired reach of the Lac qui Parle River and Yellow Bank River systems.

1.2 WATERSHED STUDY AREA

The headwaters for both the Lac qui Parle River and the Yellow Bank River are located in Deuel and Grant Counties, South Dakota. The Lac qui Parle River drains portions of Lincoln, Yellow Medicine, and Lac qui Parle counties in Minnesota. The West Branch and South Branch of the Lac qui Parle River join east of Dawson, Minnesota to form the main stem of the Lac qui Parle River. The Lac qui Parle River discharges ultimately to the Minnesota River just above Lac qui Parle dam and the County Highway 33 river crossing. The Yellow Bank River watershed is located in northeastern Lac qui Parle County (north of the Lac qui Parle River watershed.) The North Fork and the South Fork of the Yellow Bank River join in Yellow Bank Township Section

25 to form the main stem of the Yellow Bank River. The main stem Yellow Bank River ultimately discharges to the Minnesota River east of Odessa, MN (Figure 1.1).

Figure 1.1 – Location of the Lac qui Parle River and Yellow Bank River Watersheds.

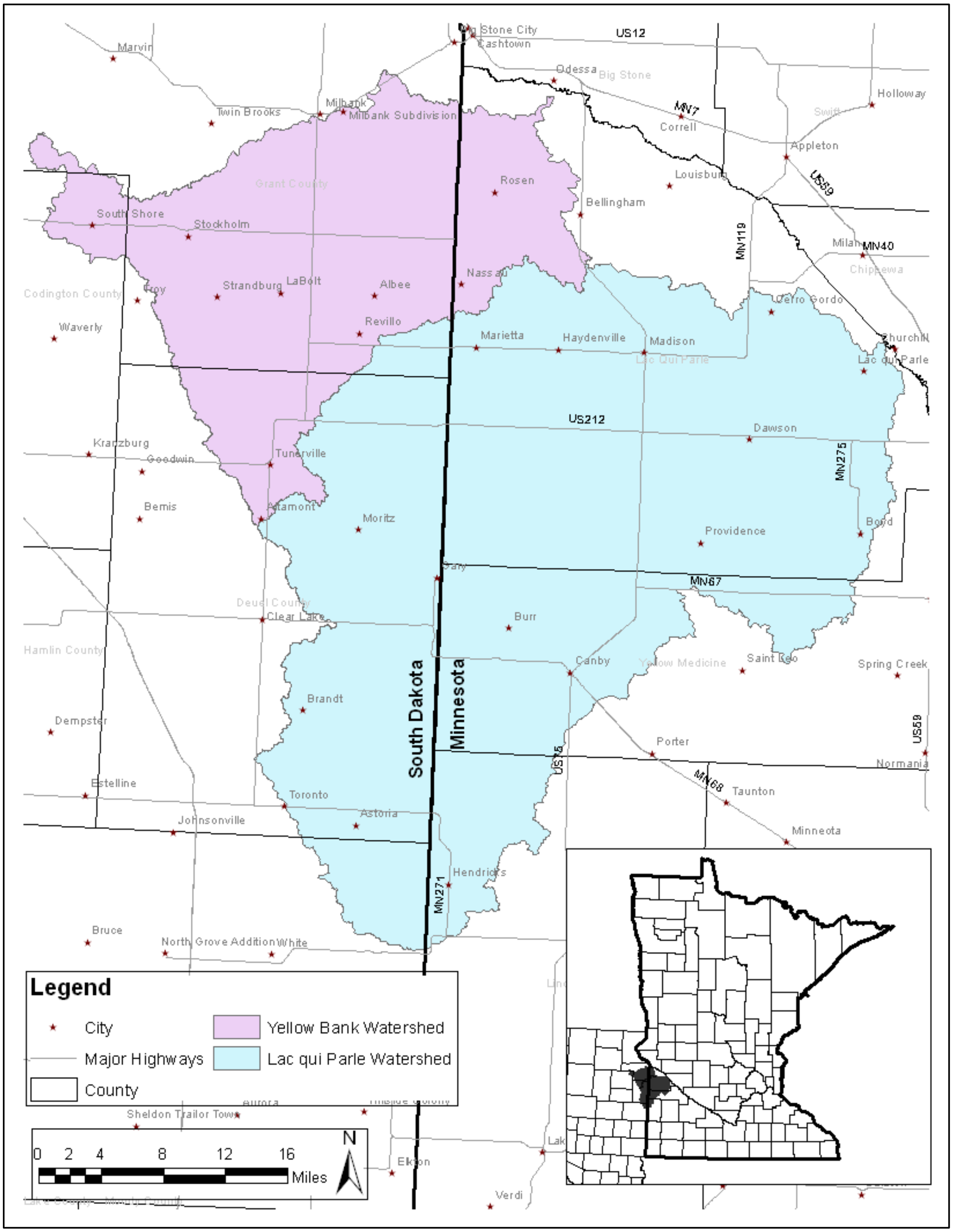


Table 1.1 shows the total watershed area for both the Lac qui Parle and Yellow Bank River at their respective discharge points to the Minnesota River. Also shown in the table is the area of each watershed that lies in Minnesota, expressed in both acres and as a percentage of the total watershed for each river.

Table 1.1 – Watershed Area by State

Watershed (8-digit Hydrologic Unit Code)	Total Area (Ac.)	Area in MN (Ac.)	% of Watershed in MN	% of Watershed in SD
Yellow Bank River Major Watershed (07020001)	282,044	37,923	13.4%	86.6%
Lac qui Parle River Major Watershed (07020003)	702,122	489,294	69.7%	30.3%
TOTAL	984,166			

1.3 SUMMARY BY ECOREGIONS, AGROECOREGIONS AND LAND COVER

The portion of both watersheds within Minnesota lies in the Northern Glaciated Plains (NGP) ecoregion, characterized by rolling terrain, fertile soils, and extensive cultivation for row crops. An ecoregion is a geographical area where the land use (agriculture, forest, prairie, etc.), underlying geology, potential native plant community, and soils are relatively similar. Ecoregion divisions are relatively coarse with seven ecoregions covering the entire state of Minnesota.

Advancement in land management research suggests

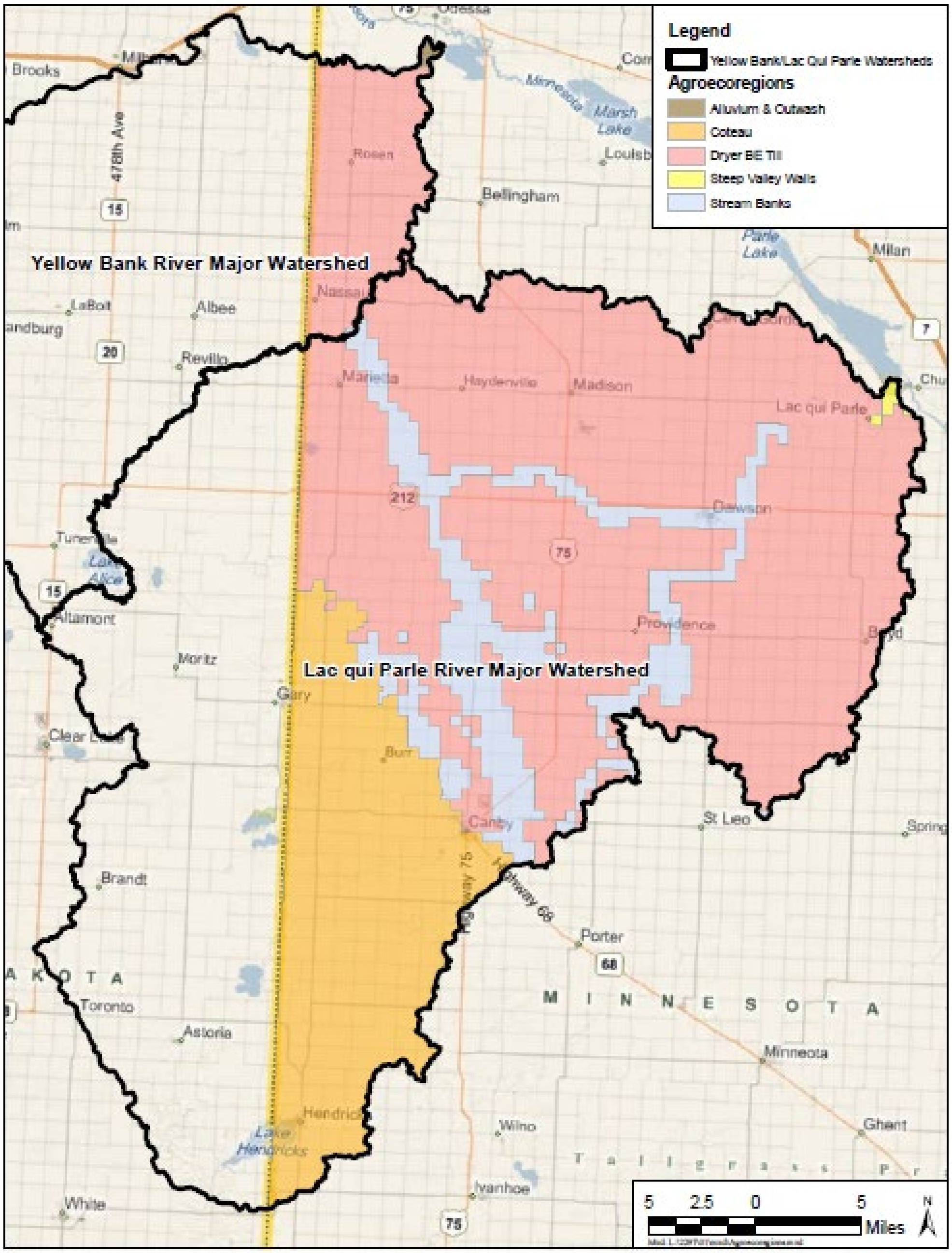
> "..that watershed management in highly agricultural watershed will be most effective when hydrologic watersheds are used as a framework that is complemented by agroecoregions to identify, and target regions where specific combinations of best management practices for agricultural sediment and phosphorus abatement are most appropriate." (Hatch et. al., 2001)

The concept of agroecoregions arose out of discussions organized and funded by the Minnesota Department of Agriculture beginning in 1995 (Mulla 2002). According to Mulla,

> "Agroecoregions are zones having unique soil, landscape, and climatic characteristics which confer unique limitations and potentials for crop and animal production. Each agroecoregion contains unique physiographic factors that influence the potential for production of nonpoint source pollution and the potential for adoption of farm management practices."

The portion of Lac qui Parle and Yellow Bank watersheds located within Minnesota are predominately comprised of two agroecoregions, the Coteau and the Dryer Blue Earth Till (Figure 1.2). Agroecoregions information is not readily available for South Dakota.

Figure 1.2 – Agroecoregions in the Lac qui Parle and Yellow Bank River Watersheds.



The following two tables summarize the percentage Minnesota acres by agroecoregion within the project area watershed.

Table 1.2 – Yellow Bank River Watershed Agroecoregions Summary

Agroecoregion Type	Percentage of Type in MN
Stream Banks	0.3%
Alluvium & Outwash	1.4%
Dryer BE Till	98.3%
TOTAL	100.0%

Table 1.3 – Lac qui Parle River Watershed Agroecoregions Summary

Agroecoregion Type	Percentage of Type in MN
Steep Valley Walls	0.2%
Stream Banks	12.0%
Coteau	22.8%
Dryer BE Till	65.0%
TOTAL	100.0%

The Coteau agroecoregion is located primarily in the upper reaches of the Lac qui Parle River watershed and is characterized by landscapes with long northeastern facing slopes of moderate steepness (2-6%). The soils are predominantly loamy and well-drained, though much of the Coteau has a high water erosion potential due mainly to moderately steep slopes. The Dryer Blue Earth Till covers the middle and lower portions of the Lac qui Parle watershed and most of the Yellow Bank River watershed. Most of the land has relatively flat slopes (0-6%). Soils are predominantly loamy, with landscapes having a complex mixture of well and poorly drained soils. Drainage in depressional areas is poor where drainage tile is not used. Depressions in agricultural fields are commonly tile drained. Water erosion potential is moderate in most areas.

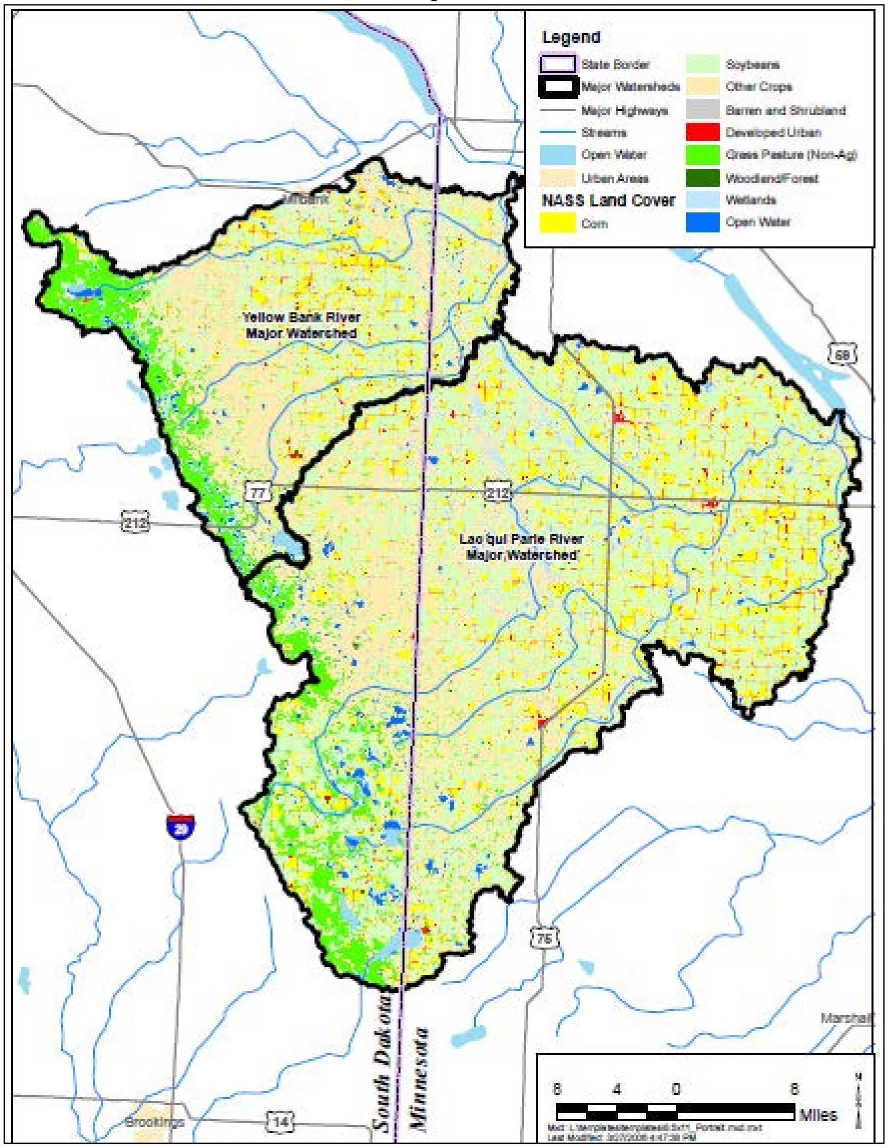
The land cover of the Lac qui Parle and Yellow Bank River project area watershed as provided by the National Agricultural Statistics Service (NASS) is shown in Figure 1.3. Table 1.4 presents the number of acres of each land cover type within the project area watershed in 2008, split out between Minnesota and South Dakota.

Table 1.4 – Watershed Land Cover by Type by State

NASS Land Cover Category (LCC)	Total Acres of LCC in Watershed	Percentage of LCC by Total Acres	Acres of LCC in Minnesota	Percentage of LCC by MN Acres
Corn	256,862	26%	166,145	32%
Soybeans	259,051	26%	172,690	33%
Other cropland	191,259	19%	92,046	18%
Grass Pasture (non-ag)	135,962	14%	13,095	2%
Woodland/Forest	11,336	1%	6,800	1%
Barren and shrubland	176	0%	74	0%
Developed Urban	63,979	7%	36,850	7%
Water	15,058	2%	4,855	1%
Wetlands	49,682	5%	32,352	6%
TOTAL	983,365	100%	524,907	100%

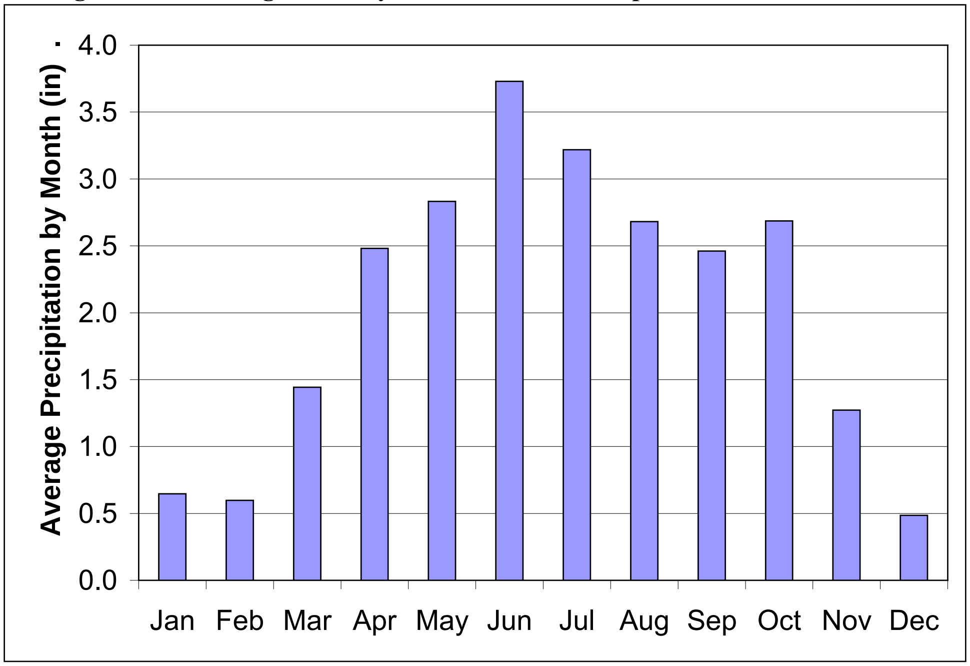
Discrepancies in total areas for NASS LCC and the watershed total area (Table 1.1) are due to the extent of the GIS coverage available for NASS LCC coverage.

Figure 1.3 – NASS Land Cover in the Lac qui Parle and Yellow Bank River Watersheds.



Based on 40 years of precipitation values available from Minnesota State Climatologist for Madison, MN, near the center of the study area, the average annual precipitation is 23.1 inches. The average monthly distribution of precipitation is shown in Figure 1.4.

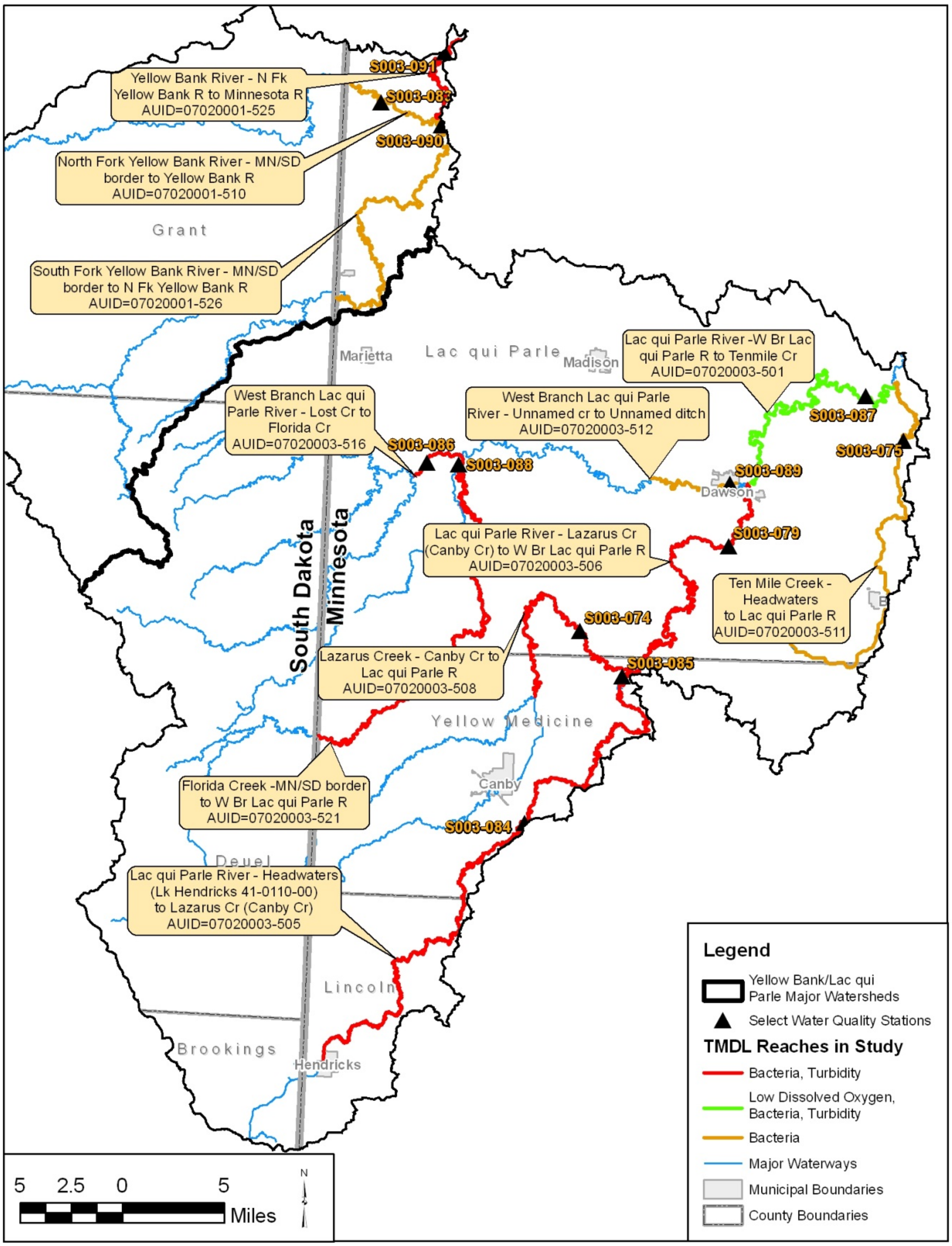
Figure 1.4 – Average Monthly Distribution of Precipitation at Madison, MN.



1.4 PROBLEM IDENTIFICATION

As a result of water quality evaluations, the State of Minnesota has determined that certain reaches within the Lac qui Parle River and Yellow Bank River systems in Minnesota exceed the State established standards for bacteria, turbidity, and dissolved oxygen (see parameter specific sections for standards). A map showing the impaired reaches and their watersheds is presented in Figure 1.5. Also shown are the locations of the primary monitoring stations in the watershed.

Figure 1.5 – Bacteria, Turbidity, and Low Dissolved Oxygen-Impaired Reaches in the Lac qui Parle and Yellow Bank River Watersheds.



1.5 IMPAIRMENT SUMMARY

This TMDL report addresses 19 impairments on eight reaches of the Lac qui Parle River and three reaches of the Yellow Bank River. The MPCA's projected schedule for TMDL completions, as indicated on Minnesota's 303(d) impaired waters list (as noted in Table 1.5), implicitly reflects Minnesota's priority ranking of this TMDL. 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.

Table 1.5 – Bacteria, Turbidity, and Dissolved Oxygen Impairments in the Lac qui Parle River and Yellow Bank River Watersheds

Reach Description	Yr Listed	Assessment Unit ID	Affected use	Pollutant or stressor	Target start// completion
Florida Creek, MN/SD Border to W. Br. Lac qui Parle River	06	07020003-521	Aquatic recreation	Fecal coliform	2012//2016
			Aquatic life	Turbidity	2014//2018
Lazarus Creek, Canby Creek to Lac qui Parle River	06	07020003-508	Aquatic recreation	Fecal coliform	2012//2016
			Aquatic life	Turbidity	2014//2018
W. Br. Lac qui Parle River, Unnamed Creek to Unnamed Ditch	06	07020003-512	Aquatic recreation	Fecal coliform	2012//2016
W. Br. Lac qui Parle River, Lost Creek to Florida Creek	06	07020003-516	Aquatic recreation	Fecal coliform	2012//2016
	10[1]		Aquatic life	Turbidity	2009//2011
Lac qui Parle River, Headwaters to Lazarus Creek	06	07020003-505	Aquatic recreation	Fecal coliform	2012//2016
			Aquatic life	Turbidity	2014//2018
Lac qui Parle River, Lazarus Creek to W. Br. Lac qui Parle River	06	07020003-506	Aquatic recreation	Fecal coliform	2012//2016
			Aquatic life	Turbidity	2014//2018
Lac qui Parle River, W. Br Lac qui Parle River to Ten Mile Creek	94	07020003-501	Aquatic life	Low oxygen	2004//2008
	06		Aquatic recreation	Fecal coliform	2012//2016
			Aquatic life	Turbidity	2014//2018
Ten Mile Creek, Headwaters to Lac qui Parle River	06	07020003-511	Aquatic recreation	Fecal coliform	2009//2011
N. Fk. Yellow Bank River, MN/SD Border to Yellow Bank River	06	07020001-510	Aquatic recreation	Fecal coliform	2017//2021
S. Fk. Yellow Bank River, MN/SD Border to N. Fk. Yellow Bank River	06	07020001-526	Aquatic recreation	Fecal coliform	2017//2021
Yellow Bank River, N. Fk. Yellow Bank River to Minnesota River	06	07020001-525	Aquatic recreation	Fecal coliform	2006//2008
	10[1]		Aquatic life	Turbidity	2009//2011

[1] Reach expected to appear on 2010 list of impaired waters

1.6 IMPAIRED WATERS AND MINNESOTA WATER QUALITY STANDARDS

1.6.1 Beneficial Use Classifications

This TMDL report addresses exceedances of the state standard for bacteria, turbidity and dissolved oxygen in the Lac qui Parle River and Yellow Bank River watersheds of Minnesota. A discussion of beneficial water use classes in Minnesota and the standards for those classes is provided in order to define the regulatory context and explain the rationale behind the environmental result of the TMDL. All waters of Minnesota are assigned classes based on their suitability for the following beneficial uses (Minn. Rules Ch. 7050.0140 and 7050.0220):

1. Domestic consumption
2. Aquatic life and recreation
3. Industrial consumption
4. Agriculture and wildlife
5. Aesthetic enjoyment and navigation
6. Other uses
7. Limited resources value

A. Cold water sport fish (trout waters), also protected for drinking water
B. Cool and warm water sport fish, also protected for drinking water
C. Cool and warm water sport fish, indigenous aquatic life, and wetlands, and
D. Limited resource value waters

According to Minn. Rules Ch. 7050.0470, all of the listed reaches above except three are Class 2C and 3C waters. Lazarus Creek is specifically listed as a 2B water. Ten Mile Creek and Yellow Bank River downstream of the confluence with North Fork Yellow Bank River and South Fork Yellow Bank River are not listed in 7050.0470 and therefore classified as 2B, 3C, 4A, 4B, 5, and 6 waters (Minn. Rules Ch. 7050.0430). Table 1.6 summarizes the beneficial use classifications by assessment unit ID (AUID).

Table 1.6 – Beneficial Use Classifications

	Assessment Unit ID	Class
Florida Creek, MN/SD Border to W. Br. Lac qui Parle River	07020003-521	2C and 3C
Lazarus Creek, Canby Creek to Lac qui Parle River	07020003-508	2B
W. Br. Lac qui Parle River, Unnamed Creek to Unnamed Ditch	07020003-512	2C and 3C
W. Br. Lac qui Parle River, Lost Creek to Florida Creek	07020003-516	2C and 3C
Lac qui Parle River, Headwaters to Lazarus Creek	07020003-505	2C and 3C
Lac qui Parle River, Lazarus Creek to W. Br. Lac qui Parle River	07020003-506	2C and 3C
Lac qui Parle River, W. Br. Lac qui Parle River to Ten Mile Creek	07020003-501	2C and 3C
Ten Mile Creek, Headwaters to Lac qui Parle River	07020003-511	2B, 3C, 4A, 4B, 5, and 6
N. Fk. Yellow Bank River, MN/SD Border to Yellow Bank River	07020001-510	2C and 3C
S. Fk. Yellow Bank River, MN/SD Border to N. Fk. Yellow Bank River	07020001-526	2C and 3C
Yellow Bank River, N. Fk. Yellow Bank River to Minnesota River	07020001-525	2B, 3C, 4A, 4B, 5, and 6

Classification as a 2B water is intended to protect cool and warm water fisheries, while classification as a 2C water is intended to protect indigenous fish and associated aquatic communities, and 3C protects water for industrial use and cooling. All surface waters classified as Class 2 are also protected for industrial, agricultural, aesthetics, navigation, and other uses.

Since Class 2B and 2C are the only classes with standards for the impairments of concern, these standards are considered the most stringent. Minn. Rules Ch. 7050 contains general provisions, definitions of water use classes, specific standards of quality and purity for classified waters of the state, and the general and specific standards for point source dischargers to waters of the state.

The designated beneficial use for Class 2 waters (the most protective use class in the project area) is as follows (Minn. Rules Ch. 7050.0140):

> **Class 2 waters, aquatic life and recreation**. Aquatic life includes all waters of the state which do or may support fish, other aquatic life, bathing, boating, or other recreational purposes, and where quality control is or may be necessary to protect aquatic or terrestrial life or their habitats, or the public health, safety, or welfare.

1.6.2 Criteria Used for Listing

The criteria used for determining stream reach impairments are outlined in the MPCA document Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment – 305(b) Report and 303(d) List, January 2010. The applicable water body classifications and water quality standards are specified in Minnesota Rules Chapter 7050. Minnesota Rules Chapter 7050.0470 lists water body classifications and Chapter 7050.0222 (subp. 5) lists applicable water quality standards for the impaired Class 2C reaches.

The information provided in Section 1.0 (Introduction) applies to all of the eleven impaired reaches where the beneficial use is impaired by a combination of pollutant or stressors (bacteria, turbidity and/or low dissolved oxygen.) The following Sections 2.0 (Bacteria Impairments), 3.0 (Turbidity Impairments) and 4.0 (Low Dissolved Oxygen Impairments) present somewhat repetitive material with slight variations incorporated to specifically address the pollutant or stressor. This approach allows Sections 2.0, 3.0 and 4.0, as intended, to largely stand alone. Sections 5.0 (Implementation), 6.0 (Reasonable Assurances) and 7.0 (Public Participation) apply to all of the eleven impaired reaches for all pollutant or stressors.

2.0 Bacteria Impairments

2.1 APPLICABLE MINNESOTA WATER QUALITY STANDARD AND ENDPOINTS

2.1.1 Fecal Coliform Bacteria and *Escherichia coli* (*E. coli*)

Fecal coliform bacteria have historically been considered an indicator organism, meaning that not all the species of bacteria of this category are harmful, but they are usually associated with harmful organisms transmitted by fecal contamination. They are found in the intestines of warm-blooded animals, including humans and livestock. The presence of fecal bacteria in water suggests the presence of fecal matter and associated bacteria (i.e. some strains of *E. coli*), viruses (i.e. hepatitis A and rotaviruses), and protozoa (i.e. Giardia and *Cryptosporidium*) that are pathogenic to humans when ingested (USEPA 2001a). The decision to list the reaches identified was originally based on a fecal coliform standard in effect prior to the most recent rule revision in 2008.

The fecal coliform standard contained in the previous Minn. Rules Ch. 7050.0222 subpart 5, "Fecal Coliform Water Quality Standard for Class 2B waters", stated that fecal coliform concentrations shall "not exceed 200 organisms per 100 milliliters as a geometric mean of not less than five samples in any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 2,000 organisms per 100 milliliters. The standard applies only between April 1 and October 31." This numerical standard is commonly referred to as the chronic standard. Chronic standards provide protection for human health and the aquatic community in Class 2 waters. According to the MPCA, a chronic standard is set to represent the "highest concentration of a toxicant to which aquatic organisms can be exposed indefinitely with no harmful effects, or to which humans or wildlife consumers of aquatic organisms can be exposed for a lifetime with no harmful effects." While a standard based on an indicator organism defines a safe or acceptable level of exposure to fecal contamination, which may or may not contain harmful organisms, it is not literally the highest concentration that one can be exposed to and still be protected. Impairment assessment is based on the procedures contained in the Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment (MPCA 2005).

With the revisions of Minnesota's water quality rules in 2008, the state has changed to an *E. coli* standard because *E. coli* is a superior indicator of potential illness (MPCA 2007). Further, the costs for lab analysis to detect *E. coli* can be substantially less than for fecal coliform. The 2008 state chronic standard for *E. coli* of 126 colony-forming unit (cfu) /100 ml was adopted and is considered reasonably equivalent to the chronic fecal coliform standard of 200 organisms/100 ml from a public health protection standpoint. Further, the SONAR (Statement of Need and Reasonableness) section that supports the rationale for the change in the standard contains a log plot of paired fecal coliform and *E. coli* data that was cited as being a reasonable basis to convert fecal coliform concentrations into *E. coli* concentrations (MPCA 2007). The relationship has an R-squared valued of 0.6887 and the equation generated by the regression is $y = 1.7993x^{0.8057}$ where y is the *E. coli* concentration and x is the fecal coliform concentration. This equation is used in the report to convert fecal coliform data to *E. coli* "equivalent" data.

The focus of this TMDL is on the chronic standard of 126 cfu/ 100 ml. It is believed that achieving the necessary reductions to meet the chronic standard will also meet the goal for the acute standard (MPCA 2002).

It has been suggested that *E. coli* bacteria has the capability to reproduce naturally in water and sediment and therefore should be taken into account when identifying bacteria sources. Two Minnesota studies describe the presence and growth of "naturalized" or "indigenous" strains of *E. coli* in watershed soils (Ishii et al., 2006), and ditch sediment and water (Sadowsky et al., 2010). The latter study, supported with Clean Water Land and Legacy funding, was conducted in the Seven Mile Creek watershed, an agricultural landscape in southern Minnesota. DNA fingerprinting of *E. coli* from sediment and water samples collected in Seven Mile Creek from 2008-2010 resulted in the identification of 1568 isolates comprised of 452 different *E. coli* strains. Of these strains, 63.5% were represented by a single isolate, suggesting new or transient sources of *E. coli*. The remaining 36.5% of strains were represented by multiple isolates, suggesting persistence of specific *E. coli*. Discussions with the primary author of the Seven Mile Creek study suggest that while 36% might be used as a rough indicator of "background" levels of bacteria at this site during the study period, this percentage is not directly transferable to the concentration and count data of *E. coli* used in water quality standards and TMDLs. Additionally, because the study is not definitive as to the ultimate origins of this bacteria, it would not be appropriate to consider it as "natural" background. Finally, the author cautioned about extrapolating results from the Seven Mile Creek watershed to other watersheds without further studies.

From a pragmatic standpoint, the research on Seven Mile Creek, and other studies, suggests there may be a fraction of bacteria that will exist in streams and rivers regardless of most traditional implementation strategies to control bacteria sources. However, this TMDL study has identified several controllable sources of bacteria that could be addressed through traditional, largely voluntary, implementation strategies. As an example of such traditional practices related to livestock manure, see Spiehs and Goyal (2007).

2.2 IMPAIRMENT OVERVIEW

2.2.1 Overview of Impaired Reaches

A total of 11 reaches within the Lac qui Parle River and Yellow Bank River TMDL project area are listed for bacteria impairment. Table 2.1 summarizes information on the reaches listed as impaired for bacteria in the TMDL project area.

Table 2.1 – Bacteria Impairments in the Lac qui Parle River and Yellow Bank River Watersheds

	Yr Listed	Assessment Unit ID	Affected use	Pollutant or stressor	Target start// completion
Florida Creek, MN/SD Border to W. Br. Lac qui Parle River	06	07020003-521	Aquatic recreation	Fecal coliform	2012//2016
Lazarus Creek, Canby Creek to Lac qui Parle River	06	07020003-508	Aquatic recreation	Fecal coliform	2012//2016
W. Br. Lac qui Parle River, Unnamed Creek to Unnamed Ditch	06	07020003-512	Aquatic recreation	Fecal coliform	2012//2016
W. Br. Lac qui Parle River, Lost Creek to Florida Creek	06	07020003-516	Aquatic recreation	Fecal coliform	2012//2016
Lac qui Parle River, Headwaters to Lazarus Creek	06	07020003-505	Aquatic recreation	Fecal coliform	2012//2016
Lac qui Parle River, Lazarus Creek to W. Br. Lac qui Parle River	06	07020003-506	Aquatic recreation	Fecal coliform	2012//2016
Lac qui Parle River, W. Br. Lac qui Parle River to Ten Mile Creek	06	07020003-501	Aquatic recreation	Fecal coliform	2012//2016
Ten Mile Creek, Headwaters to Lac qui Parle River	06	07020003-511	Aquatic recreation	Fecal coliform	2009//2011
N. Fk. Yellow Bank River, MN/SD Border to Yellow Bank River	06	07020001-510	Aquatic recreation	Fecal coliform	2017//2021
S. Fk. Yellow Bank River, MN/SD Border to N. Fk. Yellow Bank River	06	07020001-526	Aquatic recreation	Fecal coliform	2017//2021
Yellow Bank River, N. Fk. Yellow Bank River to Minnesota River	06	07020001-525	Aquatic recreation	Fecal coliform	2006//2008

2.2.2 Data Sources for Lac qui Parle River and Yellow Bank River

2.2.2.1 STORET Data

Bacteria monitoring data within each listed reach was used to assess the degree of impairment for that reach as well as provide information on potential sources of bacteria loading. A list of the key monitoring stations within each listed reach is presented in Table 2.2.

Table 2.2 – Listed Reaches for Bacteria Impairments and Key Monitoring Stations

Reach Description	Assessment Unit ID	STORET ID of Key Monitoring Station(s) within Reach
Florida Cr., SD border to W. Br. Lac qui Parle River	07020003-521	S003-088
Lazarus Cr., Canby Cr. to Lac qui Parle River	07020003-508	S003-074
W. Br. Lac qui Parle River, Unnamed ditch to Unnamed Cr	07020003-512	S003-089
West Branch Lac qui Parle River, Lost Cr to Florida Cr	07020003-516	S003-086
Lac qui Parle River, Headwaters to Lazarus Cr.	07020003-505	S003-084, S003-085
Lac qui Parle River, Lazarus Cr. to W. Br. Lac qui Parle River	07020003-506	S003-079
Lac qui Parle River, W. Br. Lac qui Parle River to Ten Mile Creek	07020003-501	S003-087
Ten Mile Creek, Headwaters to Lac qui Parle River	07020003-511	S003-075
North Fork Yellow Bank River, SD Border to Yellow Bank River	07020001-510	S003-083
South Fork Yellow Bank River, SD Border to Yellow Bank River	07020001-526	S003-090
Yellow Bank River, North Fork to MN River	07020001-525	S003-091

The LQPYBWD carried out sampling for bacteria in the TMDL project area in various years over the most recent nine year period (2001–2009). Although data prior to this period exists, the more recent data better represent current conditions in the watershed. The samples taken were generally grab samples collected between April and October of each year. Prior to 2006, bacteria samples were analyzed for fecal coliform. After 2006, samples were analyzed for *E. coli*. Watershed figures by reach provided in Appendix B shows the location of the monitoring stations at which samples were collected to support this TMDL assessment. Table 2.3 shows the number of samples collected at each monitoring site within a listed reach for each of the bacteria parameters and the period of record bacteria data at each site. The sites are generally listed in upstream to downstream order within the impaired reach. All data were obtained through STORET. Of the 12 sites listed in Table 2.3, there are no paired data of fecal coliform and *E. coli*.

Table 2.3 – Bacteria Data by Monitoring Site

River/Stream	Site	STORET ID	Parameter	Year(s)	Total Number of samples (N)
Florida Creek	Highway 212	S003-088	Fecal Coliform	01-03	32
			E. coli	ND	0
Lazarus Creek	Hwy 75	S003-074	Fecal Coliform	01-03,06-07	50
			E. coli	08	16
West Br. Lac qui Parle	E. Diagonal St. - Dawson	S003-089	Fecal Coliform	01-03,06-07	58
			E. coli	08-09	34
	Hwy 212	S003-086	Fecal Coliform	01-03	42
			E. coli	ND	0
Lac qui Parle	Hwy 68 east of Canby	S003-084	Fecal Coliform	01-03,06-07	50
			E. coli	08	13
	Hwy 67 downstream of Canby	S003-085	Fecal Coliform	01-03,06-07	44
			E. coli	08	13
	CR 23 @ Dawson	S003-079	Fecal Coliform	01-03,06-07	56
			E. coli	08-09	17
	Hwy 31	S003-087	Fecal Coliform	01-04, 06-07	79
			E. coli	08-09	39
			E. coli	08	16
Ten Mile Creek	CR 18	S003-075	Fecal coliform	01-03	38
			E. coli	08-09	22
N. Fk. Yellow Bank River	CR 7	S003-083	Fecal Coliform	01-03	38
			E. coli	ND	0
S. Fk. Yellow Bank River	Twp Rd. near Bellingham	S003-090	Fecal Coliform	01-03	27
			E. coli	ND	0
Yellow Bank River	CSAH 40 near Odessa	S003-091	Fecal Coliform	01-03	38
			E. coli	08	17

Notes: ND = No data

2.2.2.2 Streamflow Data

To support development of bacteria allocations for the TMDL as well as search for linkages between violations of the bacteria standard and potential bacteria pollution sources, information on streamflow within the system was also important. Streamflow data paired with bacteria data allowed bacteria exceedances to be evaluated by flow regime. Flow regime is defined by selected flow levels ranging from dry to very high. The final bacteria TMDL loading capacities and allocations vary by flow regime. This information in turn provided insights on potential sources, with point sources being likely sources for exceedances at low flows and run-off driven processes being likely sources for high flows.

A record of daily flows for the 10 year period between 2000 and 2009 was developed for each listed reach. This period was chosen because it balances a reasonably long period of record with hydrologic conditions reflective of relatively current land use. While each reach has some bacteria monitoring in the past ten years, not all reaches contain continuous flow records. As shown in Table 2.4, there are four stations in the Lac qui Parle watershed where substantial continuous flow data is available over the past 10 years.

Table 2.4 – Summary of Available Discharge Data by Monitoring Site

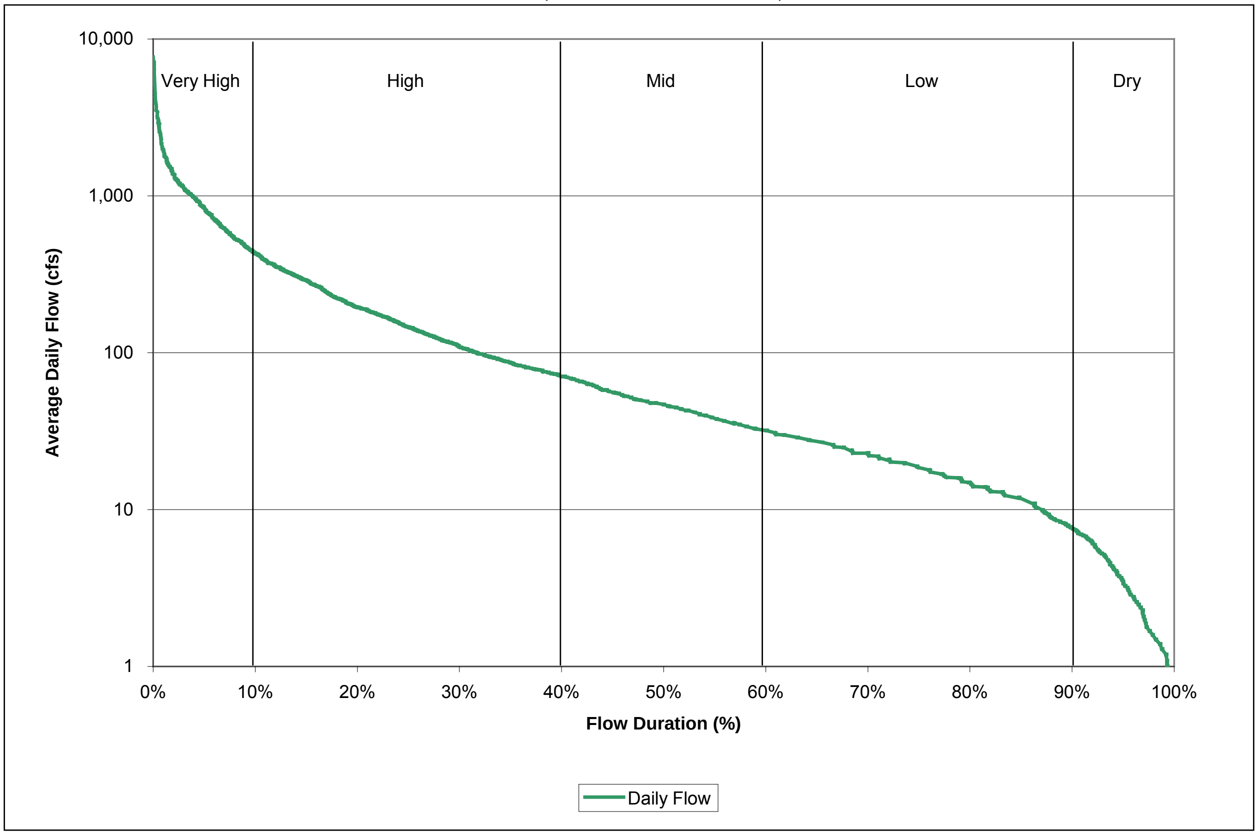
STORET ID	*Location*	*DNR ID*	*USGS ID*	*Provider*	*Years of Operation*	*Flow Record Length (Days)*
S003-089	W. Br. Lac qui Parle @ Dawson	2405001	05299800	DNR/PCA	98-99, 01-08	2490
S003-079	Lac qui Parle River @ CR 23 near Dawson	24053001	05299650	DNR/PCA	98-04, 06, 08	3014
S003-087	Lac qui Parle River @ CR 31	24023001	05300000	USGS	10-14, 31-99, 01-09	30027
S003-091	Yellow Bank River @ CR 40 near Odessa	22012001	05293000	USGS	39-09	25492

It is important to use a reliable, long-term continuous flow record (either directly monitored or simulated) when developing load duration curve-based TMDL equations. The 7Q10 is the annual 7-day minimum flow with a 10 year recurrence interval. The 7Q10 is 0.0 cubic feet per second (cfs) for all four gauges listed in Table 2.4. This statistic is based on an annual series of the smallest values of mean discharge computed over any seven consecutive days during the annual period.

To compute the flow duration curve, data gaps for each long-term flow monitoring station were filled using regression relationships between stations to create uninterrupted 10 year average daily flow records. These records were then used to simulate 10 year continuous flow records for stations with no flow data.

The simulated and actual stream discharge information was used to develop flow duration curves that facilitated an examination of the relationship between flows and elevated bacteria concentrations. For example, the flow duration curve for the Lac qui Parle River from West Branch Lac qui Parle to Ten Mile Creek (AUID 07020003-501) is shown in Figure 2.1. The curved line relates mean daily flow to the percent of time those flow values have been met or exceeded. For example, at the 50% level for the reach shown, the stream was flowing at 44 cubic feet per second for 50% or more of the time represented by the 10 year flow record. The 50% level is also the midpoint or median flow value. The curve is then divided into flow zones including very high (0-10%), high (10-40%), mid (40-60%), low (60-90%) and dry (90-100%) flow conditions.

Figure 2.1 – Flow Duration Curve for Lac Qui Parle River – W. Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)



2.2.3 Impairment Overview by Reach and Season

In order to assess the degree of impairment within each of the listed reaches, monthly geometric means using the bacteria data presented in Table 2.5 were calculated for April through October for each reach. Data were plotted as *E. coli* concentrations, which required that any raw fecal coliform data for the reach was first converted to "*E. coli* equivalent" concentration using the method cited in Section 2.1.2. Table 2.5 presents the reach information in roughly upstream to downstream order. Monthly geometric means values highlighted in yellow are those that exceed the bacteria standard of 126 cfu/100 ml.

Table 2.5 – *E. coli* Data Monthly Geometric Mean Values by Reach

AUID	Reach Description	April	May	June	July	Aug	Sept	Oct
07020003-521	Florida Creek- SD border to W. Br. Lac qui Parle River	ND	45	120	549 [1]	238	163 [1]	7 [1]
07020003-508	Lazarus Creek – Canby Cr. to Lac qui Parle River	308 [1]	74	192	297	204	203	ND
07020003-512	W. Branch Lac qui Parle River – Unnamed ditch to Unnamed Cr.	136	45	110	212	165	122	31 [1]
07020003-516	W. Branch Lac qui Parle River – Lost Cr. to Florida Cr.	ND	98	139	807 [1]	287	107	7 [1]
07020003-505	Lac qui Parle River-Headwaters to Lazarus Cr.	469	64	159	339	374	317	ND
07020003-506	Lac qui Parle River – Lazarus Cr. to W. Br. Lac qui Parle River	61	41	276	164	167	104	368 [1]
07020003-501	Lac qui Parle River – W. Branch to Ten Mile Cr.	79	52	115	128	117	116	73 [1]
07020003-511	Ten-Mile Creek – Headwaters to Lac qui Parle River	22 [1]	40	179	181	141	84	163
07020001-510	North Fk Yellow Bank River – SD border to Yellow Bank River	ND	59	185	178	141	86	7 [1]
07020001-526	South Fork Yellow Bank River – SD border to Yellow Bank River	ND	28	324	509 [1]	220	75 [1]	7 [1]
07020001-525	Yellow Bank River – North Fork Yellow Bank River to Minnesota River	89 [1]	38	224	98	50	64	73 [1]

Notes: [1] = Less than 5 data points for monthly geometric mean. ND = No data

Using the same data, an estimate of percent reduction needed to meet the chronic *E. coli* standard of 126 cfu/100 ml was also prepared by reach and by month. The formula used to calculate the percentage reductions presented in Table 2.6 is figured as follows:

$$\left(\frac{(\text{Monthly geometric mean for specific site - E. coli standard})}{\text{Monthly geometric mean for the site}}\right) * 100 = \text{Percentage Reduction}$$

Table 2.6 – Approximate Percent Reduction to Achieve Standard by Month and Reach

AUID	April	May	June	July	Aug	Sept	Oct
07020003-521	ND	None	None	77% [1]	47%	23%*	None [1]
07020003-508	59% [1]	None	34%	58%	38%	38%	ND
07020003-512	7%	None	None	41%	24%	None	None [1]
07020003-516	ND	None	9%	84% [1]	56%	None	None [1]
07020003-505	73%	None	21%	63%	66%	60%	ND
07020003-506	None	None	54%	23%	25%	None	66% [1]
07020003-501	None	None	None	2%	None	None	None [1]
07020003-511	None [1]	None	30%	30%	11%	None	23%
07020001-510	ND	None	32%	29%	11%	None	None [1]
07020001-526	ND	None	61%	75% [1]	43%	None [1]	None [1]
07020001-525	None	None	44%	None	None	None	None [1]

Notes: [1] = Less than 5 data points for monthly geometric mean ND = No data

The reduction percentage is only intended as a rough approximation. It does not account for flow and is not a required element of a TMDL. It serves to provide a starting point using site-specific water quality data for assessing the magnitude of the effort needed in the respective watersheds to achieve the standard. The reduction percentage does not supersede the allocations provided in Section 2.4.

Finally, the same data was used to calculate spring, summer, and fall geometric means to look for any obvious seasonal patterns in exceedances. Data from April and May were combined to derive geometric mean *E. coli* values for spring, June through August data were used to develop summer geometric means, and September and October data were combined to give fall values. Results are presented in Table 2.7. Again, values highlighted in yellow exceed the standard of 126 cfu/100 ml.

Table 2.7 – *E. coli* Data Seasonal Geometric Mean Values by Reach

AUID	Reach Description	Spring	Summer	Fall
07020003-521	Florida Creek- SD border to W. Br. Lac qui Parle River	45	184	56
07020003-508	Lazarus Creek – Canby Cr. to Lac qui Parle River	151	227	203
07020003-512	W. Branch Lac qui Parle River – Unnamed ditch to Unnamed Cr.	61	146	100
07020003-516	W. Branch Lac qui Parle River – Lost Cr. to Florida Cr.	98	232	73
07020003-505	Lac qui Parle River-Headwaters to Lazarus Cr.	102	248	317
07020003-506	Lac qui Parle River – Lazarus Cr. to W. Br. Lac qui Parle River	46	208	142
07020003-501	Lac qui Parle River – W. Branch to Ten Mile Cr.	59	118	110
07020003-511	Ten-Mile Creek – Headwaters to Lac qui Parle River	35	167	109
07020001-510	North Fk Yellow Bank River – SD border to Yellow Bank River	59	163	56
07020001-526	South Fork Yellow Bank River – SD border to Yellow Bank River	28	298	33
07020001-525	Yellow Bank River – North Fork Yellow Bank River to Minnesota River	74	107	66

Based on this information, the following conclusions can be drawn:

- The data from the last 9 years shows that there are violations of the *E. coli* standard for one or more months for each of the reaches listed. Nine of the eleven listed reaches show exceedances of the standard in at least three months
- In the listed reaches of both the Lac qui Parle River and Yellow Bank River systems, the exceedances of the standard appear to be more frequent and severe in the upper reaches. The percent reductions needed to reach the standard are consequently much higher for those upper reaches. It is possible that addressing the exceedances in the upper reaches of the system may have a significant beneficial effect on addressing exceedances in the lower reaches of the same system.
- Seasonal geometric means for each of the listed reaches show that a substantial majority of the exceedances of the standard (nine of thirteen) occur during the summer. The upper most reach of the Lac qui Parle River (Headwaters to Lazarus Creek) and the listed reach of Lazarus Creek appear to be especially prone to exceedances.

2.3 ALLOCATION METHODOLOGY

2.3.1 Overview of Load Duration Curve Approach

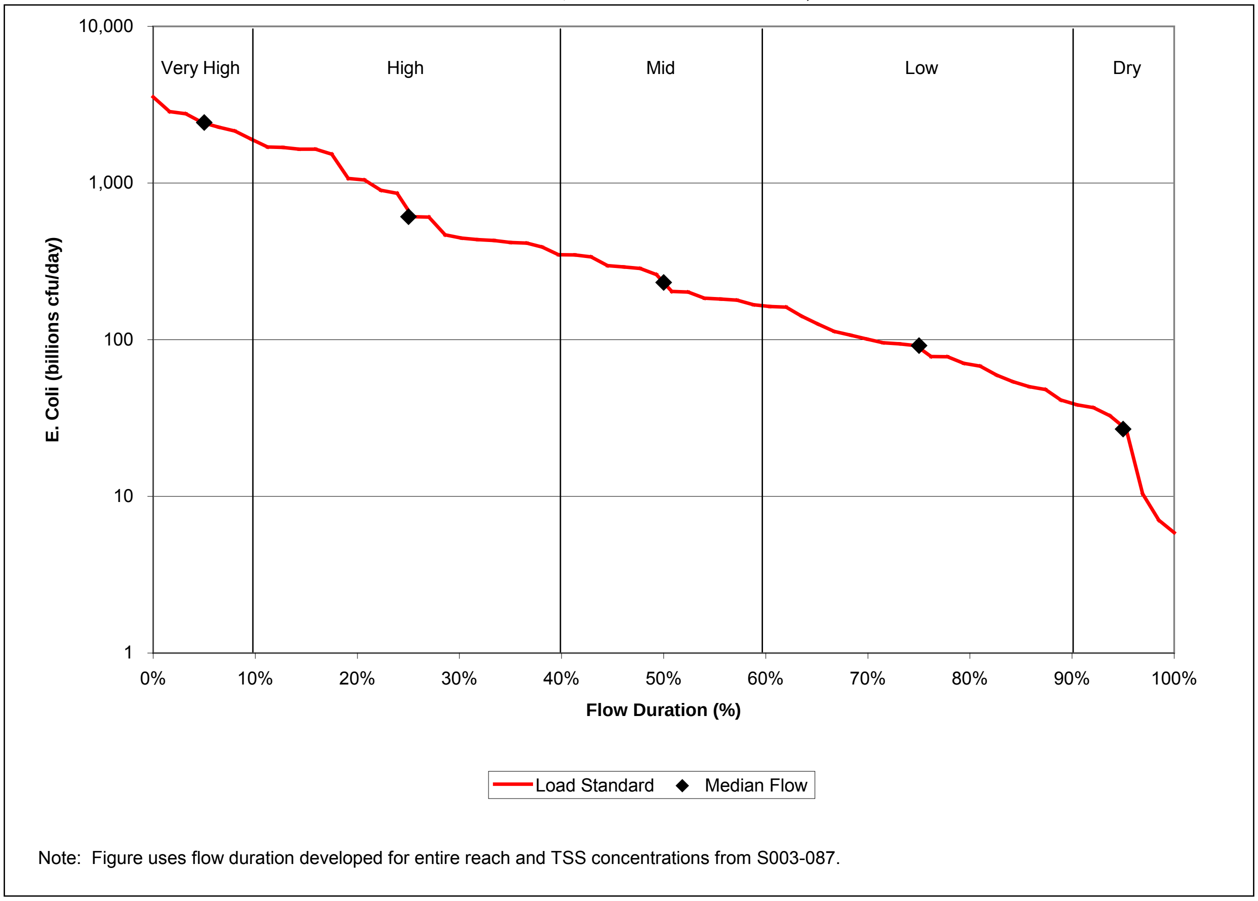
Load duration analysis as described by Cleland (2002) was used to integrate flow and the bacteria standard to provide loading capacities and allocations across the full range of flows. The first step in the process was to develop an adequate flow record for the reaches of interest.

Section 2.2.2.2 describes the approach taken to develop a 10 year period of daily flow records at the STORET monitoring sites at the bottom of each impaired reach.

The second step was to use the daily flow record to develop a monthly mean flow duration curve on which to base the load duration curve. Because the *E. coli* listing criteria is based on monthly geometric means from April through October, it is more appropriate to create load duration curves for this time period using mean monthly flows instead of mean daily flows. As described in Section 2.2.2.2, the monthly flow duration curve could also be expressed in terms of flow regimes, with 0-10th percentile flows representing very high flow conditions, 10th-40th percentile representing high, 40th-60th percentile the mid flow range, 60th-90th percentile low flows and 90th-100th percentile dry conditions.

Load duration curves for *E. coli* were then developed for each impaired reach (provided in Appendix C). To do this, each average monthly flow (represented in cfs) for the 10 year flow record from April through October was multiplied by the chronic *E. coli* standard (126 cfu/100 ml) and plotted on a logarithmic duration curve. For example, the load duration curve for a reach is shown in Figure 2.2. The line shown represents the assimilative capacity of the stream across all flows. To develop the TMDL, the median load within each of the five flow regimes were used to represent the total monthly loading capacity for that flow regime. Those values were then converted to a daily load in billions of organisms per day by dividing the monthly loading capacity by 30.6 (the average number of days in a month over the April–October period).

Figure 2.2 – Bacteria Load Duration Curve for Lac qui Parle River (West Br. Lac qui Parle River to Ten Mile Creek, AUID 07020003-501)



2.3.2 Margin of Safety

A Margin of Safety (MOS) is required in the TMDL to account for variability and uncertainties in the relationship between load and wasteload allocations and water quality.

In this TMDL report, an explicit MOS equal to 10% of the total load was used, based on a similar approach used in the "Groundhouse River TMDL for Fecal Coliform and Biota (Sediment) Impairments." This means that 10% of the loading capacity for each flow regime was subtracted before allocations were made among sources. It should also be noted that adaptive management will be employed in the implementation of this TMDL creating an implicit component to the MOS as well.

2.3.3 Accounting for South Dakota in Allocations

Many of the bacteria impaired reaches addressed in this document have watersheds that extend into South Dakota. Table 2.8 summarizes by bacteria impaired reach the total watershed area at the bottom of each reach and the percentage of each watershed that lies within Minnesota and South Dakota, respectively.

Table 2.8 – Listed Reach Descriptors and Watershed Area Summary

Description	AUID Number	Total Watershed Area (ac.)[1]	% Total in MN	% Total in SD
Florida Creek- SD border to W. Br. Lac qui Parle	07020003-521	96,000	50.8%	49.2%
Lazarus Creek-Canby Creek to Lac qui Parle Mainstem	07020003-508	85,600	85.8%	14.2%
W. Branch, Lac qui Parle River-Un-named ditch to Un-named tributary	07020003-512	302,000	51.1%	48.9%
W. Br. Lac qui Parle River-Lost Creek to Florida Creek	07020003-516	140,800	42.6%	57.4%
Mainstem Lac qui Parle River-Headwaters to Lazarus Creek	07020003-505	115,900	53.7%	46.3%
Mainstem, Lac qui Parle River-Lazarus Creek to W. Br. Lac qui Parle	07020003-506	247,200	73.4%	26.6%
Mainstem Lac qui Parle River-W. Br. To Ten-Mile Creek	07020003-501	623,800	65.8%	34.2%
Ten Mile Creek	07020003-511	77,900	100%	0.0%
North Fork, Yellow Bank River-SD border to Yellow Bank River mainstem	07020001-510	135,600	3.5%	96.5%
South Fork, Yellow Bank River-SD border to Yellow Bank River mainstem	07020001-526	136,600	18.1%	81.9%
Mainstem, Yellow Bank River, North Fork to Minnesota River	07020001-525	300,100	18.7%	81.3%

[1] Watershed area is calculated based on the downstream end of the listed reach; watershed area rounded to nearest 100 acres.

The effect of flows from South Dakota in developing these TMDLs was important to take into account. This is because the calculations of loading capacity and the allocations themselves are heavily dependent on flows within each listed reach, and a portion of the flow within each of those reaches is contributed by South Dakota. Allocating the entire loading capacity to Minnesota would leave none for sources in South Dakota and would likely compromise the validity of the TMDLs.

In the absence of good flow monitoring information at the South Dakota/Minnesota border, an assumption was made that the loading capacity available for allocation to Minnesota sources should be proportionate to the percentage of the total drainage area at the bottom of each listed reach. Thus, if 65% of the watershed at the bottom of an impaired reach lies within Minnesota, the TMDL for that reach would be based on the allocation of 65% of the loading capacity among Minnesota sources. The Minnesota target of 126 cfu/100 ml *E. coli* was used to develop the loading capacity before it was proportioned to the percentage of drainage area. It is important to note that these TMDLs do not make allocations for the South Dakota portion of the basin; they merely reflect the assumption that Minnesota sources are entitled to only a portion of the loading capacity for their use because of the effect of flow contributions from South Dakota.

Finally, it is important to note that the states of South Dakota and Minnesota apply different water quality standards to reaches of the same streams that lie in each state. For example, both states classify the inter-state streams addressed in this TMDL assessment project to support indirect contact recreation as a beneficial use. However, Minnesota applies the same bacteria standard to water bodies classified for indirect contact recreation as it does for those classified for direct contact recreation (200 organisms/100 ml fecal coliform or 126 cfu/100 ml *E. coli*). South Dakota, on the other hand, applies a less stringent bacteria standard to waters classified to support indirect contact recreation. This has resulted in generally less stringent water quality standards in South Dakota than in Minnesota for inter-state streams in this TMDL project area for bacteria. Table 2.9 summarizes the differences in the standards that each state applies to the streams that cross the inter-state boundary and are affected by the LQPYB TMDL assessment.

Table 2.9 – Comparison of South Dakota and Minnesota Water Quality Standards for Bacteria for Interstate Streams that Support an Indirect Contact Beneficial Use within the LQPYB TMDL Project Area

Parameter	Applicable South Dakota Standard	Applicable Minnesota Standard
Fecal coliform bacteria	≤ 1000 organisms /100 ml	≤ 200 organisms/100 ml
E. coli bacteria	≤ 630 cfu/100 ml	≤ 126 cfu/100 ml

If South Dakota does not meet Minnesota bacteria standards for streamflows discharged across the border, exceedances of Minnesota's bacteria standards in Minnesota are likely even if Minnesota sources are complying with the allocations set out in this TMDL.

2.3.4 Overview of Minnesota's TMDL

Following the methodology described in Section 2.3.1 "Overview of Load Duration Curve Approach" the median load was determined for each of the five flow regimes for each of the eleven listed reaches using the load duration curves for *E. coli* as provided in Appendix C. These loads are reported in tables provided in Section 2.4 "Allocation by Reach" as the "Total Daily Loading Capacity." The Total Daily Loading Capacity was allocated across state boundaries following methodology described in Section 2.3.3 "Accounting for South Dakota in Allocations." The remainder is the "Loading Capacity for Minnesota" which consists of three main components; a Margin of Safety (MOS), a wasteload allocation (WLA) for point sources, and a load allocation (LA) for diffuse sources. The MOS was explained in Section 2.3.2 and is subtracted from the loading capacity first. Next the WLA is subtracted. Finally, all of the remaining load capacity is generally assigned to the LA.

TMDL = Σ Wasteload Allocation (WLA; Point Sources)
+ Σ Load Allocation (LA; diffuse sources)
+ Margin of Safety (MOS)

The WLA is the amount of pollutant from existing point sources. In this TMDL report that includes three sub-categories; permitted treatment facilities requiring NPDES permits, livestock facilities requiring NPDES permits, and noncompliant septic systems. The permitted treatment facilities requiring NPDES include industrial or municipal water or wastewater treatment facilities. These WLAs are listed by reach in Section 2.4 and expressed in terms of *E. coli*. Equivalent permit effluent limits should always be individually expressed in terms of fecal coliform organisms, as presented in Table 2.10. This is based on the MPCA's decision and rationale to not change the permitted effluent limits for facilities discharging sewage from fecal coliform concentrations to *E. coli* concentrations (MPCA, 2007 SONAR Book III, Section H.)

Livestock facilities requiring an NPDES permit are assigned an allocation of “zero,” since their permits do not allow any discharge from the permitted facility. Noncompliant septic systems are assigned a “zero” allocation as well because they are illegal. There are no entities in the project area subject to Municipal Separate Storm Sewer Systems (MS4) stormwater permit requirements (MNR040000). Activities permitted by the MPCA under the industrial stormwater (MNR50000) and construction stormwater (MNR100001) programs are not included, based on guidance from MPCA they are not considered a source of bacteria.

The MPCA recommends that WLAs be shown for all impaired reaches downstream of an NPDES point source, based on the reasoning that if the total loading capacity for a downstream reach is calculated based on flow contributions from the entire upstream watershed, allocations should be shown for all loading sources in the entire watershed. Point sources are summarized in Table 2.10 and Table 2.11 by assessment unit ID (AUID) used as a unique identification of an impaired reach.

Table 2.10 – Summary of Permitted Treatment Facilities

Facility	NPDES Permit Number	Assessment Unit ID	WLA TMDL (*E. coli*) Billion org/day	Equivalent Permit Limits (Fecal coliform) Billion org/day
AMPI – Dawson	MN0048968	07020003-501	11.637	18.471
*Ag Processing, Inc.- Dawson	MN0040134	07020003-512	---	---
Canby WWTP	MN001236-SD-2	07020003-508	12.400	19.682
Dawson WWTP	MN0021881	07020003-512	2.246	3.565
Hendricks WWTP	MN0021121	07020003-505	11.207	17.790
*Madison WTP	MN0061077	07020003-501	---	---
Madison WWTP	MNG55028	07020003-501	2.289	3.634
Marietta WWTP	MNG580160	07020003-516	1.598	2.536

Note: * Indicates facilities that are not permitted for bacteria.

Table 2.11 – Summary of Permitted Feedlot Facilities

Facility	NPDES Permit Number	Assessment Unit ID
Randy and Todd Mortenson Farm	MNG440190	07020003-512
Exetare Partnership LLP - Dawson Site	MNG440124	07020003-511
Greg Bothun Farm - Sec 6	MNG440465	07020003-501
Jeffrey Abraham Farm - Sec 21	MNG440738	07020003-511
Lee Johnson Farm	MNG440431	07020003-511
Greg Bothun Farm - Sec 12	MNG440552	07020003-501
Mike & Jared Anhalt Turkey Farm	MNG440930	07020003-521
Cori Bothun Farm - Sec 28	MNG440760	07020003-506
Ten Brook Pork LLP - Site III	MNG440739	07020003-511
Joe Bothun Farm - Sec 1	MNG440553	07020003-501
Charlie Prestholdt Farm	MNG440807	07020003-501
Brent Dahl Farm	MNG440932	07020003-501
David Dahl Hog Farm	MNG440868	07020003-501
Brad Lundy Farm	MNG440837	07020003-501
Brian Boehnke Farm Site F065	MNG440735	07020001-525
Stratmoen Hog Finishing Inc	MNG440424	07020003-511
Alfred Jessen Farm	MNG440534	07020003-511
Wayne Dahl Hog Farm	MNG440446	07020003-501
B-C-H Enterprises LLP - Site I	MNG440425	07020003-511
Robert Verhelst Farm	MNG440952	07020003-505
Hogs Unlimited Inc	MNG440417	07020003-511
Dave DeJong Farm Sec 1	MNG440565	07020003-511

The LA is reported as a single category attributed to the amount of pollutant from existing diffuse sources and natural background, but does not quantify these sources. Potential diffuse sources included in this TMDL are manure runoff from farm fields, pastures, and feedlots not regulated under the NPDES program. The LA also includes stormwater runoff from communities not regulated under the NPDES MS4 program and bacteria loads from wildlife and pets.

2.4 ALLOCATIONS BY REACH

The following sub-sections present the TMDL allocations for each bacteria impaired reach, following approach described in Section 2.3 "Allocation Methodology."

2.4.1 Florida Creek (AUID 07020003-521)

Table 2.12 summarizes information for **Florida Creek; South Dakota border to W. Branch Lac qui Parle River (AUID 07020003-521)** and Map B1 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 2.12 – Summary for Reach – Florida Creek: South Dakota border to W. Branch Lac qui Parle River (AUID 07020003-521)

Stream Name	Florida Creek
AUID	07020003-521
Total Watershed Area	96,000 acres
Watershed Area in MN	48,800 acres
Percent Watershed Area in MN	50.8%
No. of Permitted Point Sources Dischargers	0
Monitoring Station STORET ID	S003-088

As summarized in Table 2.10, there are no permitted treatment facilities discharging to this impaired reach. Table 2.13 summarizes the feedlots requiring NPDES permits located in the direct watershed of this impaired reach.

Table 2.13 – Feedlots Requiring NPDES Permits in Reach – Florida Creek: South Dakota border to W. Branch Lac qui Parle River (AUID 07020003-521)

Facility	NPDES Permit Number
Mike & Jared Anhalt Turkey Farm	MNG440930

Table 2.14 provides the average daily *E. coli* total daily loading capacities and allocations for Minnesota and South Dakota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 2.14 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
Total Daily Loading Capacity	549.32	163.26	45.09	8.67	0.06
Loading Capacity - MN	279.05	82.94	22.91	4.40	0.03
Loading Capacity - SD	270.27	80.32	22.18	4.27	0.03

Table 2.15 provides the average daily *E. coli* total daily loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml.

Table 2.15 – *E. coli* Loading Capacities and Allocations – Florida Creek: South Dakota border to W. Branch Lac qui Parle River (AUID 07020003-521)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	279.05	82.94	22.91	4.40	0.03
Σ WLA					
NPDES Permitted Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	251.14	74.65	20.62	3.96	0.03
MOS	27.91	8.29	2.29	0.44	0.00

2.4.2 Lazarus Creek (AUID 07020003-508)

Table 2.16 summarizes information for **Lazarus Creek; Canby Creek to Lac qui Parle River (AUID 07020003-508)** and Map B2 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 2.16 – Summary for Reach – Lazarus Creek: Canby Creek to Lac qui Parle River (AUID 07020003-508)

Stream Name	Lazarus Creek
AUID	07020003-508
Total Watershed Area	85,621 acres
Watershed Area in MN	73,471 acres
Percent Watershed Area in MN	85.8%
No. of Permitted Point Sources Dischargers	1
Monitoring Station STORET ID	S003-074

Table 2.17 presents information on treatment facilities requiring NPDES permits discharging to this impaired reach. There are no feedlots requiring NPDES permits located in the direct watershed of this impaired reach.

Table 2.17 – Permitted Point Source Dischargers to Reach – Lazarus Creek: Canby Creek to Lac qui Parle River (AUID 07020003-508)

Facility	NPDES Permit Number	Discharge Type	Facility Design Flow	Ave Daily Pond Discharge Vol. (Ponds only)	Permit Limit Based WLA (billions of organisms per day)
Canby WWTP	MNG580154	Stabilization Pond	N/A	2.6 mgd	19.682 (FC)

Table 2.18 provides the average daily *E. coli* total daily loading capacities and allocations for Minnesota and South Dakota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 2.18 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
Total Daily Loading Capacity	366.90	96.60	37.69	9.46	1.08
Loading Capacity - MN	314.80	82.88	32.34	8.12	0.93
Loading Capacity - SD	52.10	13.72	5.35	1.34	0.15

Table 2.19 provides the average daily *E. coli* loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml.

Table 2.19 – *E. coli* Loading Capacities and Allocations – Lazarus Creek: Canby Creek to Lac qui Parle River (AUID 07020003-508)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	314.80	82.88	32.34	8.12	0.93
Σ WLA					
NPDES Permitted Treatment Facilities	12.40	12.40	12.40	*	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	270.92	62.19	16.71	*	*
MOS	31.48	8.29	3.23	na	na

The WLA for treatment facilities requiring NPDES permits is based on the design flow. The WLA exceeded the Low and Dry flow regimes TMDL allocated to Minnesota, as denoted in Table 2.19 by a "*." The WLA allocation is determined by formula:

*Allocation = (flow contribution from a given source) * (water quality standard)*

2.4.3 West Branch Lac qui Parle River (AUID 07020003-512)

Table 2.20 summarizes information for **West Branch Lac qui Parle River, Unnamed ditch to Unnamed creek (AUID 07020003-512)** and Map B3 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 2.20 – Summary for Reach - West Branch Lac qui Parle River, Unnamed ditch to Unnamed creek (AUID 07020003-512)

Stream Name	West Branch Lac qui Parle River
AUID	07020003-512
Total Watershed Area	302,000 acres
Watershed Area in MN	154,250 acres
Percent Watershed Area in MN	51.1%
No. of Permitted Point Sources Dischargers	2
Monitoring Station STORET ID	S003-089

Table 2.21 and presents the information on treatment facilities requiring NPDES permits discharging to this impaired reach. Table 2.22 presents the information on feedlots requiring NPDES permits located in the direct watershed of this impaired reach.

Table 2.21 – Permitted Point Source Dischargers to Reach - West Branch Lac qui Parle River, Unnamed ditch to Unnamed creek (AUID 07020003-512)

Facility	NPDES Permit Number	Discharge Type	Facility Design Flow	Ave Daily Pond Discharge Vol. (Ponds only)	Permit Limit Based WLA (billions of organisms per day)
Dawson WWTP	MN0021881	Continuous	0.471 mgd	N/A	3.565 (FC)
*Ag Processing, Inc.	MN0040134	Continuous	1.5 mgd	N/A	(no bacteria limit)

Note: * Indicates facilities that are not permitted for bacteria.

Table 2.22 – Feedlots Requiring NPDES Permits in Reach - West Branch Lac qui Parle River, Unnamed ditch to Unnamed creek (AUID 07020003-512)

Facility	NPDES Permit Number
Randy and Todd Mortenson Farm	MNG440190

Table 2.23 provides the average daily *E. coli* total daily loading capacities and allocations for Minnesota and South Dakota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 2.23 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
Total Daily Loading Capacity	1728.07	513.60	141.85	27.28	0.20
Loading Capacity - MN	883.04	262.45	72.49	13.94	0.10
Loading Capacity - SD	845.03	251.15	69.36	13.34	0.10

Table 2.24 provides the average daily *E. coli* loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml.

Table 2.24 – *E. coli* Loading Capacities and Allocations – West Branch Lac qui Parle River, Unnamed ditch to Unnamed creek (AUID 07020003-512)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	883.04	262.45	72.49	13.94	0.10
Σ WLA					
NPDES Permitted Treatment Facilities	3.84	3.84	3.84	3.84	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	790.90	232.36	61.40	8.71	*
MOS	88.30	26.25	7.25	1.39	na

The WLA for treatment facilities requiring NPDES permits is based on the design flow. The WLA exceeded the Dry flow regime TMDL allocated to Minnesota, as denoted in Table 2.24 by a “*.” The WLA allocation is determined by formula:

*Allocation = (flow contribution from a given source) * (water quality standard)*

The WLAs for this reach includes Dawson WWTP and also includes the upstream permitted treatment facility of Marietta WWTP, see table 2.10 for the individual WLAs, and does not account for fate and transport of the upstream loads.

Permitted feedlots upstream of this reach are given a zero WLA as their permit does not allow for discharge. There is one upstream permitted feedlot from AUID 07020003-521 as shown in table 2.11. Fate and transport of the upstream loads are not accounted for.

2.4.4 West Branch Lac qui Parle River (AUID 07020003-516)

Table 2.25 summarizes information for **West Branch Lac qui Parle River, Lost Creek to Florida Creek (AUID 07020003-516)** and Map B4 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 2.25 – Summary for Reach - West Branch Lac qui Parle River, Lost Creek to Florida Creek (AUID 07020003-516)

Stream Name	West Branch Lac qui Parle River
AUID	07020003-516
Total Watershed Area	140,821 acres
Watershed Area in MN	60,021 acres
Percent Watershed Area in MN	42.6 %
No. of Permitted Point Sources Dischargers	1
Monitoring Station STORET ID	S003-086

Table 2.26 presents information on treatment facilities requiring NPDES permits discharging to this impaired reach. There are no feedlots requiring NPDES permits located in the direct watershed of this impaired reach.

Table 2.26 – Permitted Point Source Dischargers to Reach - West Branch Lac qui Parle River, Lost Creek to Florida Creek (AUID 07020003-516)

Facility	NPDES Permit Number	Discharge Type	Facility Design Flow	Ave Daily Pond Discharge Vol. (Ponds only)	Permit Limit Based WLA (billions of organisms per day)
Marietta WWTP	MNG580160	Stabilization Pond	N/A	0.335 mgd	2.536 (FC)

Table 2.27 provides the average daily *E. coli* total daily loading capacities and allocations for Minnesota and South Dakota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 2.27 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
Total Daily Loading Capacity	805.70	239.46	66.14	12.72	0.09
Loading Capacity - MN	343.23	102.01	28.18	5.42	0.04
Loading Capacity - SD	462.47	137.45	37.96	7.30	0.05

Table 2.28 provides the average daily *E. coli* loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml.

Table 2.28 – *E. coli* Loading Capacities and Allocations – West Branch Lac qui Parle River, Lost Creek to Florida Creek (AUID 07020003-516)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	343.23	102.01	28.18	5.42	0.04
Σ WLA					
NPDES Permitted Treatment Facilities	1.60	1.60	1.60	1.60	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	307.31	90.21	23.76	3.28	*
MOS	34.32	10.20	2.82	0.54	na

The WLA for treatment facilities requiring NPDES permits is based on the design flow. The WLA exceeded the Dry flow regime TMDL allocated to Minnesota, as denoted in Table 2.28 by a "*." The WLA allocation is determined by formula:

*Allocation = (flow contribution from a given source) * (water quality standard)*

2.4.5 Lac qui Parle River (AUID 07020003-505)

Table 2.29 summarizes information for **Lac qui Parle River, Headwaters to Lazarus Creek (AUID 07020003-505)** and Map B5 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 2.29 – Summary for Reach - Lac qui Parle River, Headwaters to Lazarus Creek (AUID 07020003-505)

Stream Name	Lac qui Parle River
AUID	07020003-505
Total Watershed Area	115,890 acres
Watershed Area in MN	62,290 acres
Percent Watershed Area in MN	53.7%
No. of Permitted Point Sources Dischargers	1
Monitoring Station STORET ID	S003-084, S003-085

Table 2.30 presents information on treatment facilities requiring NPDES permits discharging to this impaired reach. Table 2.31 presents information on feedlots requiring NPDES permits located in the direct watershed of this impaired reach.

Table 2.30 – Permitted Point Source Dischargers to Reach - Lac qui Parle River, Headwaters to Lazarus Creek (AUID 07020003-505)

Facility	NPDES Permit Number	Discharge Type	Facility Design Flow	Ave Daily Pond Discharge Vol. (Ponds only)	Permit Limit Based WLA (billions of organisms per day)
Hendricks WWTP	MN0021121	Stabilization Pond	N/A	2.35 mgd	17.790 (FC)

Table 2.31 – Feedlots Requiring NPDES Permits in Reach - Lac qui Parle River, Headwaters to Lazarus Creek (AUID 07020003-505)

Facility	NPDES Permit Number
Robert Verhelst Farm	MNG440952

Table 2.32 provides the average daily *E. coli* total daily loading capacities and allocations for Minnesota and South Dakota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 2.32 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
Total Daily Loading Capacity	494.95	130.31	50.84	12.76	1.45
Loading Capacity - MN	265.79	69.98	27.30	6.85	0.78
Loading Capacity - SD	229.16	60.33	23.54	5.91	0.67

Table 2.33 provides the average daily *E. coli* loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml.

Table 2.33 – *E. coli* Loading Capacities and Allocations – Lac qui Parle River, Headwaters to Lazarus Creek (AUID 07020003-505)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	265.79	69.98	27.30	6.85	0.78
Σ WLA					
NPDES Permitted Treatment Facilities	11.21	11.21	11.21	*	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	228.00	51.77	13.36	*	*
MOS	26.58	7.00	2.73	na	na

The WLA for treatment facilities requiring NPDES permits is based on the design flow. The WLA exceeded the Low and Dry flow regimes TMDL allocated to Minnesota, as denoted in Table 2.33 by a "*." The WLA allocation is determined by formula:

*Allocation = (flow contribution from a given source) * (water quality standard)*

2.4.6 Lac qui Parle River (AUID 07020003-506)

Table 2.34 summarizes information for **Lac qui Parle River, Lazarus Creek to W. Branch Lac qui Parle River (AUID 07020003-506)** and Map B6 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 2.34 – Summary for Reach - Lac qui Parle River, Lazarus Creek to W. Branch Lac qui Parle River (AUID 07020003-506)

Stream Name	Lac qui Parle River
AUID	07020003-506
Total Watershed Area	247,172 acres
Watershed Area in MN	181,422 acres
Percent Watershed Area in MN	73.4 %
No. of Permitted Point Sources Dischargers	0
Monitoring Station STORET ID	S003-079

As summarized in Table 2.10, there are no permitted treatment facilities discharging to this impaired reach. Table 2.35 presents information on feedlots requiring NPDES permits located in the direct watershed of this impaired reach.

Table 2.35 – Feedlots Requiring NPDES Permits in Reach - Lac qui Parle River, Lazarus Creek to W. Branch Lac qui Parle River (AUID 07020003-506)

Facility	NPDES Permit Number
Cori Bothun Farm - Sec 28	MNG440760

Table 2.36 provides the average daily *E. coli* total daily loading capacities and allocations for Minnesota and South Dakota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 2.36 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
Total Daily Loading Capacity	1059.20	278.86	108.80	27.32	3.11
Loading Capacity - MN	777.45	204.68	79.86	20.05	2.28
Loading Capacity - SD	281.75	74.18	28.94	7.27	0.83

Table 2.37 provides the average daily *E. coli* loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml.

Table 2.37 – *E. coli* Loading Capacities and Allocations – Lac qui Parle River, Lazarus Creek to W. Branch Lac qui Parle River (AUID 07020003-506)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	777.45	204.68	79.86	20.05	2.28
Σ WLA					
NPDES Permitted Treatment Facilities	23.61	23.61	23.61	*	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	676.09	160.60	48.26	*	*
MOS	77.75	20.47	7.99	na	na

The WLA for treatment facilities requiring NPDES permits is based on the design flow. The WLA exceeded the Low and Dry flow regimes TMDL allocated to Minnesota, as denoted in Table 2.37 by a "*." The WLA allocation is determined by formula:

*Allocation = (flow contribution from a given source) * (water quality standard)*

The WLAs for this reach includes the upstream permitted treatment facilities of Canby WWTP and Hendricks WWTP, see table 2.10 for the individual WLAs, and does not account for fate and transport of the upstream loads.

Permitted feedlots upstream of this reach are given a zero WLA as their permit does not allow for discharge. There is one upstream permitted feedlot from AUID 07020003-505 as shown in table 2.11. Fate and transport of the upstream loads are not accounted for.

2.4.7 Lac qui Parle River (AUID 07020003-501)

Table 2.38 summarizes information for **Lac qui Parle River, West Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)** and Map B7 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 2.38 – Summary for Reach - Lac qui Parle River, West Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)

Stream Name	Lac qui Parle River
AUID	07020003-501
Total Watershed Area	623,811 acres
Watershed Area in MN	410,311 acres
Percent Watershed Area in MN	65.8%
No. of Permitted Point Sources Dischargers	3
Monitoring Station STORET ID	S003-087

Table 2.39 presents information on treatment facilities requiring NPDES permits discharging to this impaired reach. Table 2.40 presents information on feedlots requiring NPDES permits located in the direct watershed of this impaired reach.

Table 2.39 – Permitted Point Source Dischargers to Reach - Lac qui Parle River, West Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)

Facility	NPDES Permit Number	Discharge Type	Facility Design Flow	Ave Daily Pond Discharge Vol. (Ponds only)	Permit Limit Based WLA (billions of organisms per day)
AMPI	MN0048968	Stabilization pond	N/A	2.44 mgd	18.471 (FC)
Madison WWTP	MNG550028	Continuous	0.48 mgd	N/A	3.634 (FC)
*Madison WTP	MN0061077	Continuous	0.1 mgd	N/A	(no bacteria limit)

Note: * Indicates that the facility does not have a permit limit.

Table 2.40 – Feedlots Requiring NPDES Permits in Reach - Lac qui Parle River, West Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)

Facility	NPDES Permit Number
Joe Bothun Farm - Sec 1	MNG440553
Charlie Prestholdt Farm	MNG440807
Brent Dahl Farm	MNG440932
David Dahl Hog Farm	MNG440868
Brad Lundy Farm	MNG440837
Greg Bothun Farm - Sec 6	MNG440465
Greg Bothun Farm - Sec 12	MNG440552
Wayne Dahl Hog Farm	MNG440446

Table 2.41 provides the average daily *E. coli* total daily loading capacities and allocations for Minnesota and South Dakota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 2.41 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
Total Daily Loading Capacity	2432.65	609.73	231.74	91.62	26.88
Loading Capacity - MN	1600.68	401.20	152.48	60.29	17.69
Loading Capacity - SD	831.97	208.53	79.26	31.33	9.19

Table 2.42 provides the average daily *E. coli* loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml.

Table 2.42 – *E. coli* Loading Capacities and Allocations – Lac qui Parle River, West Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	1600.68	401.20	152.48	60.29	17.69
Σ WLA					
NPDES Permitted Treatment Facilities	41.38	41.38	41.38	41.38	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	1399.23	319.70	95.85	12.88	*
MOS	160.07	40.12	15.25	6.03	na

The WLA for treatment facilities requiring NPDES permits is based on the design flow. The WLA exceeded the Dry flow regime TMDL allocated to Minnesota, as denoted in Table 2.42 by a "*." The WLA allocation is determined by formula:

*Allocation = (flow contribution from a given source) * (water quality standard)*

The WLAs for this reach includes AMPI, Madison WWTP, and Madison WTP and also includes the upstream permitted treatment facilities of Marietta WWTP, Dawson WWTP, Canby WWTP, Ag Processing, Inc. and Hendricks WWTP, see table 2.10 for the individual WLAs, and does not account for fate and transport of the upstream loads.

Permitted feedlots upstream of this reach are given a zero WLA as their permit does not allow for discharge. There is one upstream permitted feedlot from AUID 07020003-521, two from AUID 07020003-512, one from AUID 07020003-505, and one from AUID 07020003-506 as shown in table 2.11. Fate and transport of the upstream loads are not accounted for.

2.4.8 Ten Mile Creek (AUID 07020003-511)

Table 2.43 summarizes information for **Ten Mile Creek, Headwaters to Lac qui Parle River (AUID 07020003-511)** and Map B8 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 2.43 – Summary for Reach - Ten Mile Creek, Headwaters to Lac qui Parle River (AUID 07020003-511)

Stream Name	Ten Mile Creek
AUID	07020003-511
Total Watershed Area	77,950 acres
Watershed Area in MN	77,950 acres
Percent Watershed Area in MN	100.0%
No. of Permitted Point Sources Dischargers	0
Monitoring Station STORET ID	S003-075

As summarized in Table 2.10, there are no permitted treatment facilities discharging to this impaired reach. Table 2.44 summarizes the feedlots requiring NPDES permits located in the direct watershed of this impaired reach.

Table 2.44 – Feedlots Requiring NPDES Permits in Reach - Ten Mile Creek, Headwaters to Lac qui Parle River (AUID 07020003-511)

Facility	NPDES Permit Number
Ten Brook Pork LLP - Site III	MNG440739
Hogs Unlimited Inc	MNG440417
Exetare Partnership LLP - Dawson Site	MNG440124
Jeffrey Abraham Farm - Sec 21	MNG440738
Lee Johnson Farm	MNG440431
Stratmoen Hog Finishing Inc	MNG440424
Alfred Jessen Farm	MNG440534
B-C-H Enterprises LLP - Site I	MNG440425
Dave DeJong Farm Sec 1	MNG440565

Table 2.45 provides the average daily *E. coli* total daily loading capacities and allocations for Minnesota and South Dakota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 2.45 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
Total Daily Loading Capacity	308.51	77.33	29.39	11.62	3.41
Loading Capacity - MN	308.51	77.33	29.39	11.62	3.41
Loading Capacity - SD	0.00	0.00	0.00	0.00	0.00

Table 2.46 provides the average daily *E. coli* loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml.

Table 2.46 – *E. coli* Loading Capacities and Allocations – Ten Mile Creek, Headwaters to Lac qui Parle River (AUID 07020003-511)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	308.51	77.33	29.39	11.62	3.41
Σ WLA					
NPDES Permitted Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	277.66	69.60	26.45	10.46	3.07
MOS	30.85	7.73	2.94	1.16	0.34

2.4.9 North Fork Yellow Bank River (AUID 07020001-510)

Table 2.47 summarizes information for **North Fork Yellow Bank River, South Dakota Border to Yellow Bank River (AUID 07020001-510)** and Map B9 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 2.47 – Summary for Reach - North Fork Yellow Bank River, South Dakota Border to Yellow Bank River (AUID 07020001-510)

Stream Name	North Fork Yellow Bank River
AUID	07020001-510
Total Watershed Area	135,563 acres
Watershed Area in MN	4,763 acres
Percent Watershed Area in MN	3.5 %
No. of Permitted Point Sources Dischargers	0
Monitoring Station STORET ID	S003-083

As summarized in Table 2.10 and Table 2.11, there are no permitted treatment facilities discharging to and no feedlots requiring NPDES permits located in the direct watershed of this impaired reach.

Table 2.48 provides the average daily *E. coli* total daily loading capacities and allocations for Minnesota and South Dakota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 2.48 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
Total Daily Loading Capacity	522.65	135.16	30.20	14.34	4.61
Loading Capacity - MN	18.29	4.73	1.06	0.50	0.16
Loading Capacity - SD	504.36	130.43	29.14	13.84	4.45

Table 2.49 provides the average daily *E. coli* loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml.

Table 2.49 – *E. coli* Loading Capacities and Allocations – North Fork Yellow Bank River, South Dakota Border to Yellow Bank River (AUID 07020001-510)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	18.29	4.73	1.06	0.50	0.16
Σ WLA					
NPDES Permitted Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	16.46	4.26	0.95	0.45	0.14
MOS	1.83	0.47	0.11	0.05	0.02

2.4.10 South Fork Yellow Bank River (AUID 07020001-526)

Table 2.50 summarizes information for **South Fork Yellow Bank River, South Dakota Border to Yellow Bank River (AUID 07020001-526)** and Map B10 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 2.50 – Summary for Reach - South Fork Yellow Bank River, South Dakota Border to Yellow Bank River (AUID 07020001-526)

Stream Name	South Fork Yellow Bank River
AUID	07020001-526
Total Watershed Area	136,600 acres
Watershed Area in MN	24,750 acres
Percent Watershed Area in MN	18.1%
No. of Permitted Point Sources Dischargers	0
Monitoring Station STORET ID	S003-090

As summarized in Table 2.10 and Table 2.11, there are no permitted treatment facilities discharging to and no feedlots requiring NPDES permits located in the direct watershed of this impaired reach.

Table 2.51 provides the average daily *E. coli* total daily loading capacities and allocations for Minnesota and South Dakota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 2.51 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
Total Daily Loading Capacity	526.65	136.19	30.43	14.45	4.65
Loading Capacity - MN	95.32	24.65	5.51	2.62	0.84
Loading Capacity - SD	431.33	111.54	24.92	11.83	3.81

Table 2.52 provides the average daily *E. coli* loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml.

Table 2.52 – *E. coli* Loading Capacities and Allocations – South Fork Yellow Bank River, South Dakota Border to Yellow Bank River (AUID 07020001-526)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	95.32	24.65	5.51	2.62	0.84
Σ WLA					
NPDES Permitted Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	85.79	22.18	4.96	2.36	0.76
MOS	9.53	2.47	0.55	0.26	0.08

2.4.11 Yellow Bank River (AUID 07020001-525)

Table 2.53 summarizes information for **Yellow Bank River, North Fork Yellow Bank River to Minnesota River (AUID 07020001-525)** and Map B11 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 2.53 – Summary for Reach - Yellow Bank River, North Fork Yellow Bank River to Minnesota River (AUID 07020001-525)

Stream Name	Yellow Bank River
AUID	07020001-525
Total Watershed Area	300,080 acres
Watershed Area in MN	56,030 acres
Percent Watershed Area in MN	18.7 %
No. of Permitted Point Sources Dischargers	0
Monitoring Station STORET ID	S003-091

As summarized in Table 2.10, there are no permitted treatment facilities discharging to this impaired reach. Table 2.54 presents information on feedlots requiring NPDES permits located in the direct watershed of this impaired reach.

Table 2.54 – Feedlots Requiring NPDES Permits in Reach - Yellow Bank River, North Fork Yellow Bank River to Minnesota River (AUID 07020001-525)

Facility	NPDES Permit Number
Brian Boehnke Farm Site F065	MNG440735

Table 2.55 provides the average daily *E. coli* total daily loading capacities and allocations for Minnesota and South Dakota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 2.55 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
Total Daily Loading Capacity	1156.94	299.19	66.85	31.74	10.21
Loading Capacity - MN	216.35	55.95	12.50	5.94	1.91
Loading Capacity - SD	940.59	243.24	54.35	25.80	8.30

Table 2.56 provides the average daily *E. coli* loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the chronic monthly geometric mean standard of 126 cfu/100 ml.

Table 2.56 – *E. coli* Loading Capacities and Allocations – Yellow Bank River, North Fork Yellow Bank River to Minnesota River (AUID 07020001-525)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	216.35	55.95	12.50	5.94	1.91
Σ WLA					
NPDES Permitted Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	194.71	50.35	11.25	5.35	1.72
MOS	21.64	5.60	1.25	0.59	0.19

2.5 POLLUTANT SOURCE ASSESSMENT

To attempt to better link potential sources of bacteria with bacteria impairments in the receiving waters, three evaluations were conducted. They are described in the following sections.

2.5.1 Exceedance Patterns by Flow Regime

The first evaluation involved looking at the relationships between individual sample values and the flow regimes within which those samples were collected to try to determine the most likely sources. Table 2.57 presents a general conceptual relationship between potential sources of pollutant loading and the flow conditions under which those sources of loading are likely to be most significant. Table 2.57 illustrates, for example, that sources not dependent on runoff as a delivery mechanism to the receiving water-such as point sources, "straight-pipe" septic systems, and/or livestock with direct access to the receiving water, have a high potential as significant contributors to an impairment under low flow and dry conditions when surface runoff is minimal or absent. As streamflow increases, runoff-driven processes (such as bacteria transported by runoff from feedlots without runoff controls or from areas with recent surface-applied manure) can dominate.

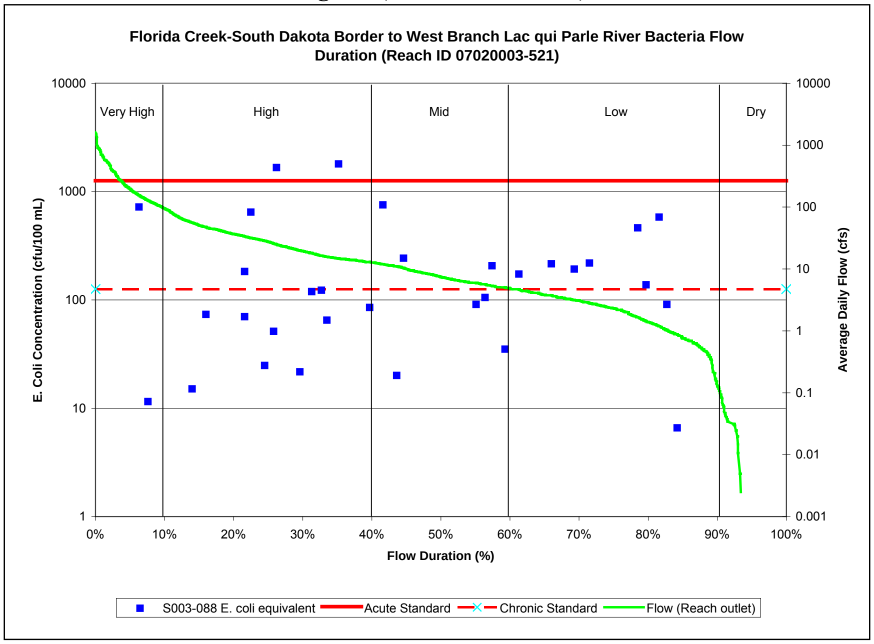
Table 2.57 – Conceptual Relationship between Flow Regime and Potential Pollutant Sources

Point Source Contributing Source Area	**Flow Regime**				
	Very High	High	Mid	Low	Dry
NPDES Permitted Treatment Facilities				M	H
Septic System w/ Noncompliant connection				M	H
Livestock in receiving water				M	H
Sub-surface treatment systems			H	M	
Stormwater Runoff – Impervious Areas		H	H	H	
Combined Sewer Overflows	H	H	H		
Stormwater Runoff – Pervious Areas	H	H	M		
Bank Erosion	H	H	M		

Note: Potential relative importance of source areas to contribute loads under given hydrologic condition (H: High; M: Medium), based on USEPA Doc. 841-B-07-006.

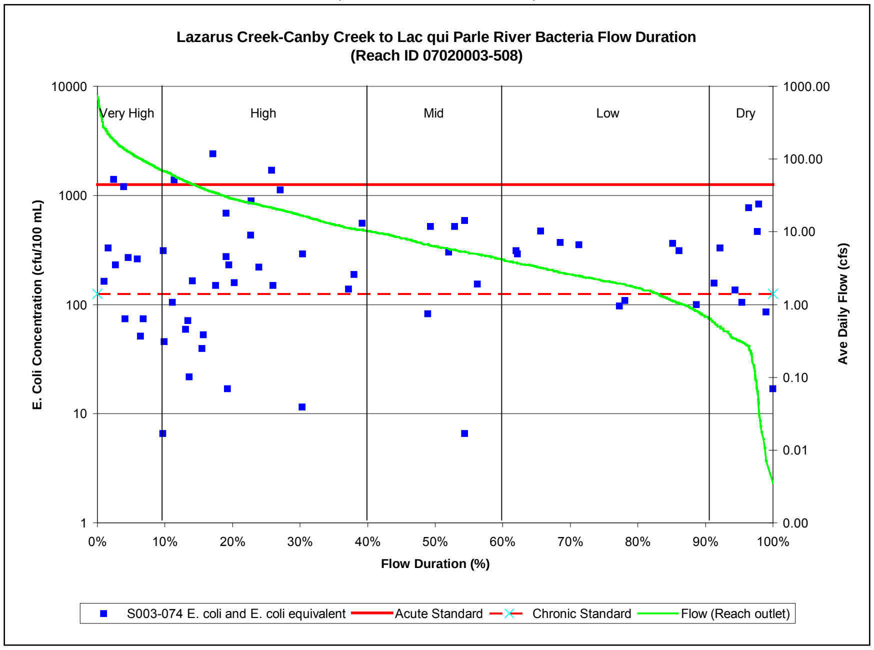
Figures 2.3 through 2.13 show plots of bacteria concentrations and flow duration information for each of the eleven reaches listed as impaired for bacteria. The flow duration curve is based on actual and/or simulated 10 year flow record for reach developed as described in Section 2.2.2. As the reader may notice, some flow duration curves do not extend to 100 percent flow duration. In Figure 2.3, the flow duration curve represents a stream that ceases to flow for relatively long periods, consistent with a 7Q10 of 0.00 cfs. Bacteria values are monitored *E. coli* concentrations or fecal coliform concentrations converted to "*E. coli*-equivalent" concentration using the relationship explained in Section 2.1.2. The type of data and monitoring site from which it was obtained are listed at the bottom of each graph. Finally, the most likely potential source areas based on flow regime are also discussed in the following paragraph.

Figure 2.3 – Florida Creek (MN/SD border to W. Br. Lac qui Parle River) - *E. coli* Concentrations by Flow Regime (Station S003-088)



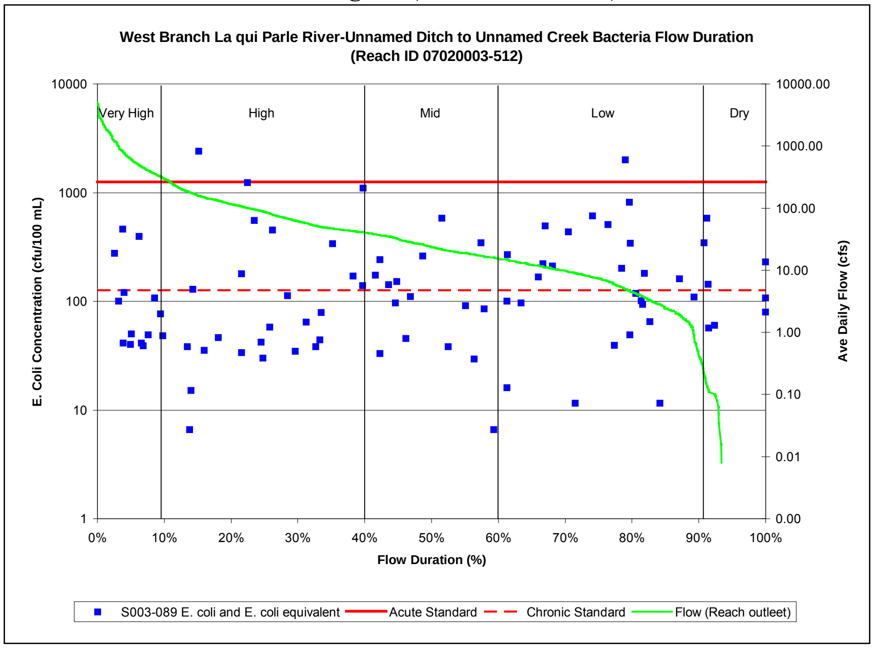
Note: Figure presents flow duration information developed at the downstream end of the reach and bacteria concentrations from the station(s) noted.

Figure 2.4 – Lazarus Creek (Canby Creek to Lac qui Parle River) - *E. coli* Concentrations by Flow Regime (Station S003-074)



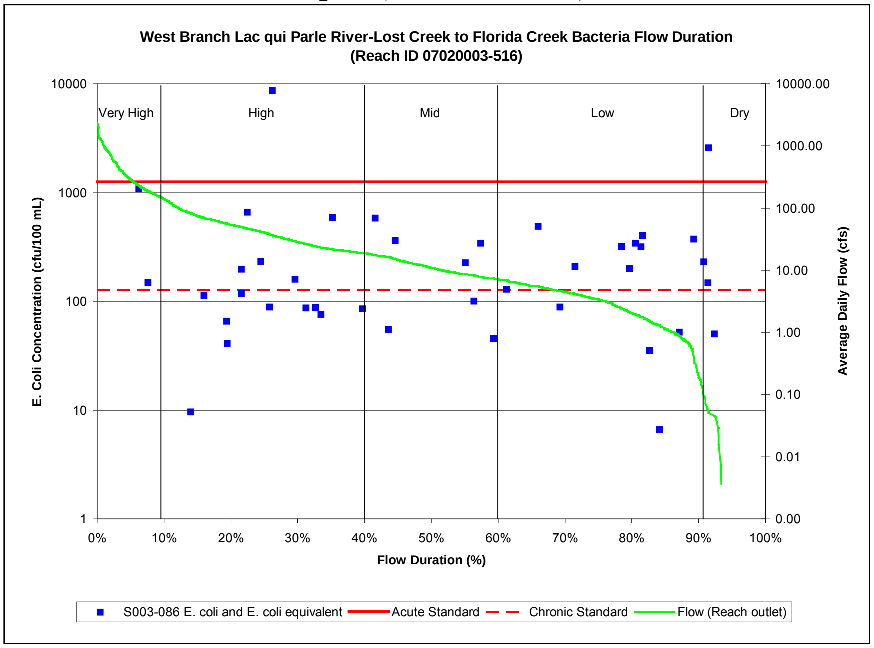
Note: Figure presents flow duration information developed at the downstream end of the reach and bacteria concentrations from the station(s) noted.

Figure 2.5 – W. Branch Lac qui Parle River (Un-named Creek to Unnamed Ditch) - *E. coli* Concentrations by Flow Regime (Station S003-089)



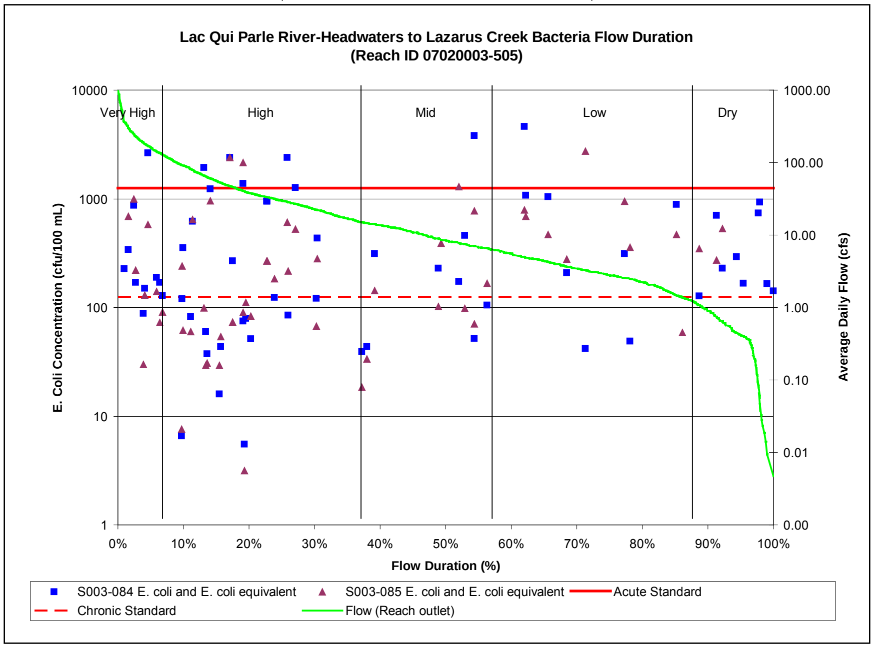
Note: Figure presents flow duration information developed at the downstream end of the reach and bacteria concentrations from the station(s) noted.

Figure 2.6 – W. Branch Lac qui Parle River (Lost Creek to Florida Creek) - *E. coli* Concentrations by Flow Regime (Station S003-086)



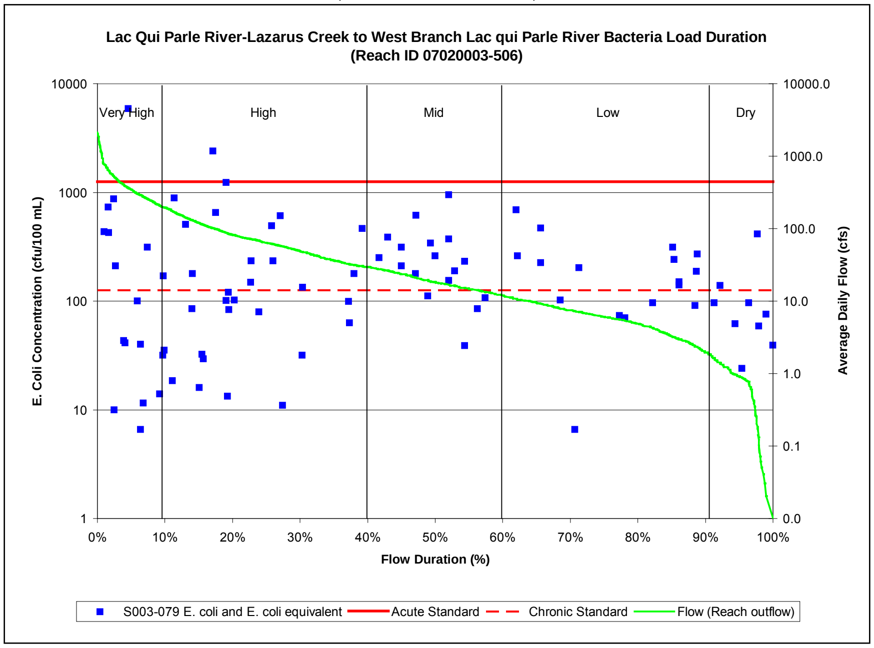
Note: Figure presents flow duration information developed at the downstream end of the reach and bacteria concentrations from the station(s) noted.

Figure 2.7 – Lac qui Parle River (Headwaters to Lazarus Creek) - *E. coli* Concentrations by Flow Regime (Stations S003-084 and -085)



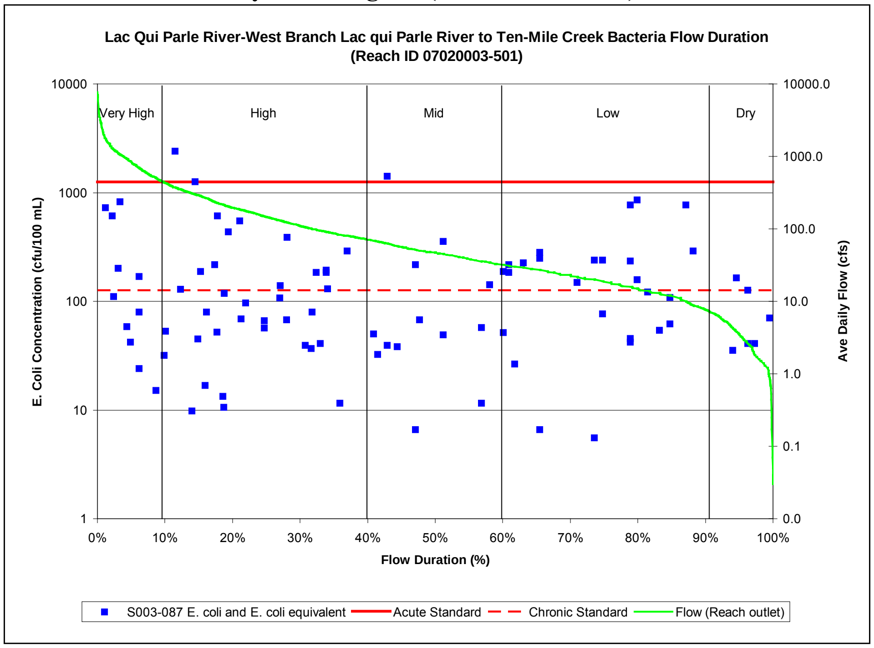
Note: Figure presents flow duration information developed at the downstream end of the reach and bacteria concentrations from the station(s) noted.

Figure 2.8 – Lac qui Parle River (Lazarus Creek to W. Branch) - *E. coli* Concentrations by Flow Regime (Station S003-079)



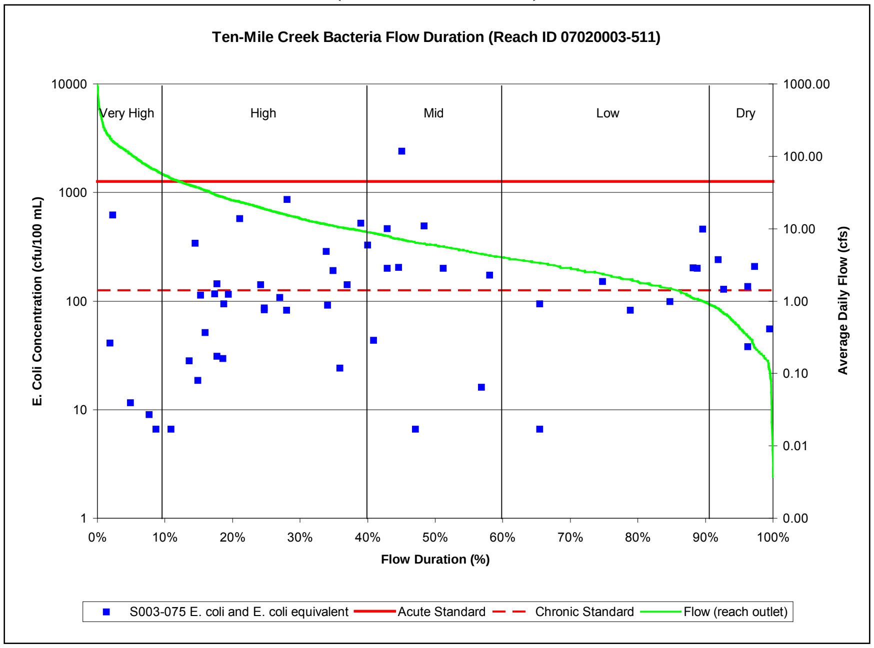
Note: Figure presents flow duration information developed at the downstream end of the reach and bacteria concentrations from the station(s) noted.

Figure 2.9 – Lac qui Parle River (W. Branch Lac qui Parle River to Ten Mile Creek) - *E. coli* Concentrations by Flow Regime (Station S003-087)



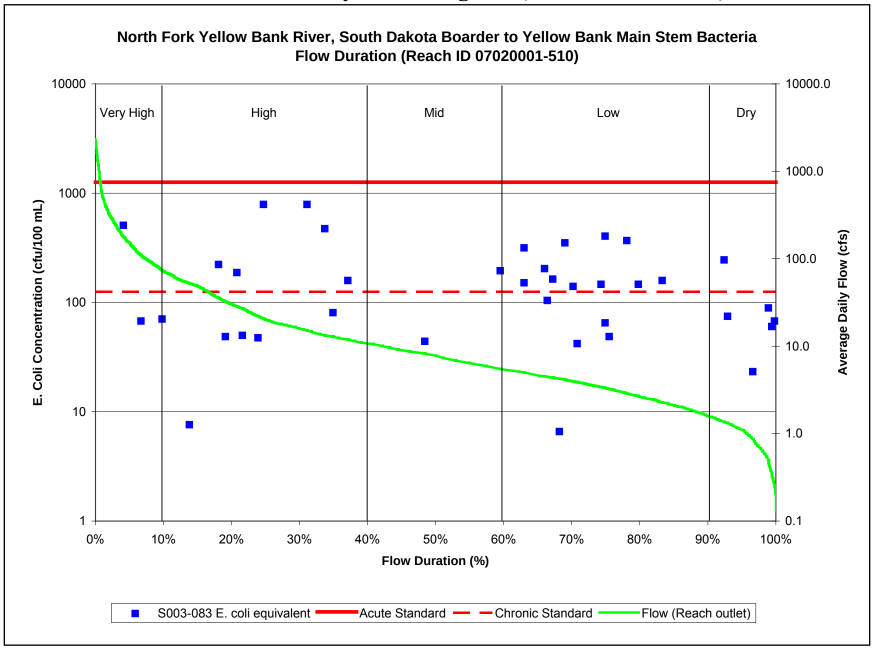
Note: Figure presents flow duration information developed at the downstream end of the reach and bacteria concentrations from the station(s) noted.

Figure 2.10 – Ten Mile Creek (Headwaters to Lac qui Parle River) - *E. coli* Concentrations by Flow Regime (Station S003-075)



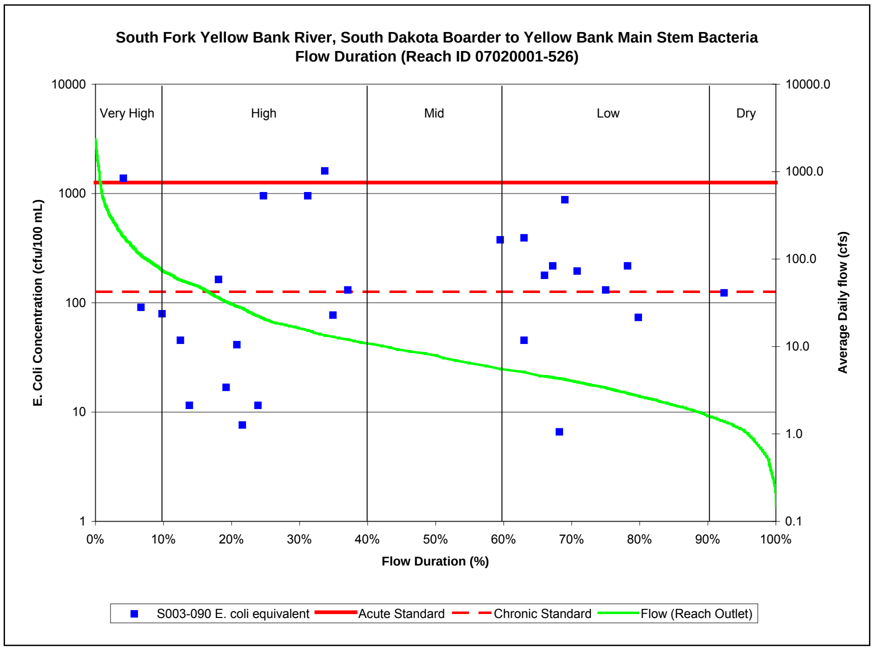
Note: Figure presents flow duration information developed at the downstream end of the reach and bacteria concentrations from the station(s) noted.

Figure 2.11 – North Fork - Yellow Bank River (South Dakota border to Yellow Bank River) - *E. coli* Concentrations by Flow Regime (Station S003-083)



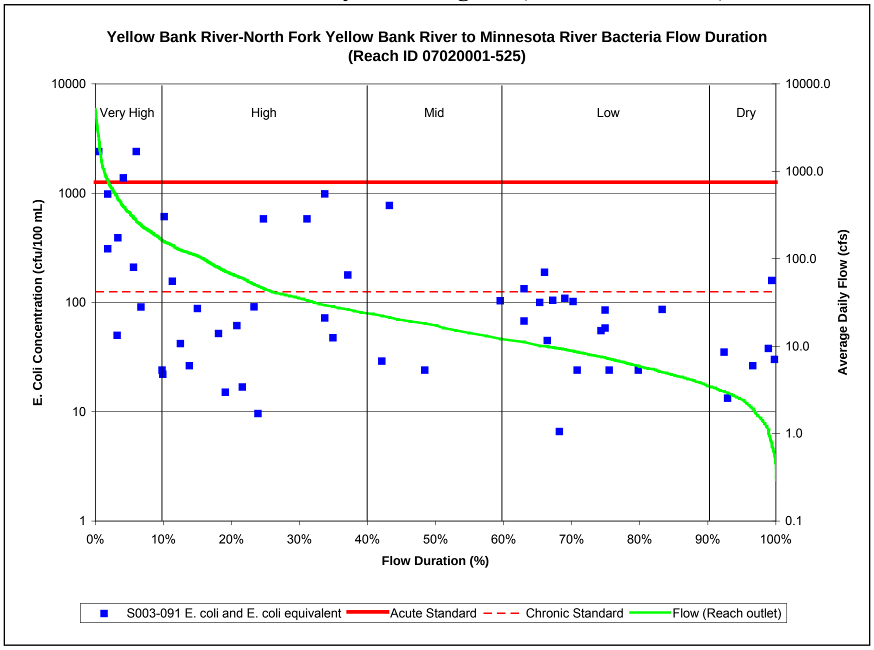
Note: Figure presents flow duration information developed at the downstream end of the reach and bacteria concentrations from the station(s) noted.

Figure 2.12 – South Fork - Yellow Bank River (South Dakota border to Yellow Bank River) - *E. coli* Concentrations by Flow Regime (Station S003-090)



Note: Figure presents flow duration information developed at the downstream end of the reach and bacteria concentrations from the station(s) noted.

Figure 2.13 – Yellow Bank River (North Fork Yellow Bank River to Minnesota River) - *E. coli* Concentrations by Flow Regime (Station S003-091)



Note: Figure presents flow duration information developed at the downstream end of the reach and bacteria concentrations from the station(s) noted.

Conclusions that can be drawn from the data presented are as follows:

- The information presented in Figures 2.3 – 2.13 indicates generally a good to excellent distribution of sample data across high, mid-, and low flow regimes.
- Data for almost all stations shows frequent exceedances during low flow conditions. Exceedances are particularly numerous for the stations on the Lac qui Parle River above Lazarus Creek, Lazarus Creek itself, and the stations on the North and South Fork of the Yellow Bank River, where most of the samples collected during low flow regimes showed exceedances of the standard. High bacteria concentrations during low flow conditions suggest sources such as septic systems, overgrazed pastures with direct access to streams, and/or wildlife as probable sources.
- Numerous exceedances also occur at mid-, high, and very high flow regimes, though their incidence is lower as a percentage of the samples taken. This reflects the probable role of summer precipitation events generating runoff episodes that cause delivery of bacterial loads to the receiving water. Possible sources for exceedances at these flow regimes include runoff from feedlots without runoff controls and fields that may have received surface applications of manure just prior to the runoff event.
- Exceedances of the bacteria standard generally seem to be most severe at upstream sites and decrease in severity the further downstream the station. This may support focusing on working in a generally upstream-to-downstream progression during implementation.

2.5.2 Permitted Point Sources

The second evaluation was an assessment of permitted point source Discharge Monitoring Records (DMRs). Table 2.58 presents: industrial and municipal treatment facilities of interest; where they discharge their effluent; and recent information on the quality of their discharges. The NPDES permit number for each facility is shown below the facilities name.

Table 2.58 – Summary of Fecal Coliform Data for Permitted Point Source Dischargers

Source	Years	Fecal Coliform Bacteria Limit (CMA)	Mean FC (cfu/100 ml)	Max FC (cfu/100 ml)	Notes
AMPI – Dawson [1] (MN0048968)	2002-2009	200 organisms/100 ml	N/A	N/A	Pond discharge
Ag Processing, Inc.- Dawson [2] (MN0040134)	2003-2009	None	N/A	N/A	Continuous discharge
Canby WWTP [3] (MN001236-SD-2)	1999-2009	200 organisms/100 ml	59	775	Pond discharge 2 of 26 samples over 200 organisms/100 ml
Dawson WWTP [2] (MN0021881)	1999-2009	200 organisms/100 ml	41	450	Continuous discharge 2 of 73 samples over 200 organisms/100 ml
Hendricks WWTP [4] (MN0021121)	1999-2009	200 organisms/100 ml	22	89	Pond discharge
Madison WTP [1]	1999-2009	N/A		N/A	Continuous discharge
Madison WWTP [1] (MNG55028)	1999-2009	200 organisms/100 ml	31	211	Continuous discharge
Marietta WWTP [5] (MNG580160)	1999-2009	200 organisms/100 ml	21	91	Pond discharge

CMA = Calendar Monthly Average
Reach Receiving Discharge:

[1] Lac qui Parle River - W, Branch to Ten Mile Creek (AUID 07020003-501)
[2] Lac qui Parle River - Unnamed ditch to Unnamed Creek (AUID 07020003-512)
[3] Lazarus Creek - Canby Creek to Lac qui Parle River (AUID 07020003-508)
[4] Lac qui Parle River - Headwaters to Lazarus Creek (AUID 07020003-505)
[5] W. Branch Lac qui Parle River - Lost Creek to Florida Creek (AUID 07020003-516)

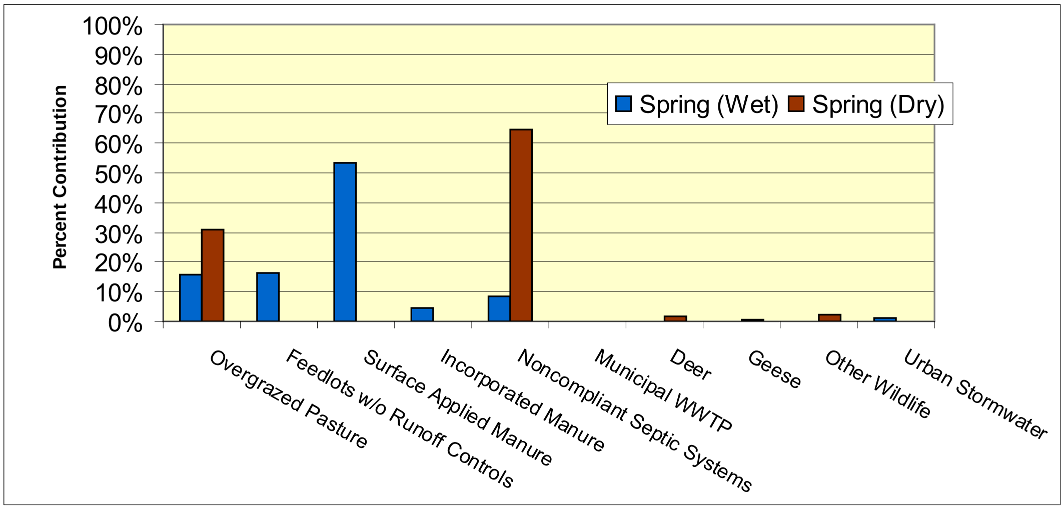
As shown in Table 2.58 above, all permitted dischargers with bacteria discharge limits have those limits set at 200 organisms/100 ml for fecal coliform, equivalent to the current *E. coli* standard of 126 cfu/100 ml. DMRs for the most recent 10 years show that exceedances of the discharge limits do occur. However, even where exceedances are shown for the Canby and Dawson facilities, they are very infrequent. Compliance of each facility with their current NPDES permit will be sufficient to meet their allocations.

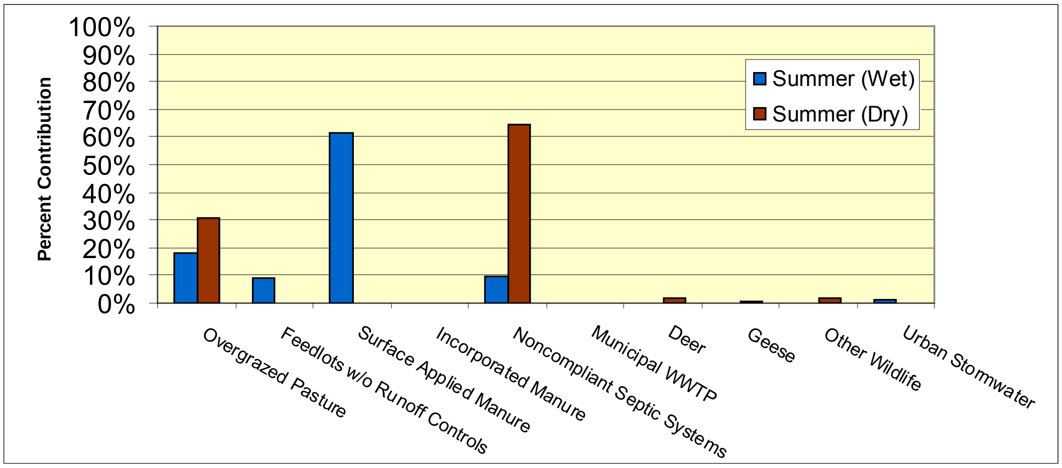
2.5.3 Accounting by Bacteria Source

The third evaluation was an accounting of bacteria sources and delivery potential based on estimates of source numbers within the project area watershed. It should be noted that the major assumptions on which the bacteria source accounting analysis was based were reviewed by persons with local knowledge of agricultural and manure-handling practices as presented in Appendix A "Bacteria Loading by Source: Methodology and Estimates of Relative Contribution."

The methodology outlined in Appendix A "Technical Memorandum on Bacteria Loading by Source" was applied to the bacteria production information to estimate the delivery potential by source for wet and dry conditions by season for the spring, summer, and fall. Figures 2.14-2.15 summarize this information for the watershed tributary to the furthest downstream bacteria impaired reach in the Lac qui Parle River watershed (AUID 07020003-501) and for the furthest downstream reach of the Yellow Bank River (AUID 07020001-525).

Figure 2.14 – Estimated Delivery Potential by Season, Flow Condition, and Source for Lac qui Parle River – W. Branch to Ten Mile Creek (AUID 07020003-501)





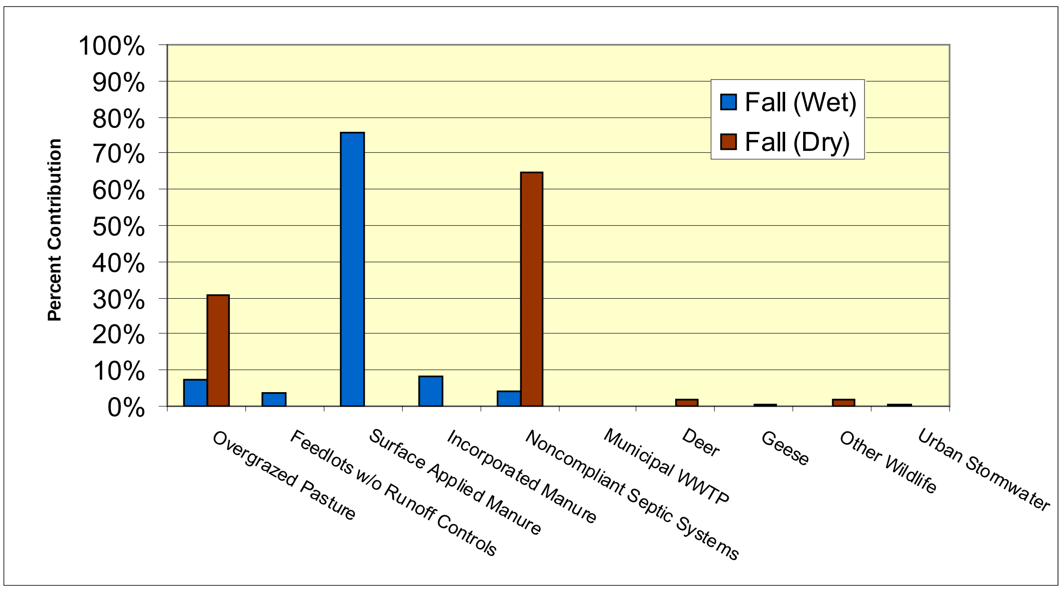
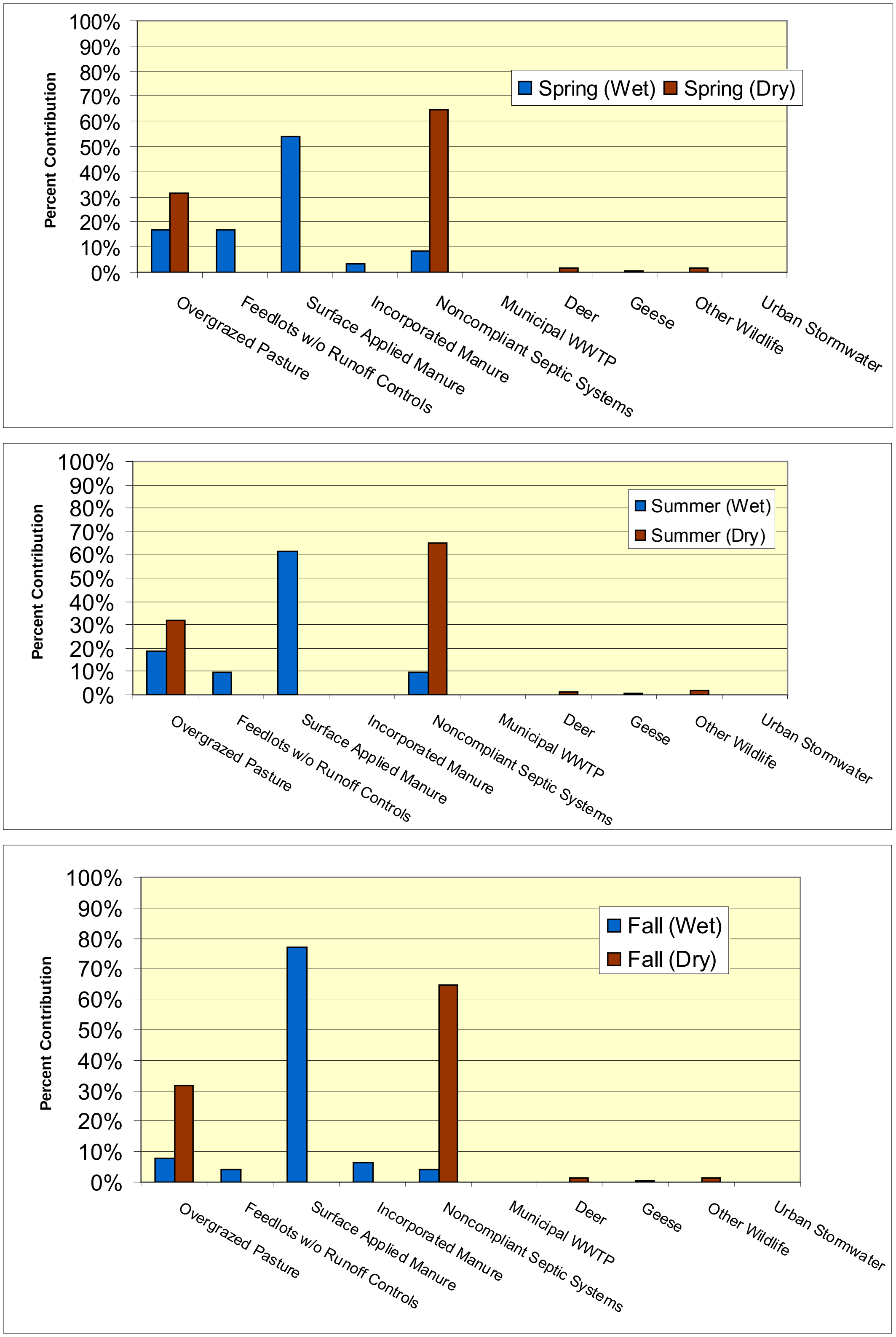


Figure 2.15– Estimated Delivery Potential by Season, Flow Condition, and Source for Yellow Bank River – North Fork Yellow Bank to Minnesota River (AUID 07020001-525)



In conclusion:

- Over-grazed riparian pasture and noncompliant septic systems have a high likelihood of being major contributors of bacteria loading during dry conditions in all seasons. This is because they can contribute bacteria load to receiving waters when other sources do not due to low or no runoff.
- Surface applied manure, over-grazed pastures, and feedlots without runoff controls appear likely to be the biggest contributors of bacteria loading during wet conditions across all seasons. Loads from these sources are generally transported entirely or in large part by runoff.
- Studies show that there is a persistence of a specific *E. coli* in sediment and water; however, they are not definitive as to the magnitude of the contribution. Additionally, the studies are not definitive as to the ultimate origins of this bacteria, so it may not be appropriate to consider it as "natural" background.

2.6 CRITICAL CONDITIONS AND SEASONAL VARIATION

EPA states the critical condition " . . . *can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (eg. flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence"* (USEPA 1999).

Bacteria levels are generally at their worst during the summer months (June, July, August) as described in Section 2.2.3. Rather than only assessing conditions during the season when the water quality standard applies (April through October), the load duration approach incorporates seasonality by evaluating allowable loads on a daily basis over the entire range of estimated flows and presenting daily allowable loads that vary by flow. As is evident in the flow duration plots showing observed *E. coli* equivalent concentrations relative to the acute and chronic standards, the relationship between exceedances of the standard and flow regime varies widely depending on the reach; some reaches showing widespread violations across all flow regimes and others showing most exceedances within a small range of flow regimes. Further, seasonal variation was addressed in accounting of bacteria sources. It is known that bacteria also die-off, hibernate and multiply in soils, beaches and stream sediments. At the time of this report, there is an indeterminate understanding of the magnitude of this process as a source or sink of bacteria in the listed reaches, due to lack of site-specific data to better understand the relationship of how this is a source or sink by flow regimes.

The allocation of point source loads (i.e., the WLA) also takes into account critical conditions by assuming the facilities will always discharge at their maximum design flows and permitted concentration limits. In reality, facilities typically discharge below design flows and display effluent quality that is better than their assigned effluent limits.

2.7 RESERVE CAPACITY

Reserve capacity refers to load that is available for future growth. With regard to permitted point source dischargers, the main potential impact could be to new or expanded discharges from treatment facilities requiring NPDES permits. Should authorization for new or expanded discharges be sought, approval is not likely to have an adverse impact on the listed reach involved provided discharge limits are met. This is because increased flows associated with those discharges will add to the overall loading capacity of the system. This would be the case as long as bacteria effluent limits for point sources are not set above the water quality standards.

The allocations for non-permitted sources are for all current and future sources. This means that any expansion of non-permitted sources will be expected to comply with the load allocations provided in this report. Human population growth in the rural areas of the project area watershed will result in the installation of new subsurface sewage treatment systems (SSTSs) to treat bacteria, since noncompliant septic ("straight pipe") systems are illegal. New SSTSs will be required to meet current codes and will not contribute to the delivered bacteria load in the project area watershed. As new systems are constructed to serve new construction, and some systems at existing homes will be upgraded tending to reduce loads overall. Thus, changes in the rural human population should not change the load allocations presented in this TMDL. Other additional non-permitted sources (such as livestock) could very well make meeting the TMDL more difficult over time. Therefore, continued efforts to prevent bacteria delivery to streams in the project area will be critical.

3.0 Turbidity Impairments

3.1 APPLICABLE MINNESOTA WATER QUALITY STANDARD AND ENDPOINTS

3.1.1 Turbidity Standard

Turbidity in water is caused by suspended sediment, organic material, dissolved salts, and stains that scatter light in the water column, making the water appear cloudy. Excess turbidity can degrade aesthetic qualities of water bodies, increase the cost of treatment for drinking water or food processing uses, and harm aquatic life. Adverse ecological impacts caused by excessive turbidity include hampering the ability of aquatic organisms to visually locate food, negative effects on gill function, and smothering of spawning beds and benthic organism habitat.

The turbidity standard found in Minn. R. 7050.0222 subpart 4 for 2B and 2C water is 25 nephelometric turbidity units (NTUs). Impairment assessment procedures for turbidity are provided by MPCA (2005). The water body is added to the impaired waters list when greater than ten percent of the data points collected within the previous 10 year period exceed the 25 NTU standard (or equivalent values for total suspended solids or transparency tube data). This TMDL is written for Class 2 waters, as this is the more protective class.

3.2 IMPAIRMENT OVERVIEW

3.2.1 Overview of Impaired Reaches

A total of seven reaches within the Lac qui Parle River and Yellow Bank River TMDL project area are listed for turbidity impairment. Table 3.1 summarizes information on the reaches listed as impaired for turbidity in TMDL project area.

Table 3.1 – Turbidity Impairments in the Lac qui Parle River and Yellow Bank River Watersheds

Reach Description	Yr Listed	Assessment Unit ID	Affected use	Pollutant or stressor	Target start// completion
Florida Creek, MN/SD Border to W. Br. Lac qui Parle River	06	07020003-521	Aquatic life	Turbidity	2014//2018
Lazarus Creek, Canby Creek to Lac qui Parle River	06	07020003-508	Aquatic life	Turbidity	2014//2018
W. Br. Lac qui Parle River, Lost Creek to Florida Creek	10	07020003-516	Aquatic life	Turbidity	2009//2011
Lac qui Parle River, Headwaters to Lazarus Creek	06	07020003-505	Aquatic life	Turbidity	2014//2018
Lac qui Parle River, Lazarus Creek to W. Br. Lac qui Parle River	06	07020003-506	Aquatic life	Turbidity	2014//2018
Lac qui Parle River, W. Br. Lac qui Parle River to Ten Mile Creek	06	07020003-501	Aquatic life	Turbidity	2014//2018
Yellow Bank River, N. Fk. Yellow Bank River to Minnesota River	10	07020001-525	Aquatic life	Turbidity	2009//2011

3.2.2 Data Sources for Lac qui Parle River and Yellow Bank River

3.2.2.1 STORET Data

Turbidity and total suspended solids (TSS) monitoring data within each listed reach were relied on heavily to assess the degree of impairment for that reach as well as provide information on potential sources of TSS loading. A list of the key monitoring stations within each listed reach is presented in Table 3.2.

Table 3.2 – Listed Reaches for Turbidity Impairments and Key Monitoring Stations

Reach Description	Assessment Unit ID	STORET ID of Key Monitoring Station(s) within Reach
Florida Cr., SD border to W. Br. Lac qui Parle River	07020003-521	S003-088
Lazarus Cr., Canby Cr. to Lac qui Parle River	07020003-508	S003-074
W. Br. Lac qui Parle River, Lost Creek to Florida Creek	07020003-516	S003-086
Lac qui Parle River, Headwaters to Lazarus Cr.	07020003-505	S003-084, S003-085
Lac qui Parle River, Lazarus Cr. to W. Br. Lac qui Parle River	07020003-506	S003-079
Lac qui Parle River, W. Br. Lac qui Parle River to Ten Mile Cr.	07020003-501	S003-087
Yellow Bank River, North Fork to MN River	07020001-525	S003-091

All sample data supporting the analyses for turbidity presented in the following sections were secured from the STORET data base. All data collected throughout the last 10 years was used in the analyses for this TMDL. Since five turbidity impaired reaches of the LQPYBWD were listed in 2006 and two reaches were listed in 2010, the datasets used in this report are typically larger and more robust than the listing datasets. Table 3.3 summarizes the TSS data by monitoring site, from upstream to downstream.

Table 3.3 – TSS Data by Monitoring Site

River/Stream	*Site Location*	*STORET ID*	*Year(s)*	*Total Number of TSS samples (N)*
Florida Creek	Highway 212	S003-088	01-03	49
Lazarus Creek	Hwy 75	S003-074	01-03; 06-08	124
W. Br. Lac qui Parle	Highway 212	S003-086	01-03	59
Lac qui Parle	Hwy 68 east of Canby	S003-084	01-03; 06-08	122
	Hwy 67 downstream of Canby	S003-085	01-03; 06-08	111
	CR 23 @ Dawson	S003-079	01-09	188
	Hwy 31	S003-087	01-09	207
Yellow Bank River	CSAH 40 near Odessa	S003-091	01-04; 07-09	152

Note: 2003 samples use 'Non-Filterable Residue' method while all other sampling years use 'Residue by evaporation and gravimetric' method.

Table 3.4 summarizes the turbidity data by monitoring site. The second column from the right shows the total number of turbidity data points by turbidity method and monitoring site and the far right column shows the number of paired turbidity/TSS data points.

Table 3.4 – Turbidity Data by Monitoring Site

River/Stream	Site Location	STORET ID	Turbidity Method	Year(s)	Total Number of samples (N)	N with paired [TSS]
Florida Creek	Highway 212	S003-088	NTU	02-03	35	35
			NTRU	ND	0	NA
			T-Tube	01-03,07	43	43
Lazarus Creek	Hwy 75	S003-074	NTU	07-08	41	41
			NTRU	02-04, 06	67	67
			T-Tube	01-04,06-08	124	117
W. Br. Lac qui Parle	Highway 212	S003-086	NTU	02-03	43	43
			NTRU	ND	0	NA
			T-Tube	01-03, 07	65	52
Lac qui Parle	Hwy 68 east of Canby	S003-084	NTU	07-08	40	40
			NTRU	02-03,06	67	67
			T-Tube	01-03,06-08	119	116
	Hwy 67 downstream of Canby	S003-085	NTU	07-08	38	38
			NTRU	02-04,06-08	58	58
			T-Tube	01-04,06-08	113	105
	CR 23 @ Dawson	S003-079	NTU	07-09	78	78
			NTRU	02-06	100	49
			T-Tube	01-09	175	175
	Hwy 31	S003-087	NTU	07-09	87	87
			NTRU	02-06	103	60
			T-Tube	01-09	198	198
Yellow Bank River	CSAH 40 near Odessa	S003-091	NTU	07-09	83	82
			NTRU	01-04	51	50
			T-Tube	02-04, 07-09	213	193

Notes: ND = No data, NA = Not applicable

Data utilized for the development of this TMDL were collected between April of 2001 and September 2009 at each of the above stations. Although data prior to this period exists, the more recent data were thought to better represent current conditions in the watershed.

3.2.2.2 Streamflow Data

To support development of allocations to address turbidity impairments for the TMDL as well as search for linkages between violations of the turbidity standard and potential pollution sources, information on streamflow within the system was also important. Among other uses, flow data was important in developing flow regime information so that the extent of turbidity exceedances for a given reach could be characterized based on whether they occurred at high, medium, or low flows. This information in turn provided insights on potential sources, with point sources being likely sources for exceedances at low flows and run-off driven processes being likely sources for high flows. The same flow records developed for the bacteria impairment (Section 2.2.2.2, Table 2.4 and Figure 2.1) were used for the turbidity impairment analysis.

3.2.3 Development of TSS Surrogate for 25 NTU Turbidity Standard

Turbidity is a measure of the cloudiness or haziness of water caused by suspended and dissolved substances in the water column. Turbidity can be caused by increased suspended soil or sediment particles, phytoplankton growth, and dissolved substances in the water column. Since turbidity is a measure of light scatter and adsorption, turbidity cannot be expressed as a mass load. TMDLs require that loads be used to express the TMDL. Consistent with MPCA Turbidity Protocol, TSS was evaluated for use as a surrogate for turbidity. Total suspended solids (TSS) is a measurement of the amount of sediment and organic matter suspended in water and is often used for loading allocations and capacities.

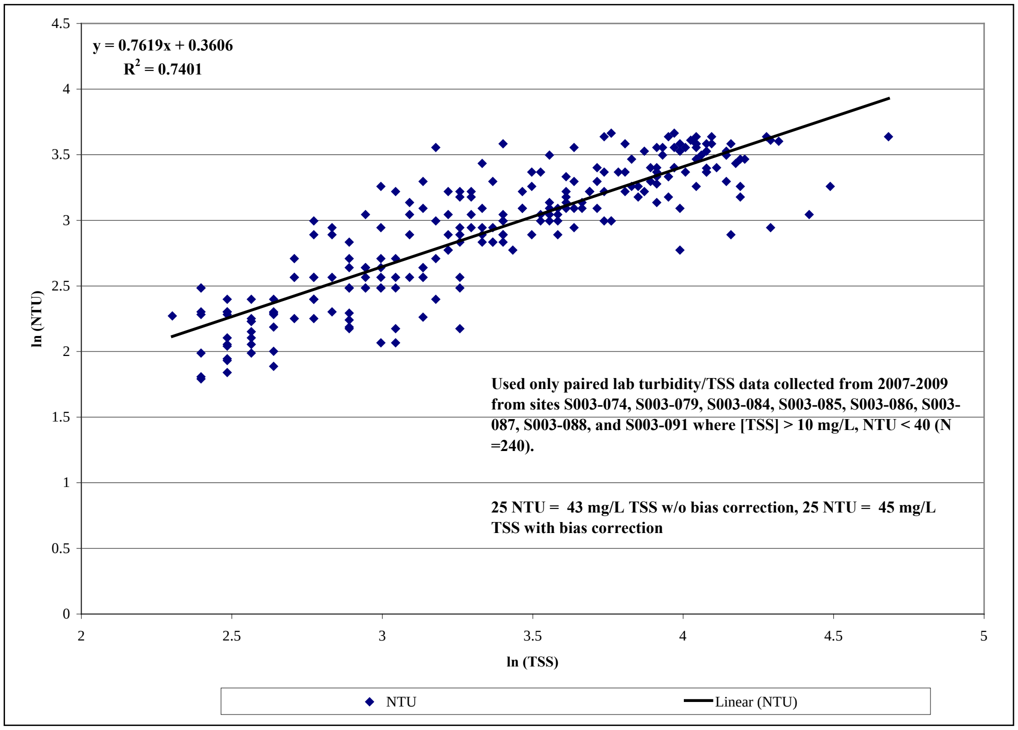
As stated in the MPCA Turbidity Protocol, "Turbidity is affected by; rainfall and catchment runoff; catchment soil erosion; bed and bank erosion; bed disturbance, e.g. by introduced fish species such as carp; waste discharge; stormwater; excessive algal growth; riparian vegetation; floodplain and wetland retention and deposition; flow; waterway type; and soil types." To account for this variability, stream-specific relationships for each surrogate variable (turbidity and TSS) must be developed if adequate data is available. Using the paired data summarized in Table 3.4, it was determined that there was adequate data collected within the Lac qui Parle River/Yellow Bank River watershed during the last ten years to develop a TSS surrogate value for the 25 NTU standard. The remainder of this section provides additional detail on the development of the site specific standard expressed as the TSS surrogate value for the 25 NTU standard.

To determine the TSS equivalent to the 25 NTU turbidity standard for this TMDL project area, paired lab turbidity and TSS samples taken at seven sites within each of the turbidity impaired reaches of the Lac qui Parle Yellow Bank River project area were used. First, individual TSS surrogates were developed for each of the seven impaired reaches. TSS surrogate values were evaluated to determine if the results were similar enough to consider either a Lac qui Parle River and Yellow Bank River TSS surrogate or one TSS surrogate that represented all seven impaired reaches. This report presents the results for one TSS surrogate representing all seven impaired reaches. Based on protocols recommended by MPCA, only sample sets with a turbidity value of 40 NTU or below and TSS values greater than 10 mg/L were used to develop the turbidity-TSS relationship (MPCA 2008). Only lab turbidity data reported in NTU were used to develop the TSS surrogate relationship.

For five of the sites, only NTU data collected between 2007 and 2009 (total of 198 paired samples) were used to define the TSS/turbidity relationship. For two other sites, the only data available was collected in 2002 and 2003 and reported as NTRU in STORET. Discussions with the lab responsible for the analyses revealed that the turbidity data were in fact reported as NTU data but recorded incorrectly in STORET as NTRU data. Thus, a total of 42 paired NTU/TSS from these two sites were added to the initial data set, creating a total data set of 240 paired values to define the TSS surrogate.

A simple regression of the natural logarithm of turbidity (y-axis) versus the natural logarithm of TSS (x-axis) was completed using the 240 paired data values for all seven sites. The analysis indicates that the turbidity standard of 25 NTU corresponds to a surrogate TSS concentration of 43 mg/L for this data set (Figure 3.1). However, informal guidance provided by MPCA suggests applying a Duan's smearing correction to the surrogate to account for the bias introduced when re-transforming the non-linear regression (Duan 1983, Ferguson 1986). After applying this bias correction method to the data set, **the corrected TSS surrogate value for the 25 NTU standard is 45 mg/L**.

Figure 3.1 – Turbidity/Total Suspended Solids Relationship for Eight Monitoring Sites within the Lac qui Parle River/Yellow Bank River Watershed



3.2.4 Converting Transparency to Total Suspended Solids

As part of the analysis of the available data, the relationship between transparency and TSS was also evaluated. Turbidity measurements are the only parameter used to determine turbidity impairments as long as a dataset of greater than 20 measurements exists. This was the case for all reaches identified as impaired for turbidity in this TMDL project area. However, there is a large volume of paired transparency and TSS data as well as transparency and turbidity at numerous sites throughout the watershed. Defining the relationship between transparency and the other two parameters can help substantially increase the data set available to determine the degree and geographic extent of impairments using watershed-specific relationships among these parameters.

Relationships between transparency tube and turbidity as well as transparency tube and TSS were constructed by combining paired data from the eight key Lac qui Parle/Yellow Bank River watershed sampling stations for the period 2002-2009 and using the same methods as the turbidity-TSS regressions discussed in Section 3.2.3. A total of 787 paired transparency/TSS data values and 302 paired transparency and NTU turbidity measurements were used to develop those respective relationships. The initial results generated equivalent transparency values, with the transparency values of about 16.7 cm equivalent to the TSS surrogate value of 45 mg/L and about a T-tube reading of 16.5 cm equivalent to the turbidity standard of 25 NTU. The results change slightly after applying a Duan's smearing correction to the surrogate to account for the bias introduced when re-transforming the non-linear regression (Duan 1983, Ferguson 1986). After applying this bias correction method to the data set, Figures 3.2 and 3.3 show the corrected results of the analysis. As expected, the results generate similar equivalent transparency values, with the transparency values of about 17.3 cm equivalent to the TSS surrogate value of 45 mg/L and about a T-tube reading of 17.8 cm equivalent to the turbidity standard of 25 NTU. A transparency value of 17 cm was used to represent the turbidity standard and the TSS surrogate where transparency data is used later in this report.

Figure 3.2 – TSS/Transparency Relationship for Eight Monitoring Sites within the Lac qui Parle Yellow Bank TMDL Watershed

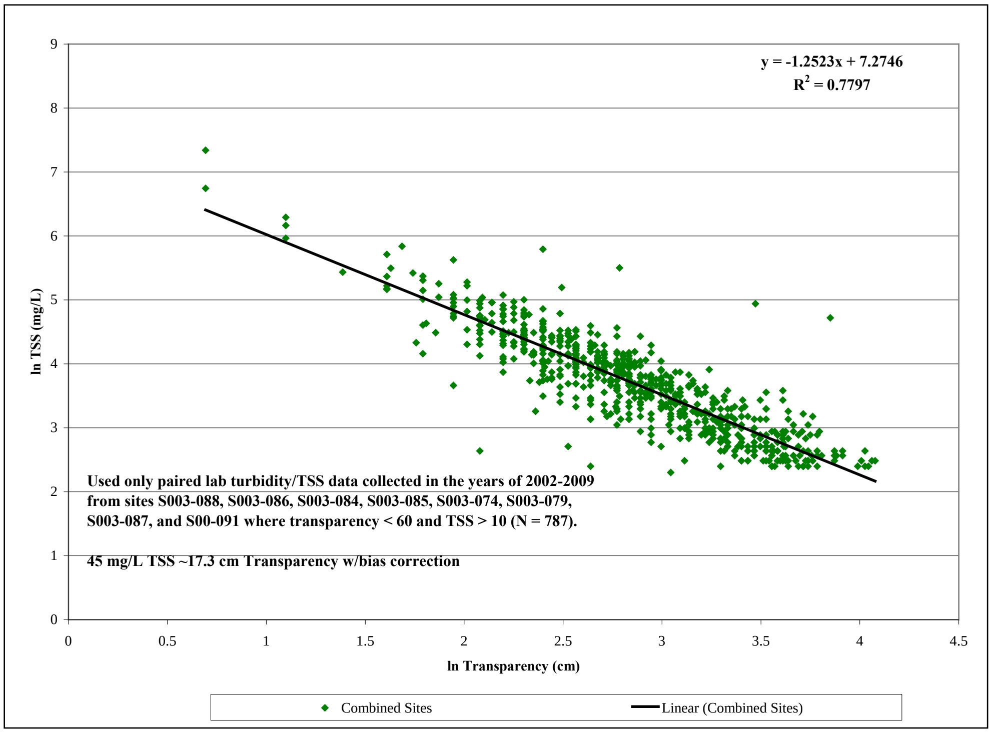
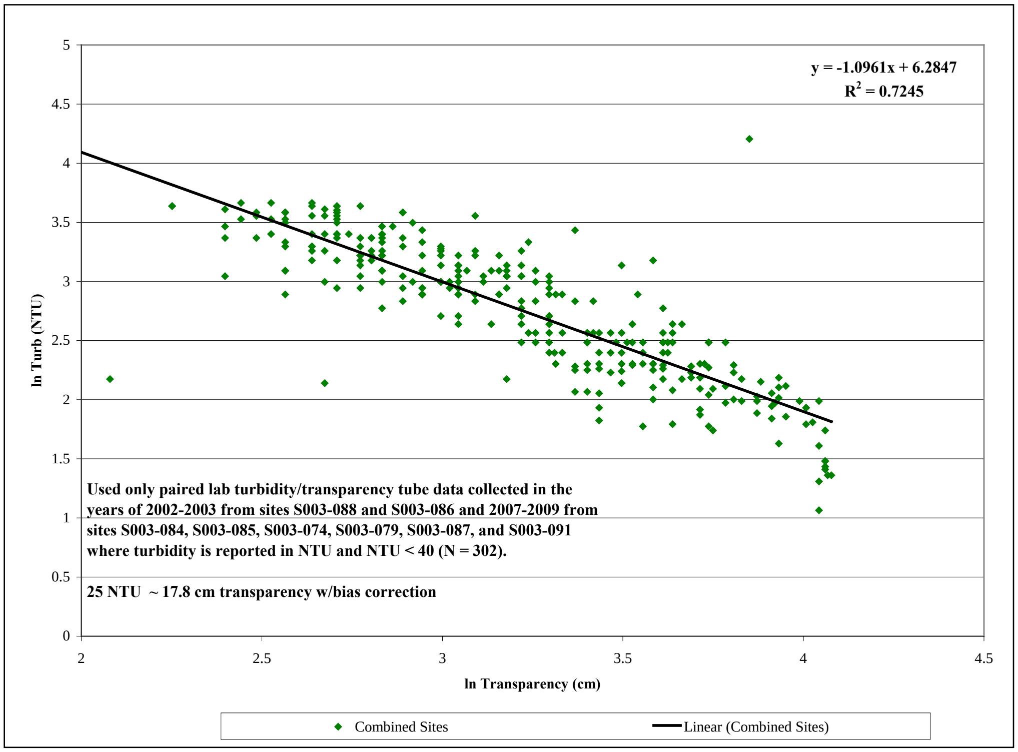


Figure 3.3 – Turbidity/Transparency Relationship for Eight Monitoring Sites within the Lac qui Parle Yellow Bank TMDL Watershed



3.2.5 Degree of Impairment

In order to estimate the degree of impairment in the listed reaches, an evaluation was conducted to determine the frequency with which turbidity data (expressed as NTU) exceeded the 25 NTU standard for each listed reach. As mentioned in Section 3.1.1, a water body is added to the impaired waters list when greater than ten percent of the data points collected within the previous 10 year period exceed the 25 NTU standard. Table 3.5 shows the percent of total samples that exceeded the 25 NTU standard for each reach. The period of record shown includes only those years for which there is high level of certainty that the turbidity data reported is expressed in NTU. Generally the greater the percentage of exceedances, the greater the magnitude of effort that will likely be needed in the respective watersheds to achieve the standard. It should be noted that this information is only intended as a rough approximation of the degree of impairment.

Table 3.5 – Turbidity Impairment Severity Summary: Lac qui Parle Yellow Bank TMDL Project Area

AUID	Reach Description	Total Number of samples (N)	Number of Samples Excceding 25 NTU Standard	% Exceeding the 25 NTU Standard	%N > 10%?	Comments
07020003-521	Florida Creek- SD border to W. Br. Lac qui Parle River	35	18	51%	Y	Period of Record Used: 2002-2003
07020003-508	Lazarus Creek – Canby Cr. to Lac qui Parle River	41	6	15%	Y	Period of Record Used: 2007-2009
07020003-516	W. Branch Lac qui Parle River – Lost Cr. to Florida Cr.	43	5	12%	Y	Period of Record Used: 2002-2003
07020003-505	Lac qui Parle River-Headwaters to Lazarus Cr.	78	53	68%	Y	Period of Record Used: 2007-2009
07020003-506	Lac qui Parle River – Lazarus Cr. to W. Br. Lac qui Parle River	78	37	47%	Y	Period of Record Used: 2007-2009
07020003-501	Lac qui Parle River – W. Branch to Ten Mile Cr.	87	37	43%	Y	Period of Record Used: 2007-2009
07020001-525	Yellow Bank River – North Fork Yellow Bank River to Minnesota River	134	36	27%	Y	Period of Record Used: 2007-2009

An estimate for the overall TSS load reduction percentage can be made for each reach using the existing data set. Table 3.6 shows the 90th percentile value for turbidity data for each of the listed reaches and the percent reduction needed to achieve the 25 NTU turbidity standard.

Table 3.6 – Estimated Percent Reduction Needed by Reach to Achieve 25 NTU Standard – Lac qui Parle Yellow Bank TMDL project Area

AUID	Reach Description	Total Number of samples (N)	90th Percentile NTU Value	Approximate % Reduction to Meet 25 NTU Standard
07020003-521	Florida Creek- SD border to W. Br. Lac qui Parle River	35	60	58%
07020003-508	Lazarus Creek – Canby Cr. to Lac qui Parle River	41	34	26%
07020003-516	W. Branch Lac qui Parle River – Lost Cr. to Florida Cr.	43	26	4%
07020003-505	Lac qui Parle River-Headwaters to Lazarus Cr.	78	85	71%
07020003-506	Lac qui Parle River – Lazarus Cr. to W. Br. Lac qui Parle River	78	54	54%
07020003-501	Lac qui Parle River – W. Branch to Ten Mile Cr.	87	72	65%
07020001-525	Yellow Bank River – North Fork Yellow Bank River to Minnesota River	134	62	60%

The reduction percentage is only intended as a rough approximation. It does not account for flow and is not a required element of a TMDL. It serves to provide a starting point using site-specific water quality data for assessing the magnitude of the effort needed in the respective watersheds to achieve the standard. The reduction percentage does not supercede the allocations provided in Section 3.4.

Based on this information, the following conclusions can be drawn:

- The data verify that all reaches meet the threshold for listing as impaired based on the most recent 10 year period of data.
- The impaired reaches of Lazarus Creek and the West Branch Lac qui Parle River are relatively mildly impaired and will require modest reductions (<26%) in turbidity to meet the 25 NTU standard.
- The other five listed reaches will require significant reductions in turbidity of between 50% and 75%.

3.3 ALLOCATION METHODOLOGY

3.3.1 Overview of Load Duration Curve Approach

Load duration analysis as described by Cleland (2002) was used to integrate flow and the TSS surrogate value for the 25 NTU turbidity standard to provide loading capacities and allocations for TSS across the full range of flows.

The first step in the process was to develop an adequate flow record for the bottom of each of the listed reaches. Section 2.2.2.2 describes the approach taken to develop a 10 year period of daily flow records at the STORET monitoring sites in each impaired reach.

The second step was to develop a daily flow duration curve on which to base the load duration curve. As described in Section 2.2.2.2, the flow duration curve is expressed in terms of flow regimes, with 0-10th percentile flows representing very high flow conditions, 10th-40th percentile representing high, 40th-60th percentile the mid flow range, 60th-90th percentile low flows and 90th-100th percentile dry conditions.

Load duration curves were developed using the flow duration curve. To do this, each average daily flow (represented in cfs) for the 10 year flow record was multiplied by the TSS surrogate for the 25 NTU turbidity standard (45 mg/L) and plotted on a logarithmic duration curve that constituted the load duration curve for that particular reach. Load duration curves for each of the seven turbidity impaired reaches are provided in Appendix D. For example, the load duration curve for Reach AUID 07020003-501 is shown in Figure 3.4. The line shown represents the assimilative capacity of the stream across all flows. To develop the TMDL, the median load within each of the five flow regimes is used to represent the total daily loading capacity (TDLC) for that flow regime (shown on Figure 3.4 as a black diamond point).

Figure 3.4 – TSS Load Duration Curve for Lac qui Parle River (West Br. Lac qui Parle River to Ten Mile Creek, AUID 07020003-501)

3.3.2 Margin of Safety

A Margin of Safety (MOS) is required in the TMDL to account for variability and uncertainties in the relationship between load and wasteload allocations and water quality.

In this TMDL report, an explicit MOS equal to 10% of the total load was used, based on a similar approach used in the "Groundhouse River TMDL for Fecal Coliform and Biota (Sediment) Impairments." This means that 10% of the loading capacity for each flow regime was subtracted before allocations were made among sources.

3.3.3 Accounting for South Dakota in Allocations

Many of the turbidity impaired reaches addressed in this document have watersheds that extend into South Dakota. Table 3.7 summarizes by turbidity impaired reach the total watershed area at the bottom of each reach and the percentage of each watershed that lies within Minnesota and South Dakota, respectively.

Table 3.7 – Listed Reach Descriptors and Watershed Area Summary

Description	AUID Number	Total Watershed Area (ac.)[1]	% Total in MN	% Total in SD
Florida Creek- SD border to W. Br. Lac qui Parle	07020003-521	96,000	50.8	49.2
Lazarus Creek-Canby Creek to Lac qui Parle River	07020003-508	85,600	85.8	14.2
W. Br. Lac qui Parle River-Lost Creek to Florida Creek	07020003-516	140,800	42.6	57.4
Lac qui Parle River-Headwaters to Lazarus Creek	07020003-505	115,900	53.7	46.3
Lac qui Parle River-Lazarus Creek to W. Br. Lac qui Parle	07020003-506	247,200	73.4	26.6
Lac qui Parle River-W. Br. To Ten Mile Creek	07020003-501	623,800	65.8	34.2
Yellow Bank River, North Fork Yellow Bank River to Minnesota River	07020001-525	300,100	18.7	81.3

[1] Watershed area is calculated based on the downstream end of the listed reach; watershed area rounded to nearest 100 acres.

The effect of flows from South Dakota in developing the TMDL was important to take into account. This is because the calculations of loading capacity and the allocations themselves are heavily dependent on flows within each listed reach, and a portion of the flow within each of those reaches is contributed by South Dakota. Allocating the entire loading capacity to Minnesota would leave none for sources in South Dakota and would likely compromise the validity of the TMDL.

In the absence of good flow monitoring information at the South Dakota/Minnesota border, an assumption was made that the loading capacity available for allocation to Minnesota sources should be proportionate to the percentage of the total drainage area at the bottom of each listed reach that lies within Minnesota. Thus, if 65% of the watershed at the bottom of an impaired reach lies within Minnesota, the TMDL for that reach would be based on the allocation of 65% of the loading capacity among Minnesota sources. The Minnesota target of 45 mg/L was used to develop the loading capacity before it was proportioned to the percentage of drainage area. It is important to note that this TMDL does not make allocations for the South Dakota portion of the basin; it merely reflects the assumption that Minnesota sources are entitled to only a portion of the loading capacity for their use because of the effect of flow contributions from South Dakota.

Finally, it is important to note that the states of South Dakota and Minnesota apply different water quality standards to reaches of the same streams that lie in each state. Minnesota applies a turbidity standard of 25 NTU to the listed waters in the TMDL project area classified for indirect contact recreation. Watershed-specific relationships between turbidity and TSS were used to develop a TSS value of 45 mg/L as a surrogate for the 25 NTU standard. South Dakota, on the other hand, applies a uniform TSS standard of 90 mg/L to waters classified to support indirect contact recreation. This has resulted in less stringent water quality standards in South Dakota than in Minnesota for inter-state streams in this TMDL project area for TSS. Table 3.8

summarizes the differences in the standards that each state applies to the streams that cross the inter-state boundary and are affected by the LQPYB TMDL assessment.

Table 3.8 – Comparison of South Dakota and Minnesota Water Quality Standards for Turbidity/TSS for Interstate Streams within the LQPYB TMDL Project Area

Parameter	Applicable South Dakota Standard	Applicable Minnesota Standard
Turbidity/Total Suspended Solids (TSS)	≤ 90 mg/L TSS (no turbidity standard)	≤ 25 NTU [1] (≤ 45 mg/L TSS) [2]

[1] Nephalometric Turbidity Units
[2] TSS concentration surrogate for 25 NTU based on analysis of paired turbidity/TSS data from turbidity impaired reaches in the Minnesota portion of the Lac qui Parle/Yellow Bank River system

If South Dakota does not meet Minnesota turbidty/TSS standards for streamflows discharged across the border, exceedances of Minnesota's standards in Minnesota are likely even if Minnesota sources are complying with the allocations set out in this TMDL.

3.3.4 Overview of Minnesota's TMDL

Following the methodology described in Section 3.3.1 "Overview of Load Duration Curve Approach" the median load was determined for each of the five flow regimes for each of the seven turbidity impaired reaches using the load duration curves for TSS as provided in Appendix D. These loads are reported in tables provided in Section 3.4 "Allocation by Reach" as the "Total Daily Loading Capacity." The Total Daily Loading Capacity was allocated across state boundaries following methodology described in Section 3.3.3 "Accounting for South Dakota in Allocations." The remainder is the "Loading Capacity for Minnesota" which consist of three main components; a Margin of Safety (MOS), a wasteload allocation (WLA) for point sources, and a load allocation (LA) for diffuse sources. The MOS was explained in Section 3.3.2 and is subtracted from the loading capacity first. Next the WLA is subtracted. Finally, all of the remaining load capacity is generally assigned to the LA.

TMDL = Σ Wasteload Allocation (WLA; Point Sources)
+ Σ Load Allocation (LA; diffuse sources)
+ Margin of Safety (MOS)

The WLA includes five sub-categories; treatment facilities requiring NPDES permits, livestock facilities requiring NPDES permits, "straight-pipe" septic systems, NPDES permitted industrial stormwater, and NPDES permitted construction stormwater. The treatment facilities requiring NPDES permits include industrial or municipal water or wastewater treatment facilities. The WLAs for treatment facilities requiring NPDES permits are assigned by reach in Section 3.4. Livestock facilities requiring an NPDES permit are assigned an allocation of "zero," since their permits do not allow any discharge from the permitted facility. "Straight-pipe" septic systems are assigned a "zero" allocation as well because they are illegal. There are no entities in the project area subject to Municipal Separate Storm Sewer Systems (MS4) stormwater permit requirements (MNR040000). There are occurrences of both industrial stormwater (MNR50000) and construction stormwater (MNR100001) permitted activities in the watershed. Allocations for both industrial and construction stormwater were set to 0.1% of the loading capacity assigned to Minnesota sources, based on guidance from MPCA.

MPCA recommends that WLAs be shown for all impaired reaches downstream of a treatment facilities requiring NPDES permits, based on the reasoning that if the total loading capacity for a downstream reach is calculated based on flow contributions from the entire upstream watershed, thus allocations should be shown for all loading sources in the entire watershed. Point sources are summarized in Table 3.9 and Table 3.10 by assessment unit ID (AUID).

Table 3.9 – Summary of Permitted Treatment Facilities

Facility	NPDES Permit Number	Assessment Unit ID	WLA TMDL Metric Tons TSS per day	Equivalent Permit Limits (TSS) mg/L
AMPI – Dawson	MN0048968	07020003-501	0.342	37
Ag Processing, Inc.- Dawson	MN0040134	07020003-512	0.174	30
Canby WWTP	MN001236-SD-2	07020003-508	0.442	45
Dawson WWTP	MN0021881	07020003-512	0.053	30
Hendricks WWTP	MN0021121	07020003-505	0.399	45
Madison WTP	MN0061077	07020003-501	0.011	30
Madison WWTP	MNG55028	07020003-501	0.055	30
Marietta WWTP	MNG580160	07020003-516	0.057	45

Table 3.10 – Summary of Permitted Feedlot Facilities

Facility	NPDES Permit Number	Assessment Unit ID
Randy & Todd Mortenson Farm	MNG440190	07020003-512
Exetare Partnership LLP - Dawson Site	MNG440124	07020003-511
Greg Bothun Farm - Sec 6	MNG440465	07020003-501
Jeffrey Abraham Farm - Sec 21	MNG440738	07020003-511
Lee Johnson Farm	MNG440431	07020003-511
Greg Bothun Farm - Sec 12	MNG440552	07020003-501
Mike & Jared Anhalt Turkey Farm	MNG440930	07020003-521
Cori Bothun Farm - Sec 28	MNG440760	07020003-506
Ten Brook Pork LLP - Site III	MNG440739	07020003-511
Joe Bothun Farm - Sec 1	MNG440553	07020003-501
Charlie Prestholdt Farm	MNG440807	07020003-501
Brent Dahl Farm	MNG440932	07020003-501
David Dahl Hog Farm	MNG440868	07020003-501
Brad Lundy Farm	MNG440837	07020003-501
Brian Boehnke Farm Site F065	MNG440735	07020001-525
Stratmoen Hog Finishing Inc	MNG440424	07020003-511
Alfred Jessen Farm	MNG440534	07020003-511
Wayne Dahl Hog Farm	MNG440446	07020003-501
B-C-H Enterprises LLP - Site I	MNG440425	07020003-511
Robert Verhelst Farm	MNG440952	07020003-505
Hogs Unlimited Inc	MNG440417	07020003-511
Dave DeJong Farm Sec 1	MNG440565	07020003-511

The MPCA used the Load Duration Curve (LDC) method to determine the loads required to attain water quality standards. The LDC method uses river flows to determine the allowable loads of TSS. A comparison between the in-stream TSS targets and technology-driven TSS effluent limits contained in MPCA NPDES permits shows that the effluent limits are below the in-stream targets. Thus, as demonstrated by Tetratech (Cleland, 2011), discharges from these facilities provide assimilative capacity beyond that which is required to offset their respective TSS loads. Although facilities are discharging below the in-stream targets, they are still discharging the pollutant of concern (TSS), and therefore individual wasteload allocations are required (wasteload allocations are listed in Section 3.4; derivation methodology is described in section 3.3).

The NPDES wasteload allocations in this TMDL are based upon current discharges. For a new or expanding (non-stormwater) NPDES-permitted facility in the watershed, permit limits will maintain discharge effluent at a concentration below the respective in-stream TSS concentration target. A new or expanding facility will increase both load and flow. This effect will be most pronounced in lower flows, when conventional point sources have the greatest impact. The increased flow will effectively increase the overall assimilative capacity of the river, as the flow increase will be larger proportionally than the load increase.

The analysis by Tetratech (Cleland, 2011) summarized above demonstrates that current discharges can be expanded and new NPDES discharges can be added while maintaining water quality standards, provided the permitted NPDES effluent concentrations remain below the in-stream targets. Given this circumstance, a streamlined process for updating TMDL wasteload allocations to incorporate new or expanding discharges will be employed. This process will apply to the non-stormwater facilities identified in section 3.3.4 of the TMDL (in the case of expansion) and any new wastewater or cooling water discharge in the portion of the Lac qui Parle River and Yellow Bank River watersheds to which this TMDL applies:

1. A new or expanding discharger will file with the MPCA permit program a permit modification request or an application for a permit reissuance. The permit application information will include documentation of the current and proposed future flow volumes and TSS loads.

2. The MPCA permit program will notify the MPCA TMDL program upon receipt of the request/application, and provide the appropriate information, including the proposed discharge volumes and the TSS loads.

3. TMDL Program staff will provide the permit writer with information on the TMDL wasteload allocation to be published with the permit's public notice.

4. The supporting documentation (fact sheet, statement of basis, effluent limits summary sheet) for the proposed permit will include information about the TSS discharge requirements, noting that for TSS, the effluent limit is below the in-stream TSS target and the increased discharge will maintain the turbidity water quality standard. The public will have the opportunity to provide comments on the new proposed permit, including the TSS discharge and its relationship to the TMDL.

5. The MPCA TMDL program will notify the EPA TMDL program of the proposed action at the start of the public comment period. The MPCA permit program will provide the permit language with attached fact sheet (or other appropriate supporting documentation) and new TSS

information to the MPCA TMDL program and the US EPA TMDL program.

6. EPA will transmit any comments to the MPCA Permits and TMDL programs during the public comment period, typically via e-mail. MPCA will consider any comments provided by EPA and by the public on the proposed permit action and wasteload allocation and respond accordingly; conferring with EPA if necessary.

7. If, following the review of comments, MPCA determines that the new or expanded TSS discharge, with a concentration below the in-stream target, is consistent with applicable water quality standards and the above analysis, MPCA will issue the permit with these conditions and send a copy of the final TSS information to the USEPA TMDL program. MPCA's final permit action, which has been through a public notice period, will constitute an update of the WLA only.

8. EPA will document the update to the WLA in the administrative record for the TMDL. Through this process EPA will maintain an up-to-date record of the applicable wasteload allocation for permitted facilities in the watershed.

The LA is reported as a single category and includes sediment transported in runoff from farm fields, pastures, and smaller feedlots that are not regulated under the NPDES program. It also includes stormwater runoff from communities and other non-permitted areas with both impervious and pervious areas. Finally, the LA also includes sediment generated by channel erosion.

In a number of reaches, the loading capacities for the “dry” and at times “low” flow regime can be virtually zero because of the absence of streamflow. Consequently, any wasteload allocation or load allocation could be interpreted as exceeding the total daily loading capacity of the stream in the flow zone. To account for this unique situation, the wasteload allocations and the load allocations are expressed as an equation rather than an absolute number. That equation is:

*Allocation = (flow contribution from a given source) * (water quality standard)*

where the surrogate water quality standard for 25 NTU is the TSS value of 45 mg/L. In essence, this amounts to a concentration-based limit to the WLA and LA sources for the affected flow regimes. This is the same methodology employed for reaches with similar situations in the recently approved Pipestone Creek Fecal Coliform Bacteria and Turbidity Total Maximum Daily Load Report (MPCA, 2008).

3.4 ALLOCATIONS BY REACH

The following sub-sections present the TMDL allocations for each turbidity impaired reach following approach described in Section 3.3 "Allocation Methodology."

3.4.1 Florida Creek (AUID 07020003-521)

Table 3.11 summarizes information for **Florida Creek; South Dakota border to W. Branch Lac qui Parle River (AUID 07020003-521)** and Map B1 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 3.11 – Summary of Reach – Florida Creek: South Dakota border to W. Branch Lac qui Parle River (AUID 07020003-521)

Stream Name	Florida Creek
AUID	07020003-521
Total Watershed Area	96,000 acres
Watershed Area in MN	48,800 acres
Percent Watershed Area in MN	50.8%
No. of Permitted Point Sources Dischargers	0
Monitoring Station STORET ID	S003-088

As summarized in Table 3.9, there are no permitted treatment facilities discharging to this impaired reach. Table 3.12 summarizes the feedlots requiring NPDES permits located in the direct watershed of this impaired reach.

Table 3.12 – Feedlots Requiring NPDES Permits in Reach – Florida Creek: South Dakota border to W. Branch Lac qui Parle River (AUID 07020003-521)

Facility	NPDES Permit Number
Mike & Jared Anhalt Turkey Farm	MNG440930

Table 3.13 provides the average daily TSS loading capacities and allocations and Minnesota and South Dakota allocations across the five flow regimes for this reach to meet the 45 mg/L TSS surrogate for the 25 NTU turbidity standard. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 3.13 – Total Daily Loading Capacities and MN and SD Allocations – Florida Creek: South Dakota border to W. Branch Lac qui Parle River (AUID 07020003-521)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
Total Daily Loading Capacity	21.15	2.99	0.81	0.25	0.01
Loading Capacity - MN	10.74	1.52	0.41	0.13	0.01
Loading Capacity - SD	10.41	1.47	0.40	0.12	0.00

The "dry" flow regime TMDL for this reach was set to the 90th percentile flow frequency load, rather than the median of loads between the 90th and 100th percentile (zero load). The median value was zero due to the observations of zero flows at S003-088.

Table 3.14 provides the average daily TSS loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the 45 mg/L TSS surrogate for the 25 NTU turbidity standard.

Table 3.14 – TSS Loading Capacities and Allocations – Florida Creek: South Dakota border to W. Branch Lac qui Parle River (AUID 07020003-521)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
MN TMDL = Σ WLA + Σ LA + MOS	10.74	1.52	0.41	0.13	0.01
Σ WLA					
NPDES Permitted Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Construction Stormwater	0.01	<0.01	<0.01	<0.01	<0.01
Industrial Stormwater	0.01	<0.01	<0.01	<0.01	<0.01
Σ LA	9.65	1.37	0.37	0.12	0.01
MOS	1.07	0.15	0.04	0.01	0.00

3.4.2 Lazarus Creek (AUID 07020003-508)

Table 3.15 summarizes information for **Lazarus Creek; Canby Creek to Lac qui Parle River (AUID 07020003-508)** and Map B2 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 3.15 – Summary for Reach – Lazarus Creek: Canby Creek to Lac qui Parle River (AUID 07020003-508)

Stream Name	Lazarus Creek
AUID	07020003-508
Total Watershed Area	85,621 acres
Watershed Area in MN	73,471 acres
Percent Watershed Area in MN	85.8%
No. of Permitted Point Sources Dischargers	1
Monitoring Station STORET ID	S003-074

Table 3.16 presents information on treatment facilities requiring NPDES permits discharging to this impaired reach. There are no livestock facilities requiring NPDES permits located in the direct watershed of this impaired reach.

Table 3.16 – Permitted Point Source Dischargers to Reach – Lazarus Creek: Canby Creek to Lac qui Parle River (AUID 07020003-508)

Facility	NPDES Permit Number	Discharge Type	Facility Design Flow	TSS Discharge Limit	Ave Daily Pond Discharge Vol. (Ponds only)	Permit Limit Based WLA (metric tons TSS per day)
Canby WWTP	MNG580154	Stabilization Pond	N/A	45 mg/L	2.6 mgd	0.442

Table 3.17 provides the average daily TSS loading capacities and allocations and Minnesota and South Dakota allocations across the five flow regimes for this reach to meet the 45 mg/L TSS surrogate for the 25 NTU turbidity standard. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 3.17 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
Total Daily Loading Capacity	12.90	2.39	0.68	0.22	0.03
Loading Capacity - MN	11.07	2.05	0.58	0.19	0.03
Loading Capacity - SD	1.83	0.34	0.10	0.03	0.00

Table 3.18 provides the average daily TSS loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the 45 mg/L TSS surrogate for the 25 NTU turbidity standard.

Table 3.18 – TSS Loading Capacities and Allocations – Lazarus Creek: Canby Creek to Lac qui Parle River (AUID 07020003-508)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
MN TMDL = Σ WLA + Σ LA + MOS	11.07	2.05	0.58	0.19	0.03
Σ WLA					
NPDES Permitted Treatment Facilities	0.44	0.44	0.44	*	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Construction Stormwater	0.01	<0.01	<0.01	*	*
Industrial Stormwater	0.01	<0.01	<0.01	*	*
Σ LA	9.50	1.40	0.08	*	*
MOS	1.11	0.21	0.06	na	na

The WLA for treatment facilities requiring NPDES permits is based on the design flow exceeded Low and Dry flow regimes TMDL available, as denoted in Table 3.18 by a "*." The WLA allocation is determined by formula:

*Allocation = (flow contribution from a given source) * (water quality standard)*

3.4.3 West Branch Lac qui Parle River (AUID 07020003-516)

Table 3.19 summarizes information for **West Branch Lac qui Parle River, Lost Creek to Florida Creek (AUID 07020003-516)** and Map B4 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 3.19 – Summary of Reach - West Branch Lac qui Parle River, Lost Creek to Florida Creek (AUID 07020003-516)

Stream Name	West Branch Lac qui Parle River
AUID	07020003-516
Total Watershed Area	140,821 acres
Watershed Area in MN	60,021 acres
Percent Watershed Area in MN	42.6 %
No. of Permitted Point Sources Dischargers	1
Monitoring Station STORET ID	S003-086

Tables 3.20 presents the information on treatment facilities requiring NPDES permits discharging to this impaired reach. There are no feedlots requiring NPDES permits located in the direct watershed to this impaired reach.

Table 3.20 – Permitted Point Source Dischargers to Reach - West Branch Lac qui Parle River, Lost Creek to Florida Creek (AUID 07020003-516)

Facility	NPDES Permit Number	Discharge Type	Facility Design Flow	TSS Discharge Limit	Ave Daily Pond Discharge Vol. (Ponds only)	Permit Limit Based WLA (metric tons TSS per day)
Marietta WWTP	MNG580160	Stabilization Pond	N/A	45 mg/L	0.335 mgd	0.057

Table 3.21 provides the average daily TSS loading capacities and allocations and Minnesota and South Dakota allocations across the five flow regimes for this reach to meet the 45 mg/L TSS surrogate for the 25 NTU turbidity standard. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 3.21 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
Total Daily Loading Capacity	31.02	4.41	1.19	0.37	0.02
Loading Capacity - MN	13.21	1.88	0.51	0.16	0.01
Loading Capacity - SD	17.81	2.53	0.68	0.21	0.01

The "dry" flow regime TMDL for this reach was set to the 90th percentile flow frequency load, rather than the median of loads between the 90th and 100th percentile (zero load). The median value was zero due to the observations of zero flows at S003-086.

Table 3.22 provides the average daily TSS loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the 45 mg/L TSS surrogate for the 25 NTU turbidity standard.

Table 3.22 – TSS Loading Capacities and Allocations – West Branch Lac qui Parle River-Lost Creek to Florida Creek (AUID 07020003-516)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
MN TMDL = Σ WLA + Σ LA + MOS	13.21	1.88	0.51	0.16	0.01
Σ WLA					
NPDES Permitted Treatment Facilities	0.06	0.06	0.06	0.06	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Construction Stormwater	0.01	<0.01	<0.01	<0.01	*
Industrial Stormwater	0.01	<0.01	<0.01	<0.01	*
Σ LA	11.81	1.63	0.40	0.08	*
MOS	1.32	0.19	0.05	0.02	na

The WLA for treatment facilities requiring NPDES permits is based on the design flow exceeded Low and Dry flow regimes TMDL available, as denoted in Table 3.22 by a "*." The WLA allocation is determined by formula:

*Allocation = (flow contribution from a given source) * (water quality standard)*

3.4.4 Lac qui Parle River (AUID 07020003-505)

Table 3.23 summarizes information for **Lac qui Parle River, Headwaters to Lazarus Creek (AUID 07020003-505)** and Map B5 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 3.23 – Summary of Reach - Lac qui Parle River, Headwaters to Lazarus Creek (AUID 07020003-505)

Stream Name	Lac qui Parle River
AUID	07020003-505
Total Watershed Area	115,890 acres
Watershed Area in MN	62,290 acres
Percent Watershed Area in MN	53.7%
No. of Permitted Point Sources Dischargers	1
Monitoring Station STORET ID	S003-084, S003-085

Table 3.24 presents information on treatment facilities requiring NPDES permits discharging to this impaired reach. Table 3.25 summarizes the feedlots requiring NPDES permits located in the direct watershed to this impaired reach.

Table 3.24 – Permitted Point Source Dischargers to Reach - Lac qui Parle River, Headwaters to Lazarus Creek (AUID 07020003-505)

Facility	NPDES Permit Number	Discharge Type	Facility Design Flow	TSS Discharge Limit	Ave Daily Pond Discharge Vol. (Ponds only)	Permit Limit Based WLA (metric tons TSS per day)
Hendricks WWTP	MN0021121	Stabilization Pond	N/A	45 mg/L	2.35 mgd	0.399

Table 3.25 – Feedlots Requiring NPDES Permits in Reach - Lac qui Parle River, Headwaters to Lazarus Creek (AUID 07020003-505)

Facility	NPDES Permit Number
Robert Verhelst Farm	MNG440952

Table 3.26 provides the average daily TSS loading capacities and allocations and Minnesota and South Dakota allocations across the five flow regimes for this reach to meet the 45 mg/L TSS surrogate for the 25 NTU turbidity standard. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 3.26 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
Total Daily Loading Capacity	17.41	3.23	0.92	0.30	0.05
Loading Capacity - MN	9.35	1.73	0.49	0.16	0.03
Loading Capacity - SD	8.06	1.50	0.43	0.14	0.02

Table 3.27 provides the average daily TSS loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the 45 mg/L TSS surrogate for the 25 NTU turbidity standard.

Table 3.27 – TSS Loading Capacities and Allocations – Lac qui Parle River, Headwaters to Lazarus Creek (AUID 07020003-505)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
MN TMDL = Σ WLA + Σ LA + MOS	9.35	1.73	0.49	0.16	0.03
Σ WLA					
NPDES Permitted Treatment Facilities	0.40	0.40	0.40	*	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Construction Stormwater	0.01	<0.01	<0.01	*	*
Industrial Stormwater	0.01	<0.01	<0.01	*	*
Σ LA	7.99	1.16	0.04	*	*
MOS	0.94	0.17	0.05	na	na

The WLA for treatment facilities requiring NPDES permits is based on the design flow exceeded Low and Dry flow regimes TMDL available, as denoted in Table 3.27 by a "*." The WLA allocation is determined by formula:

*Allocation = (flow contribution from a given source) * (water quality standard)*

3.4.5 Lac qui Parle River (AUID 07020003-506)

Table 3.28 summarizes information for **Lac qui Parle River, Lazarus Creek to W. Branch Lac qui Parle River (AUID 07020003-506)** and Map B6 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 3.28 – Summary of Reach - Lac qui Parle River, Lazarus Creek to W. Branch Lac qui Parle River (AUID 07020003-506)

Stream Name	Lac qui Parle River
AUID	07020003-506
Total Watershed Area	247,172 acres
Watershed Area in MN	181,422 acres
Percent Watershed Area in MN	73.4 %
No. of Permitted Point Sources Dischargers	0
Monitoring Station STORET ID	S003-079

As summarized in Table 3.9, there are no permitted treatment facilities discharging to this impaired reach. Table 3.29 summarizes the feedlots requiring NPDES permits located in the direct watershed to this impaired reach.

Table 3.29 – Feedlots Requiring NPDES Permits in Reach - Lac qui Parle River, Lazarus Creek to W. Branch Lac qui Parle River (AUID 07020003-506)

Facility	NPDES Permit Number
Cori Bothun Farm - Sec 28	MNG440760

Table 3.30 provides the average daily TSS loading capacities and allocations and Minnesota and South Dakota allocations across the five flow regimes for this reach to meet the 45 mg/L TSS surrogate for the 25 NTU turbidity standard. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 3.30 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
Total Daily Loading Capacity	37.25	6.90	1.97	0.65	0.10
Loading Capacity - MN	27.34	5.06	1.45	0.48	0.07
Loading Capacity - SD	9.91	1.84	0.52	0.17	0.03

Table 3.31 provides the average daily TSS loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the 45 mg/L TSS surrogate for the 25 NTU turbidity standard.

Table 3.31 – TSS Loading Capacities and Allocations – Lac qui Parle River, Lazarus Creek to West Branch Lac qui Parle (AUID 07020003-506)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
MN TMDL = Σ WLA + Σ LA + MOS	27.34	5.06	1.45	0.48	0.07
Σ WLA					
NPDES Permitted Treatment Facilities	0.84	0.84	0.84	*	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Construction Stormwater	0.02	<0.01	<0.01	*	*
Industrial Stormwater	0.02	<0.01	<0.01	*	*
Σ LA	23.73	3.71	0.46	*	*
MOS	2.73	0.51	0.15	na	na

The WLA for treatment facilities requiring NPDES permits is based on the design flow exceeded Low and Dry flow regimes TMDL available, as denoted in Table 3.31 by a "*." The WLA allocation is determined by formula:

*Allocation = (flow contribution from a given source) * (water quality standard)*

The WLAs for this reach includes the upstream permitted treatment facilities of Canby WWTP and Hendricks WWTP, see table 3.9 for the individual WLAs, and does not account for fate and transport of the upstream loads.

Permitted feedlots upstream of this reach are given a zero WLA as their permit does not allow for discharge. There is one upstream permitted feedlot from AUID 07020003-505 as shown in table 3.10. Fate and transport of the upstream loads are not accounted for.

3.4.6 Lac qui Parle River (AUID 07020003-501)

Table 3.32 summarizes information for **Lac qui Parle River, West Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)** and Map B7 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 3.32 – Summary of Reach - Lac qui Parle River, West Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)

Stream Name	Lac qui Parle River
AUID	07020003-501
Total Watershed Area	623,811 acres
Watershed Area in MN	410,311 acres
Percent Watershed Area in MN	65.8 %
No. of Permitted Point Sources Dischargers	3
Monitoring Station STORET ID	S003-087

Table 3.33 presents information on treatment facilities requiring NPDES permits discharging to this impaired reach. Table 3.34 summarizes the feedlots requiring NPDES permits located in the direct watershed to this impaired reach.

Table 3.33 – Permitted Point Source Dischargers to Reach - Lac qui Parle River, West Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)

Facility	NPDES Permit Number	Discharge Type	Facility Design Flow	TSS Discharge Limit	Ave Daily Pond Discharge Vol. (Ponds only)	Permit Limit Based WLA (metric tons TSS per day)
AMPI	MN0048968	Stabilization pond	N/A	37 mg/L	2.44 mgd	0.342
Madison WWTP	MNG550028	Continuous	0.48 mgd	30 mg/L	N/A	0.055
Madison WTP	MN0061077	Continuous	0.1 mgd	30 mg/L	N/A	0.011

Table 3.34 – Feedlots Requiring NPDES Permits in Reach - Lac qui Parle River, West Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)

Facility	NPDES Permit Number
Joe Bothun Farm - Sec 1	MNG440553
Charlie Prestholdt Farm	MNG440807
Brent Dahl Farm	MNG440932
David Dahl Hog Farm	MNG440868
Brad Lundy Farm	MNG440837
Greg Bothun Farm - Sec 6	MNG440465
Greg Bothun Farm - Sec 12	MNG440552
Wayne Dahl Hog Farm	MNG440446

Table 3.35 provides the average daily TSS loading capacities and allocations and Minnesota and South Dakota allocations across the five flow regimes for this reach to meet the 45 mg/L TSS surrogate for the 25 NTU turbidity standard. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 3.35 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
Total Daily Loading Capacity	90.59	15.79	5.06	2.25	0.42
Loading Capacity - MN	59.61	10.39	3.33	1.48	0.28
Loading Capacity - SD	30.98	5.40	1.73	0.77	0.14

Table 3.36 provides the average daily TSS loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the 45 mg/L TSS surrogate for the 25 NTU turbidity standard.

Table 3.36 – TSS Loading Capacities and Allocations – Lac qui Parle River, West Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
MN TMDL = Σ WLA + Σ LA + MOS	59.61	10.39	3.33	1.48	0.28
Σ WLA					
NPDES Permitted Treatment Facilities	1.54	1.54	1.54	*	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Construction Stormwater	0.05	0.01	<0.01	<0.01	*
Industrial Stormwater	0.05	0.01	<0.01	<0.01	*
Σ LA	52.02	7.80	1.47	*	*
MOS	5.96	1.04	0.33	na	na

The WLA for treatment facilities requiring NPDES permits is based on the design flow exceeded Low and Dry flow regimes TMDL available, as denoted in Table 3.36 by a "*." The WLA allocation is determined by formula:

*Allocation = (flow contribution from a given source) * (water quality standard)*

The WLAs for this reach includes the upstream permitted treatment facilities of Marietta WWTP, Dawson WWTP, Ag Processing, Inc., Canby WWTP and Hendricks WWTP, see table 3.9 for the individual WLAs, and does not account for fate and transport of the upstream loads.

Permitted feedlots upstream of this reach are given a zero WLA as their permit does not allow for discharge. There is one upstream permitted feedlot from AUID 07020003-521, two from AUID 07020003-512, one from AUID 07020003-505 and one from AUID 07020003-506 as shown in table 3.10. Fate and transport of the upstream loads are not accounted for.

3.4.7 Yellow Bank River (AUID 07020001-525)

Table 3.37 summarizes information for **Yellow Bank River, North Fork Yellow Bank River to Minnesota River (AUID 07020001-525)** and Map B11 in Appendix B shows the extent of the watershed, the location of the impaired reach, and the location of the key monitoring site(s) in this reach.

Table 3.37 – Summary of Reach - Yellow Bank River, North Fork Yellow Bank River to Minnesota River (AUID 07020001-525)

Stream Name	Yellow Bank River
AUID	07020001-525
Total Watershed Area	300,080 acres
Watershed Area in MN	56,030 acres
Percent Watershed Area in MN	18.7 %
No. of Permitted Point Sources Dischargers	0
Monitoring Station STORET ID	S003-091

As summarized in Table 3.9, there are no permitted treatment facilities discharging to this impaired reach. Table 3.38 summarizes the feedlots requiring NPDES permits located in the direct watershed to this impaired reach.

Table 3.38 – Feedlots Requiring NPDES Permits in Reach - Yellow Bank River, North Fork Yellow Bank River to Minnesota River (AUID 07020001-525)

Facility	NPDES Permit Number
Brian Boehnke Farm Site F065	MNG440735

Table 3.39 provides the average daily TSS loading capacities and allocations and Minnesota and South Dakota allocations across the five flow regimes for this reach to meet the 45 mg/L TSS surrogate for the 25 NTU turbidity standard. Minnesota and South Dakota allocations are proportional to the watershed in each state.

Table 3.39 – MN and SD Allocations

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
Total Daily Loading Capacity	37.42	5.05	1.98	0.85	0.26
Loading Capacity - MN	7.00	0.94	0.37	0.16	0.05
Loading Capacity - SD	30.42	4.11	1.61	0.69	0.21

Table 3.40 provides the average daily TSS loading capacities and allocations for Minnesota across the five flow regimes for this reach to meet the 45 mg/L TSS surrogate for the 25 NTU turbidity standard.

Table 3.40 – TSS Loading Capacities and Allocations – Yellow Bank River, North Fork Yellow Bank River to Minnesota River (AUID 07020001-525)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
MN TMDL = Σ WLA + Σ LA + MOS	7.00	0.94	0.37	0.16	0.05
Σ WLA					
NPDES Permitted Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Construction Stormwater	0.01	<0.01	<0.01	<0.01	<0.01
Industrial Stormwater	0.01	<0.01	<0.01	<0.01	<0.01
Σ LA	6.28	0.85	0.33	0.14	0.04
MOS	0.70	0.09	0.04	0.02	0.01

3.5 SOURCE ASSESSMENT SUMMARY

To attempt to better link potential sources of TSS with turbidity impairments in the receiving water, three evaluations were conducted. They are described in the following sections.

3.5.1 Exceedance Patterns by Flow Regime

The first evaluation involved looking at the relationships between individual sample values and the flows regimes within which those samples were collected to try to determine the most likely sources. Table 3.41 presents a general conceptual relationship between potential sources of pollutant loading and the flow conditions under which those sources of loading are likely to be most significant. It illustrates, for example, that sources not dependent on runoff as a delivery mechanism to the receiving water-such as point sources, “straight-pipe” septic systems, and/or livestock with direct access to the receiving water- can have a high potential as significant contributors to an impairment under low flow and dry conditions when surface runoff is minimal or absent. As streamflow increases, runoff-driven processes-such as pollutants transported by runoff from upland or floodplain areas and channel instability caused by hydraulic overloading-often dominate.

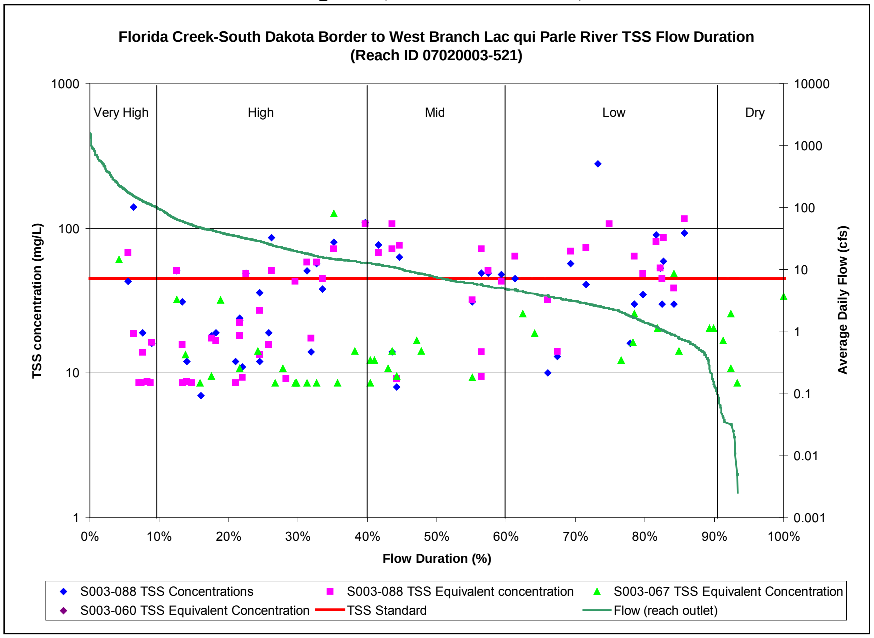
Table 3.41 – Conceptual Relationship between Flow Regime and Potential Pollutant Sources

Point Source Contributing Source Area	**Flow Regime**				
	Very High	High	Mid	Low	Dry
NPDES Permitted Treatment Facilities				M	H
Septic System w/ Noncompliant connection				M	H
Livestock in receiving water				M	H
Sub-surface treatment systems			H	M	
Stormwater Runoff – Impervious Areas		H	H	H	
Combined Sewer Overflows	H	H	H		
Stormwater Runoff – Pervious Areas	H	H	M		
Bank Erosion	H	H	M		

Note: Potential relative importance of source areas to contribute loads under given hydrologic condition (H: High; M: Medium), based on USEPA Doc. 841-B-07-006.

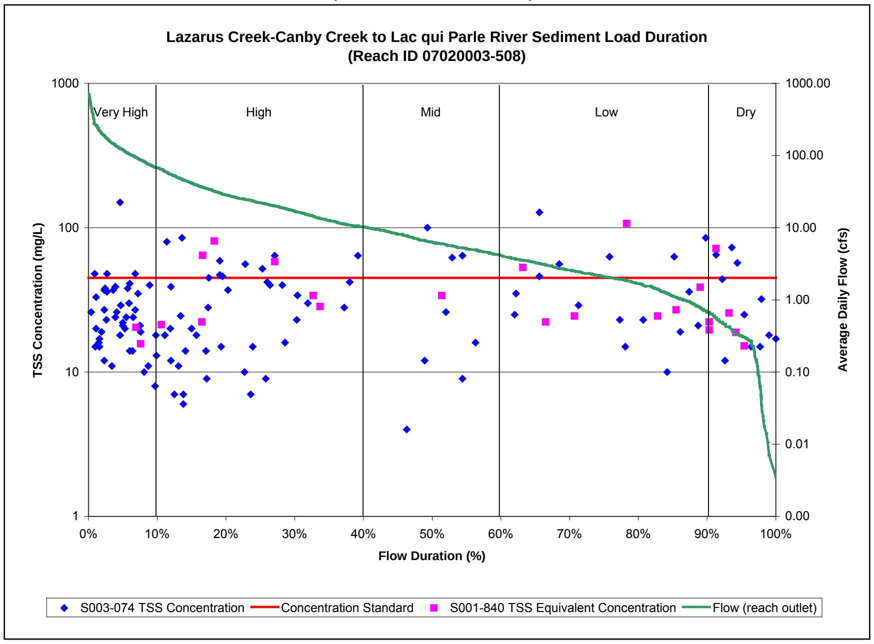
Figures 3.5 through 3.11 show plots of TSS concentrations and flow duration information for each of the seven reaches listed as impaired for turbidity. The flow duration curve is based on actual and/or simulated 10 year flow record for the reach developed as described in Section 3.2.2. As the reader may notice, some flow duration curves do not extend to 100 percent flow duration. In this instance, the flow duration curve represents a stream that ceases to flow for relatively long periods, consistent with a 7Q10 of 0.00 cfs. TSS values are either TSS data for that specific reach or transparency data that was been converted to TSS values (noted as “TSS equivalent concentrations”) using the relationship explained in Section 3.2.3. The type of data and monitoring site from which it was obtained are listed at the bottom of each graph.

Figure 3.5 – Florida Creek (MN/SD border to W. Br. Lac qui Parle River) - TSS Concentrations by Flow Regime (Station S003-088)



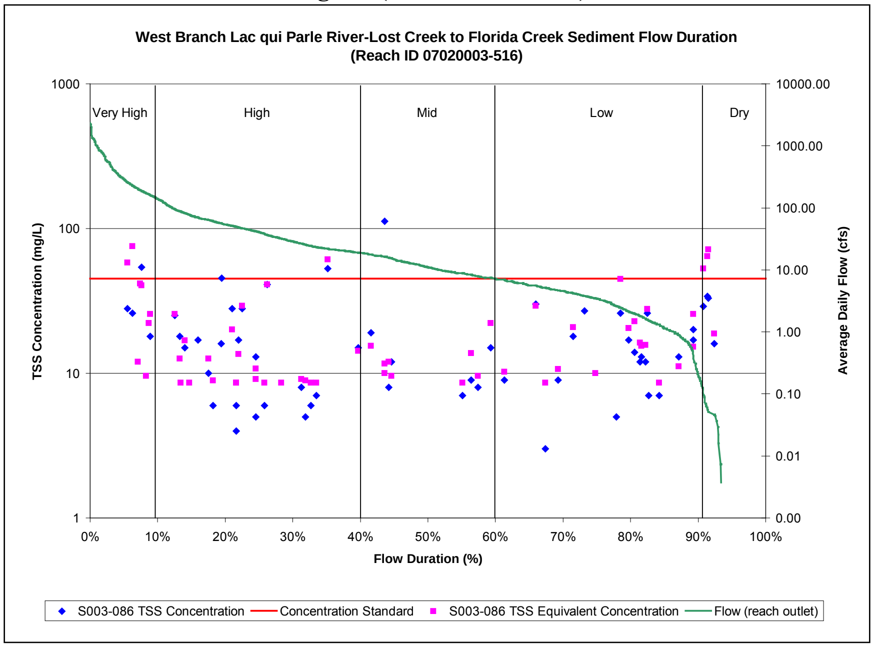
Note: Figure presents flow duration information developed at the downstream end of the reach and TSS concentrations from the station(s) noted.

Figure 3.6 – Lazarus Creek (Canby Creek to Lac qui Parle River) - TSS Concentrations by Flow Regime (Station S003-074)



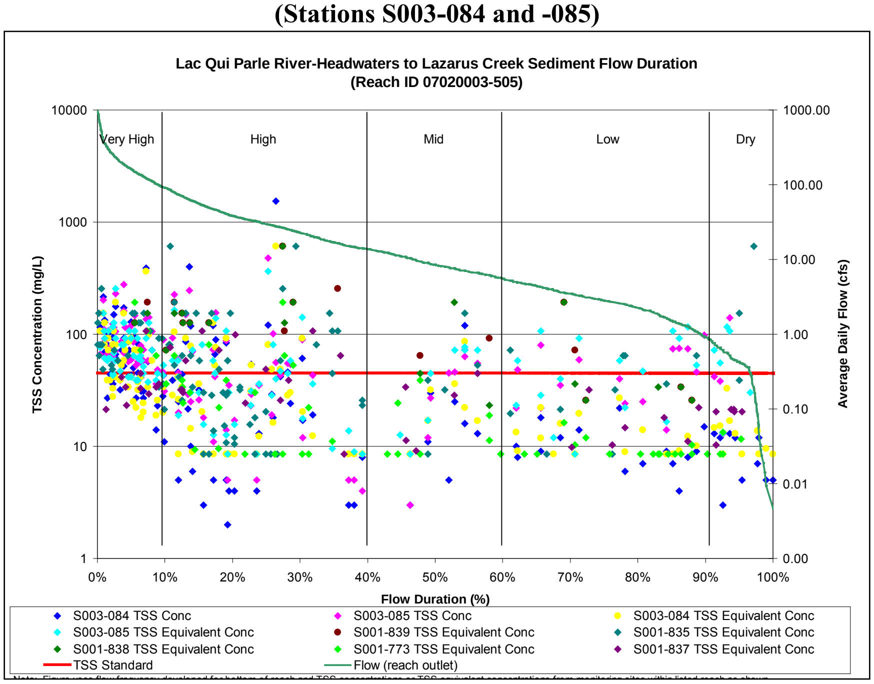
Note: Figure presents flow duration information developed at the downstream end of the reach and TSS concentrations from the station(s) noted.

Figure 3.7 – W. Branch Lac qui Parle River (Lost Creek to Florida Creek) - TSS Concentrations by Flow Regime (Station S003-086)



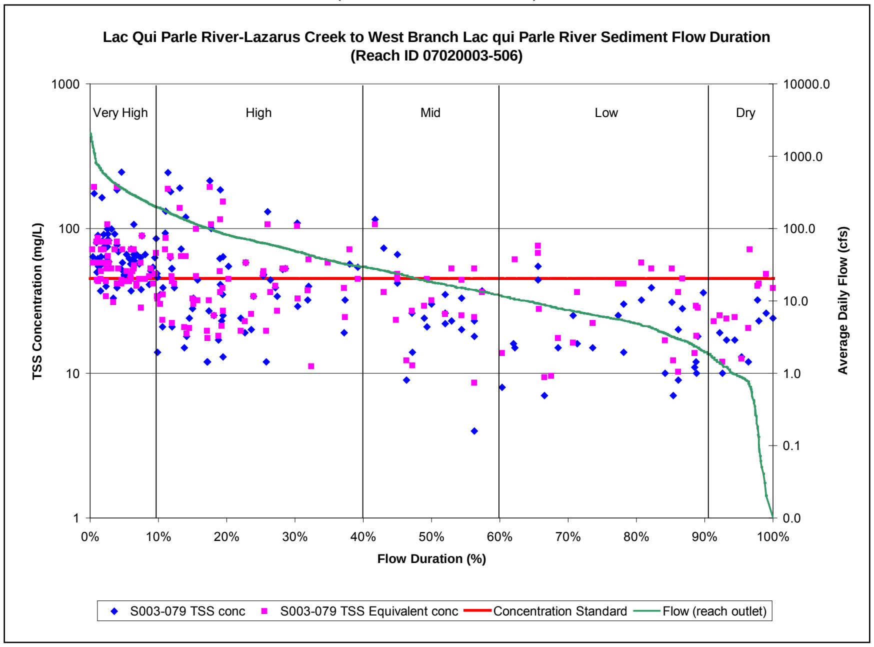
Note: Figure presents flow duration information developed at the downstream end of the reach and TSS concentrations from the station(s) noted.

Figure 3.8 – Lac qui Parle River (Headwaters to Lazarus Creek) – TSS Concentrations by Flow Regime (Stations S003-084 and -085)



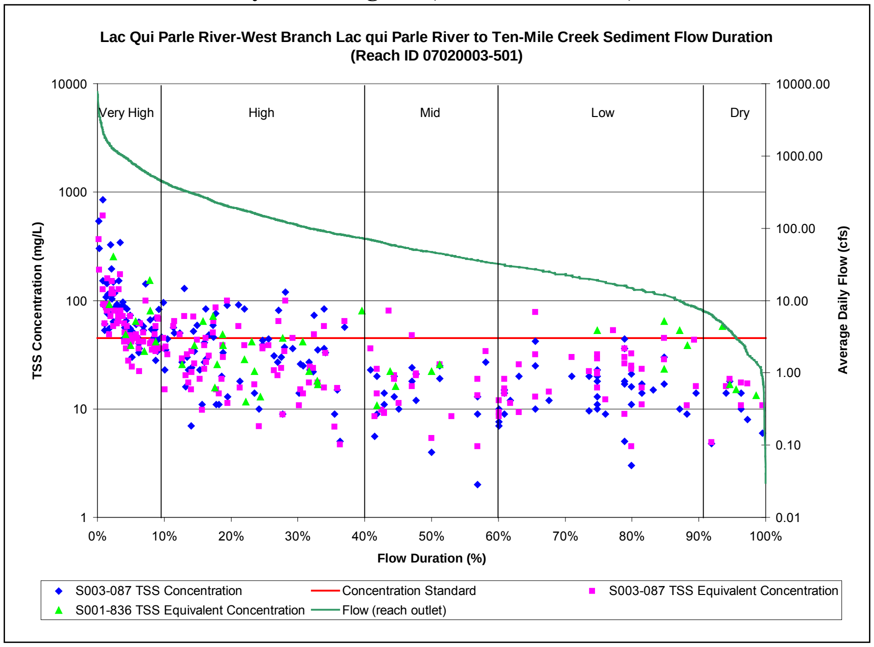
Note: Figure presents flow duration information developed at the downstream end of the reach and TSS concentrations from the station(s) noted.

Figure 3.9 – Lac qui Parle River (Lazarus Creek to W. Branch) – TSS Concentrations by Flow Regime (Station S003-079)



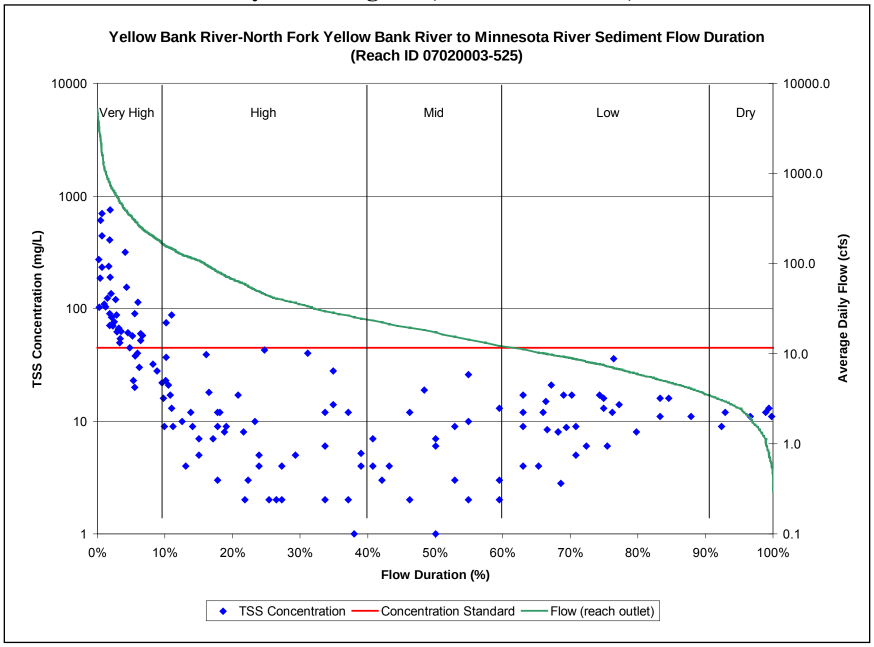
Note: Figure presents flow duration information developed at the downstream end of the reach and TSS concentrations from the station(s) noted.

Figure 3.10 – Lac qui Parle River (W. Branch Lac qui Parle River to Ten Mile Creek) - TSS Concentrations by Flow Regime (Station S003-087)



Note: Figure presents flow duration information developed at the downstream end of the reach and TSS concentrations from the station(s) noted.

Figure 3.11 – Yellow Bank River (North Fork Yellow Bank River to Minnesota River) - TSS Concentrations by Flow Regime (Station S003-091)



Note: Figure presents flow duration information developed at the downstream end of the reach and TSS concentrations from the station(s) noted.

Conclusions that can be drawn from the data presented are as follows:

- The information presented Figures 3.5 – 3.11 indicate a good distribution of sample data across the full range of flow conditions for all sites.
- The Lac qui Parle River sites all seem to show a distinct pattern of numerous exceedances of the standard at "high" and "very high" flow regimes and relatively few exceedances in the "mid-", "low", and "dry" flow regimes. The Yellow Bank River also follows this pattern. This suggests that the exceedances are likely caused by runoff-driven mechanisms, such as delivery of sediment to the river from upstream areas and/or bank instability under higher flow conditions. These flows are typically significant storm events during the spring and summer months.
- The plotted data from Florida Creek and Lazarus Creek suggests a modest impairment, but with exceedances of the standard spread across low, mid, and high flow regimes. This suggests a variety of causes, which could include runoff driven processes that deliver pollutants from upland or floodplain areas, channel instability caused by hydraulic overloading resulting in mass wasting of stream banks, channel instability caused by livestock access to the stream, and/or point source inputs such as from straight-pipe septic connections.
- Plotted data for the West Branch Lac qui Parle River (Lost Creek to Florida Creek) suggests only a mild impairment, with sporadic exceedances in low, high, and very high flow regimes. Again, this suggests a variety of causes, which could include runoff driven processes that deliver sediment, bank instability, livestock access to the stream, and/or point source inputs such as from straight-pipe septic connections.

3.5.2 Discharge Monitoring Report Evaluations for Permitted Point Sources

The second evaluation was an evaluation of permitted point source discharge monitoring records (DMRs). The industrial and municipal treatment facilities of interest, where they discharge their effluent, and recent information on the quality of their discharges is presented in Table 3.42. The NPDES permit number for each facility is shown below the facilities name.

Table 3.42 – Summary of TSS Data for Permitted Point Source Dischargers

Source	Years	TSS Limit (CMA)	Mean TSS (mg/L)	Max TSS (mg/L)	Notes
AMPI – Dawson [1] (MN0048968)	2002-2009	30 mg/L	16 mg/L	41 mg/L	Pond discharge
Ag Processing, Inc.- Dawson [2] (MN0040134)	2003-2009	30 mg/L	6 mg/L	26 mg/L	Continuous discharge
Canby WWTP [3] (MN001236-SD-2)	1999-2009	45 mg/L	46 mg/L	96 mg/L	Pond discharge 33/80 over 45 mg/L
Dawson WWTP [2] (MN0021881)	1999-2009	30 mg/L	10 mg/L	53 mg/L	Continuous discharge 1/246 over 45 mg/L
Hendricks WWTP [4] (MN0021121)	1999-2009	45 mg/L	21 mg/L	160 mg/L	Pond discharge 10/83 over 45 mg/L
Madison WTP [1]	1999-2009	30 mg/L	9 mg/L	22 mg/L	Continuous discharge
Madison WWTP [1] (MNG55028)	1999-2009	30 mg/L	12 mg/L	44 mg/L	Continuous discharge
Marietta WWTP [5] (MNG580160)	1999-2009	45 mg/L	27 mg/L	48 mg/L	Pond discharge 3/31 over 45 mg/L

CMA = Calendar Monthly Average
Reach Receiving Discharge:
[1] Lac qui Parle River – W, Branch to Ten Mile Creek (AUID 07020003-501)
[2] Lac qui Parle River – Unnamed ditch to Unnamed Creek (AUID 07020003-512)
[3] Lazarus Creek – Canby Creek to Lac qui Parle River (AUID 07020003-508)
[4] Lac qui Parle River – Headwaters to Lazarus Creek (AUID 07020003-505)
[5] W. Branch Lac qui Parle River – Lost Creek to Florida Creek (AUID 07020003-516)

As shown in Table 3.42 above, all permitted dischargers have TSS discharge limits at or below the TSS surrogate value of 45 mg/L. DMRs for the most recent 10 years show that occasional exceedances of the discharge limits occur. However, only the discharges from the stabilization ponds serving Canby and to some extent Hendricks show somewhat frequent exceedances of the standard. Compliance of each facility with their current NPDES permit will be sufficient to meet their allocations.

3.5.3 Relative Soil Loss Potential

The third evaluation was an assessment of relative soil loss potential for upland areas. Upland areas can contribute to excess turbidity by way of sheet/rill erosion of soil either overland or by way of surface tile intakes or wind-eroded soil settling into ditches that are then flushed during precipitation events. Relative soil loss potential was assessed for upland areas in Minnesota that are tributary to reaches impaired for turbidity. The approach used was modeled after the Revised Universal Soil Loss Equation (RUSLE). The key inputs for the analysis were as follows:

- Land cover from the 2008 National Agricultural Statistics Service.
- A soil erodibility factor (adjusted K) from the SSURGO soils data base.
- A general slope steepness factor was obtained from the U.S. Geological Survey's 30 meter Digital Elevation Model.

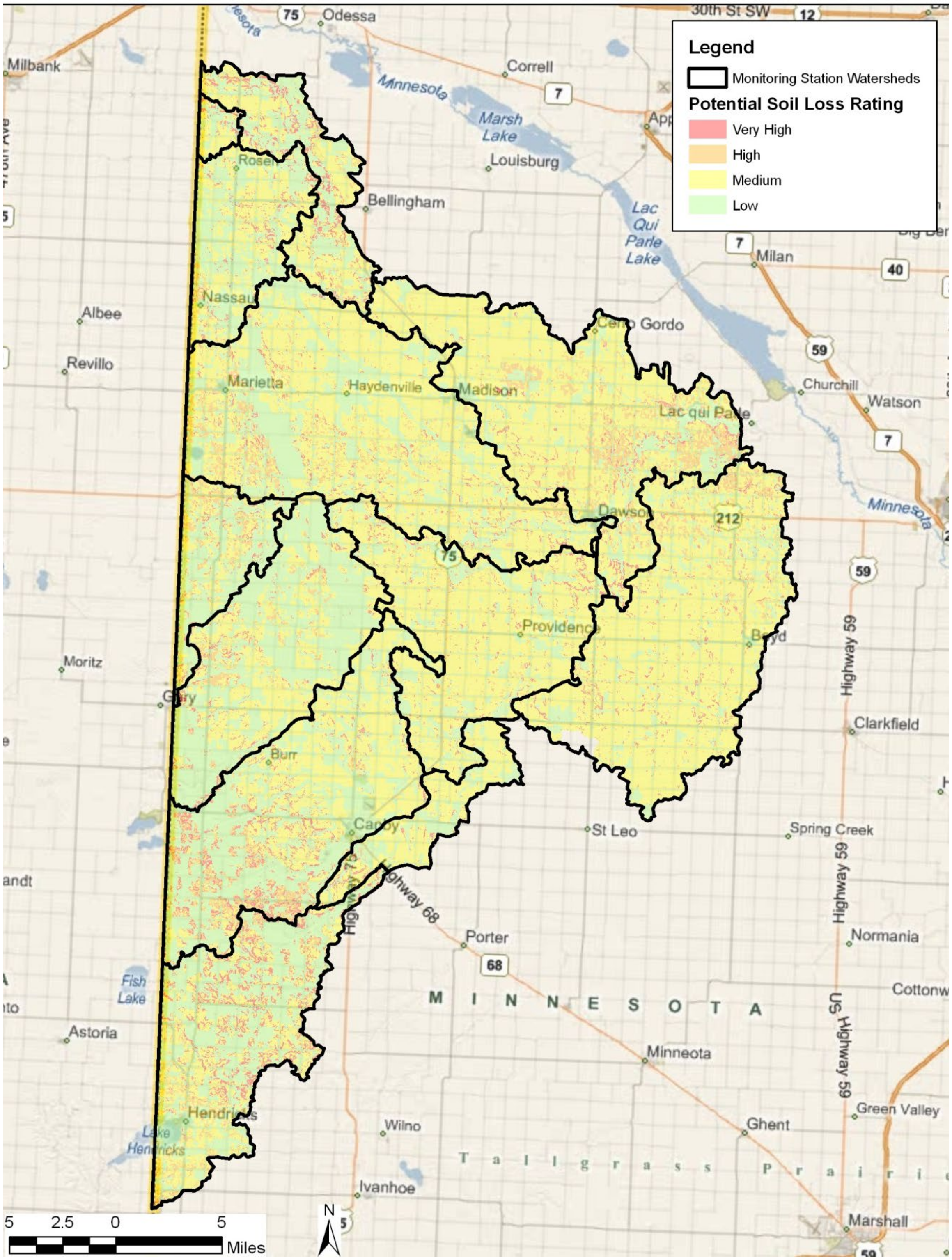
In all, over 40,000 polygons were evaluated and color coded to identify areas of very high, high, moderate, and low relative potential for soil loss. Figure 3.12 summarizes the results of the assessment in graphic form, and Table 3.43 summarizes the results of the analysis for each of the listed turbidity impaired reaches based on the percent of land evaluated that falls into each soil loss potential category. The analysis shows mostly low levels of soil loss potential with the exception of areas of mostly row crops on steeper slopes that appear to be mostly adjacent to stream corridors. Intermittent streams within row cropped areas that lack adequate buffers could be causing excess sediment delivery, and these should continue to be identified and addressed.

It should be noted that the working digital copy of Figure 3.12 might be helpful in showing potential "hotspots" in each subwatershed to guide a more detailed desk-top and field assessment. It does not take into account the actual potential for sediment to be delivered to the receiving water nor does it account for bank erosion.

Table 3.43 – Percent of Land in Minnesota by Soil Loss Potential Category

Monitoring Station	Reach ID	Very High	High	Medium	Low
S003-088	07020003-521	3%	4%	32%	61%
S003-074	07020003-508	7%	6%	38%	49%
S003-089	07020003-512	3%	5%	46%	46%
S003-086	07020003-516	5%	8%	28%	60%
S003-084	07020003-505	11%	6%	33%	50%
S003-085	07020003-505	9%	5%	40%	47%
S003-079	07020003-506	7%	4%	48%	41%
S003-087	07020003-501	5%	5%	50%	40%
S003-075	07020003-511	3%	4%	74%	19%
S003-083	07020001-510	10%	0%	51%	40%
S003-090	07020001-526	5%	1%	43%	51%
S003-091	07020001-525	8%	1%	44%	46%

Figure 3.12 – Relative Soil Loss Potential in Lac qui Parle Yellow Bank TMDL Project Area



3.6 CRITICAL CONDITIONS AND SEASONAL VARIATION

EPA states the critical condition " . . . *can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (eg. flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence"* (USEPA 1999).

Turbidity levels are generally at their worst following significant storm events during the spring and summer months, as described in Section 3.5.1. Seasonal variation is wide and is more difficult to generalize due to reach-specific differences. The load duration approach incorporates seasonality by evaluating allowable loads on a daily basis over the entire range of estimated flows and presenting daily allowable loads that vary by flow. As is evident in the flow duration plots showing observed TSS concentrations relative to the surrogate standard, the relationship between exceedances of the standard and flow regime varies by reach.

The allocation of point source loads (i.e., the WLA) also takes into account critical conditions by assuming the facilities will always discharge at their maximum design flows and permitted concentration limits. In reality, facilities typically discharge below design flows and display effluent quality that is better than their assigned effluent limits.

3.7 RESERVE CAPACITY

Reserve capacity refers to load that is available for future growth. With regard to permitted point source dischargers, the main potential impact could be to new or expanded discharges from treatment facilities requiring NPDES permits. Should authorization for new or expanded discharges be sought, approval is not likely to have an adverse impact on the listed reach involved provided discharge limits are met. This is because increased flows associated with those discharges will add to the overall loading capacity of the system. As this would be the case as long as TSS effluent limits for point sources are not set above the water quality standards.

The allocations for non-permitted sources are for all current and future sources. This means that any expansion of non-permitted sources will be expected to comply with the load allocations provided in this report. Additional diffuse sources could very well make meeting the TMDL more difficult over time. Therefore, continued efforts to prevent soil/sediment delivery to the stream will be critical.

4.0 Low Dissolved Oxygen Impairment

4.1 APPLICABLE MINNESOTA WATER QUALITY STANDARD AND ENDPOINTS

4.1.1 Dissolved Oxygen Standard

The Lac qui Parle River is specified as a Class 2C and 3C water (Minnesota Rules Chapter 7050.0470). The designated beneficial uses for Class 2C waters are aquatic life support and recreation, including “boating and other forms of recreation for which the water may be suitable.” Class 3C waters are designated for industrial consumption, except food processing. Of the designated use classifications, Class 2C has the most stringent dissolved oxygen (DO) standards.

Dissolved oxygen is an important water quality parameter for the protection and management of aquatic life. All higher life forms, including fish and aquatic macroinvertebrates, are dependent on minimum levels of oxygen for critical life cycle functions such as growth, maintenance, and reproduction. Problems with oxygen depletion in river systems are often the result of excessive loadings of carbonaceous biochemical oxygen demand (CBOD) and nitrogenous biochemical oxygen demand (NBOD), particularly in combination with high temperatures and low flow conditions. The breakdown of organic compounds in the water column and/or sediment consumes water column DO. Loading of organic matter to streams can come from both natural (plant and leaf debris, in-situ primary production) and anthropogenic (wastewater effluent, agricultural animal feces) sources. The amount of oxygen that a given volume of water can hold is a function of atmospheric pressure, water temperature, and the amount of other substances dissolved in the water. For example, cool water can hold more oxygen than warm water, and water with high concentrations of dissolved minerals such as salt will have a lower DO concentration than fresh water at the same temperature.

Dissolved oxygen concentrations go through a diurnal cycle in most rivers and streams; concentrations generally reach their maximum in late afternoon and their minimum just after sunrise. Photosynthesis by algae and other green plants during the day gives off oxygen to the water which increases DO concentrations. At nightfall photosynthesis stops, but the cycle continues. Respiration of living things, including green plants and bacteria, use oxygen faster than it is replenished. This often causes a gradual decline in DO levels throughout the night that usually culminates an hour or so after sunrise. For this reason, measurements of DO to be compared to the daily minimum are best taken no later than 2 hours after sunrise. The DO samples taken later in the day are not likely to represent the low point in the daily DO cycle. Timing is not as critical in the winter because daily DO cycles are not as pronounced as they are in the summer.

Based on its 2C classification, the 5 mg/L of DO is the daily minimum standard for the Lac qui Parle River from the confluence of West Branch Lac qui Parle River and South Branch Lac qui Parle River to Ten Mile Creek. This is the only reach within the study area that has so far been listed as impaired for low dissolved oxygen. With revisions to the assessment guidance manual for 2010, a stream is considered impaired if:

1. more than 10 percent of the "suitable" (i.e. taken before 9:00 a.m.) May through September measurements, or more than 10 percent of the total May through September measurements, or more than 10 percent of the October through April measurements violate the standard, and
2. there are at least three violations (MPCA 2009). In addition, there should be at least 20 independent observations.

4.2 IMPAIRMENT OVERVIEW

4.2.1 Overview of Impaired Reaches

The reach of the Lac qui Parle River downstream of the confluence of West Branch Lac qui Parle River and South Branch Lac qui Parle River (River Mile 29.0) to Ten Mile Creek (River Mile 3.3) was listed as impaired for low dissolved oxygen in 1994. Table 4.1 summarizes information on the one reach listed as impaired for DO in the TMDL project area.

Table 4.1 – DO Impairments: Lac qui Parle River and Yellow Bank River Watersheds

Reach Description	Yr Listed	Assessment Unit ID	Affected use	Pollutant or stressor	Target start// completion
Lac qui Parle River, W. Br. Lac qui Parle River to Ten Mile Creek	94	07020003-501	Aquatic life	Dissolved Oxygen	2004//2008

4.2.2 Data Sources for Lac qui Parle River

4.2.2.1 STORET Data

Dissolved oxygen data within the listed reach was used to assess the degree of impairment for that reach as well as provide information of potential sources of low DO. A list of key monitoring stations within the listed reach is presented in Table 4.2.

Table 4.2 – Listed Reach for DO Impairment and Key Monitoring Stations

Reach Description	Assessment Unit ID	STORET ID of Key Monitoring Station(s) within Reach
Lac qui Parle River, W. Br. Lac qui Parle River to Ten Mile Creek	07020003-501	S003-380, S001-112, S001-111, S001-110, S003-675, S003-087, S001-836

Table 4.3 shows the number of samples collected at each monitoring site within the listed reach, the number of samples below the standard of 5 mg/L. All data were obtained through STORET. Figures provided in the Appendix A QUAL2K Technical Memorandum shows the location of the monitoring stations at which samples were collected to support this TMDL assessment. The locations at which the data were collected are organized in upstream to downstream order. River

mile notations provide information on how far upstream from the mouth of the Lac qui Parle River the data monitoring point is located. For example, the monitoring site designated LqP-24.4 is located on the main stem of the Lac qui Parle River 24.4 miles upstream from the mouth.

Table 4.3 – DO Data by Monitoring Station

Site	River Mile Site ID	STORET ID	Year(s)	Total Number of samples (N)	N (under 5.00 mg/L)
South of US-212, Canoe Landing	LqP-27.9	S003-380	04-05	3	3
North of US-212, End of private drive	LqP-27.3	S001-112	87, 04-09	13	3
Private Rd	LqP-26.3	S001-111	87	4	0
Private Rd	LqP-24.4	S001-110	87, 05	5	1
CSAH 27	LqP-16.2	S003-675	05, 07, 09	8	1
Hwy 31	LqP-7.5	S003-087	04-09	29	1

Between 2004 to 2009, only three events show DO below 5.00 mg/L. Those events are:

- June 12, 2004, with one 4.99 mg/L measurement at LqP-27.9
- June 29, 2004, with one 4.99 mg/L measurement at LqP-27.9
- August 4, 2005, with five measurements at LqP-27.9, LqP-27.3, LqP-24.4, LqP-16.2, and LqP-7.5, ranging from 4.01 mg/L to 4.75 mg/L.

Table 4.3 includes the data set used to make the listing determination. The listing is based on data dating back to 1987 and included 12 instantaneous DO readings in July and August of 1987, two of which were at or below the standard of 5.0 mg/L.

4.2.2.2 Streamflow Data

To support development of allocations for the DO TMDL as well as search for linkages between violations of the standard and potential pollution sources, information on streamflow within the system was also important. Streamflow data paired with DO data allowed low DO occurrences to be evaluated by flow regime. This information in turn provided insights on potential sources that are likely sources for low DO, and how they vary during low flows and during run-off driven high flows.

Flow records between 2000 and 2009 were used to develop the flow durations because it balances a reasonably long period of record with hydrologic conditions reflective of relatively current land use. As shown in Table 4.4 there is one station located in the low DO impaired reach where substantial continuous flow data is available over the past 10 years.

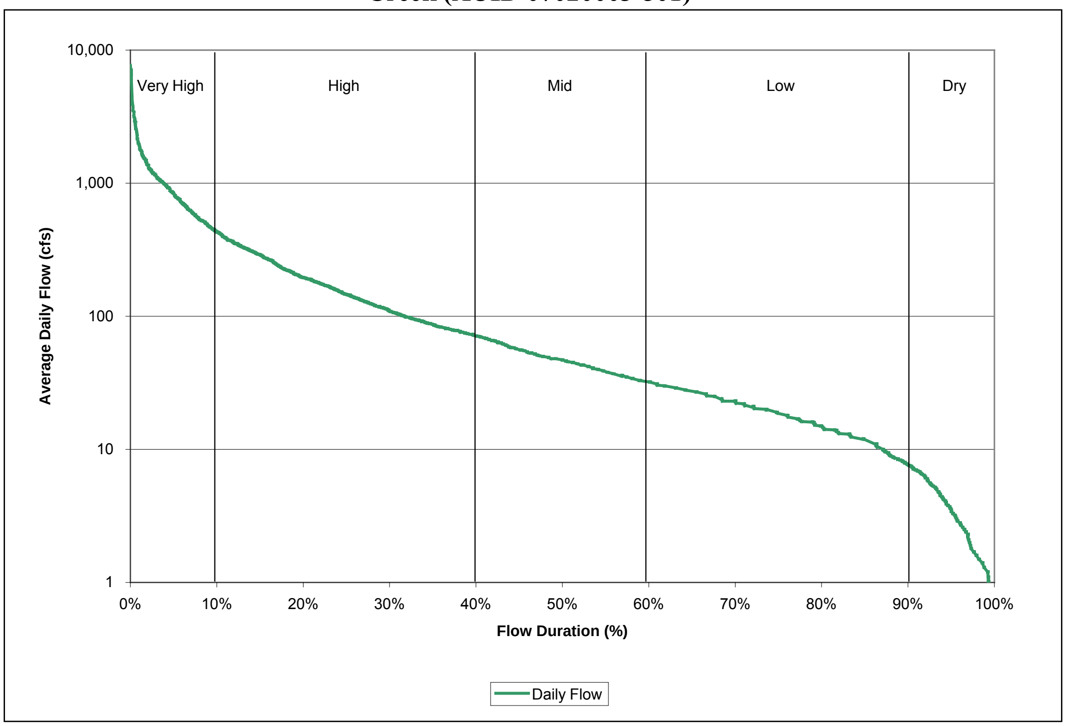
Table 4.4 – Discharge Data by Monitoring Site

STORET ID	*Location*	*DNR ID*	*USGS ID*	*Provider*	*Years of Operation*	*Flow Record Length (Days)*
S003-087	Lac qui Parle River @ CR 31	24023001	05300000	USGS	10-14, 31-99, 01-09	30027

It is important to use a reliable, long-term continuous flow record when developing flow duration curves to be used for TMDL analysis. The 7Q10 is the annual 7-day minimum flow with a 10 year recurrence interval. The 7Q10 for the listed reach based on USGS gauge 05300000 is 0.00 cfs. This statistic is based on an annual series of the smallest values of mean discharge computed over any seven consecutive days during the annual period.

The flow data was used to develop a flow duration curve for Reach AUID 07020003-501 (Lac qui Parle River from West Branch Lac qui Parle to Ten Mile Creek) is shown in Figure 4.1. The curved line relates mean daily flow to the percent of time those flow values have been met or exceeded. For example, at the 50% level for Reach AUID 07020003-501, the stream was flowing at 44 cubic feet per second for 50% or more of the time represented by the 10 year flow record. The 50% level is also the midpoint or median flow value. The curve is then divided into flow zones including very high (0-10%), high (10-40%), mid (40-60%), low (60-90%) and dry (90-100%) flow conditions.

Figure 4.1 – Flow Duration Curve for Lac Qui Parle River – W. Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)



4.2.3 Degree of Impairment

As summarized and presented in the Phase 1 Technical Memorandum provided in Appendix A, the DO portion of this TMDL focuses on data collected in the past 10 years.

The following preliminary conclusions were drawn from the available data:

- The degree of impairment within the listed reach appears relatively minor, with no readings below 4 mg/L even though the measurements documenting the violations were for the most part taken before 9:00 a.m. and can therefore be considered daily minimums.

- The two violations of the DO standard in the mid- and high flow regimes occurred near the upper end of the impaired reach and were both very minor in severity.
- The critical condition during which significant violations are most likely to occur is the late summer low flow period.
- DO violations in the West Branch of the Lac qui Parle River (one of the headwaters of the listed reach) are moderately frequent and severe, with three readings below 3 mg/L.
- The majority of the sub-5 mg/L DO readings on the West Branch of the Lac qui Parle River take place during low flow conditions, but four have occurred in the mid-range flow regime and two in the high flow regime as well.
- The low DO waters of the West Branch of the Lac qui Parle River could significantly affect DO downstream in the listed reach, especially at the upper end of the listed reach.

4.2.4 Identification of Pollutant Sources

Allocations of dissolved oxygen demanding substances are based on estimates using best available information. This section presents source linkages of potential pollution to the low DO impairment in the listed reach. In the future, allocations may be developed for upstream branches of the Lac qui Parle River. It is important to not only consider the land directly adjacent to the listed stream, but upland and upstream areas and reaches in a holistic watershed approach to implementing this TMDL.

4.2.4.1 Breakdown of Organic Matter

Oxygen depletion in streams commonly occurs from loading and subsequent breakdown of organic matter within the system. Loading of biochemical oxygen demanding (BOD) substances can be traced to both “natural” and anthropocentric sources. Algal growth is commonly identified as a source of BOD in agricultural watersheds. Natural sources of BOD include organic matter including plant decay and leaf fall. The most common human-related inputs are associated with effluent from wastewater treatment plants. There are permitted point source inputs to Lac qui Parle River as well as permitted point sources tributary to the listed reach headwaters. Permitted point source dischargers submit discharge monitoring records (DMRs) reporting various water quality parameters. The NPDES permitted treatment facilities of interest and where they discharge their effluent is presented in Table 4.5. The NPDES permit number for each facility is shown below the facilities name.

Table 4.5 – Summary of Permitted Point Source Dischargers

Source	Notes	Reach Receiving Discharge	AUID
AMPI – Dawson (MN0048968)	Seasonal Pond discharge	Lac qui Parle River W, Branch to Ten Mile Creek	07020003-501
Ag Processing, Inc.- Dawson (MN0040134)	Continuous discharge	Lac qui Parle River Unnamed ditch to Unnamed Creek	07020003-512
Dawson WWTP (MN0021881)	Continuous discharge 2 of 73 samples over 200 organisms/100 ml	Lac qui Parle River Unnamed ditch to Unnamed Creek	07020003-512
Madison WTP (MN0061077)	Continuous discharge	Lac qui Parle River W, Branch to Ten Mile Creek	07020003-501
Madison WWTP (MNG55028)	Continuous discharge	Lac qui Parle River W, Branch to Ten Mile Creek	07020003-501

Three NPDES permitted treatment facilities are located in the LQPYBWD upstream of the DO impaired reach. These are Marietta WWTP (MNG580160, AUID 07020003-516), Canby WWTP (MN001236-SD2, AUID 07020003-508) and Hendricks WWTP (MN0021121, AUID 07020003-505).

Table 4.6 summarizes the feedlots requiring NPDES permits located in the direct watershed to this impaired reach.

Table 4.6 – Feedlots Requiring NPDES Permits in Reach - Lac qui Parle River, West Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)

Facility	NPDES Permit Number
Joe Bothun Farm - Sec 1	MNG440553
Charlie Prestholdt Farm	MNG440807
Brent Dahl Farm	MNG440932
David Dahl Hog Farm	MNG440868
Brad Lundy Farm	MNG440837
Greg Bothun Farm - Sec 6	MNG440465
Greg Bothun Farm - Sec 12	MNG440552
Wayne Dahl Hog Farm	MNG440446

Four NPDES permitted feedlots are located in the LQPYBWD upstream of the DO impaired reach. These are Mike & Jared Anhalt Turkey Farm (MNG440930, AUID 07020003-521), Christensen Farms Site F031 (MNG440190, AUID 07020003-512), Cori Bothun Farm – Sec 28 (MNG440760, AUID 07020003-506) and Robert Verhelst Farm (MNG440952, AUID 07020003-505).

4.2.4.2 Water Column Biochemical Oxygen Depletion

Total BOD is comprised of two components: nitrogenous biochemical oxygen demand (NBOD) and carbonaceous biochemical oxygen demand (CBOD). CBOD is the reduction of organic carbon to carbon dioxide through the metabolic action of microorganisms. NBOD is the term for the oxygen required for nitrification, which is the biologic oxidation of ammonia to nitrate. NBOD is usually calculated by subtracting CBOD from total BOD. Carbonaceous demand is usually exerted first, normally as a result of a lag in the growth of the nitrifying bacteria necessary for oxidation of the nitrogen forms.

General rules of thumb based on stoichiometry are:

2.7 mg of oxygen is required to completely stabilize every mg of carbon.

3.43 mg of oxygen is required to completely stabilize every mg of nitrogen.

$(NH_4+ + 3/2\ 0_2 \text{------} > 2H^+ + H_20 + N0_2^-.)$

1.14 mg of oxygen is required to completely stabilize every mg of nitrogen.

$(N0_2^- + ½\ 0_2 \text{------} > N0_3^-.)$

Five-day CBOD ($CBOD_5$) monitoring in 2004 and 2005 for Lac qui Parle River indicates concentrations are low, typically around characteristic Northern Glaciated Plains ecoregion BOD_5 stream values (2.3 mg/L to 4.5 mg/L).

The Total Kjeldahl Nitrogen (TKN) concentrations of available data collected between 2001 and 2008 in the Lac qui Parle River range from 3.7 mg/L to 0.3 mg/L. TKN is the sum of organic nitrogen and ammonia (NH_3-N) in a water body. Ammonia is an inorganic form of nitrogen. High ammonia levels are typically associated with elevated NBOD as it indicates organic matter is decomposing rapidly within the system or there are significant inputs of human/animal waste. Ammonia can also indicate loading from fertilizers, septic system effluent and animal waste loading. Ammonia observations from 2004, 2005, 2007 and 2008 range between 0.34 mg/L and 0.02 mg/L. Based on TKN and ammonia samples collected on the same day at the same location, it is reasonable to conclude that TKN is mostly in the form of organic nitrogen, not ammonia. Nitrate (NO_3) plus nitrite (NO_2) as nitrogen was observed as high as 6.4 mg/L. The Northern Glaciated Plains ecoregion range for nitrates/nitrogen in streams is between 0.01 mg/L to 0.51 mg/L. MPCA notes that elevated levels of nitrates/nitrogen are often caused by over application of fertilizers that leach into waterbodies.

In summary, since Lac qui Parle River ammonia concentrations are low, short-term NBOD ($NBOD_5$) is assumed to comprise a very small fraction of total BOD_5 in the system. Thus water column BOD, while still a factor, does not appear to be the driving force of oxygen depletion in Lac qui Parle River.

4.2.4.3 Sediment Oxygen Demand

Another factor that influences oxygen concentrations in streams is sediment oxygen demand (SOD). SOD is the aerobic decay of organic materials that settle to the bottom of the stream. In natural, free-flowing streams, SOD is usually considered negligible because frequent scouring during storm events prevents long-term accumulation of organic materials. Research has found that SOD is typically higher near WWTP outfalls than downstream of WWTP outfalls. SOD is lower near outfalls with advanced treatment than those with poor secondary treatment. Sediment oxygen demand could also be influenced by animal waste and decaying plant material due to excessive nutrients from anthropogenic sources. While SOD data is not available on the impaired reach, it is likely a factor influencing oxygen depletion. Reduction/control of watershed activities associated to nutrient rich and organic enriched substances will result in lower SOD and higher DO.

4.2.4.4 Nutrients, Eutrophication and Periphyton

High in-stream nutrient concentrations can accelerate primary production allowing for increases in biological activities. When plants and algae die, bacteria decomposing the plant tissue consume DO while at the same time release nutrients into the water column. Phosphorus monitoring, between 2001 and 2008 for Lac qui Parle River, indicates concentrations are typically within the range (but sometimes elevated) of typical Northern Glaciated Plains ecoregion phosphorus stream values (0.09 mg/L to 0.25 mg/L). While chlorophyll-a concentrations (corrected for periphyton) have not been routinely monitored in Lac qui Parle River, longitudinal data was collected as part of a 2005 survey. These data shows that concentrations were lowest at the headwaters and increased downstream. While there is currently no chlorophyll-a standard for streams, some concentrations were above the 22 μg/L to 30 μg/L standard for Northern Glaciated Plains lakes which is sufficient to produce substantial algae. These data suggests that water column primary production likely plays a role in dissolved oxygen dynamics in Lac qui Parle River.

Periphyton, shown in Figure 4.2, are a broad organismal assemblage composed of attached algae, bacteria, secretions, detritus, and various species of microinvertebrates. Periphyton attach to substrate which typically do not wash away or move (e.g. rocks, logs, man-made structures), and draw nutrients from the water column to thrive.

Figure 4.2 – Periphyton

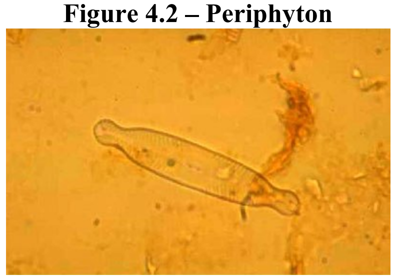


Image source: http://www.epa.gov/owow/watershed/wacademy/acad2000/rbp/5right.html

Some periphyton field data was collected in 2005, following EPA's semi-quantitative assessments of benthic algal biomass using the "Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish." The 2005 survey data consisted of water appearance, estimated water depth, substrate material (e.g. sandy, silty/muddy, cobbles, rock/sand), bottom algae growth percent coverage, and bottom vegetation percent coverage. Bottom algae growth was observed to have the highest percent coverages, between 25% to 30%, downstream of the confluence of West Branch Lac qui Parle River and South Branch Lac qui Parle River and upstream of County Ditch 27 and near the mouth of County Ditch 27. Land and water management actions that may contribute to periphyton growth, which may in turn impact water chemistry (DO and pH) include:

- Increased temperature from water management and urban runoff,
- Nutrient inputs from land-use,
- Nutrient inputs from WWTP, and
- Removal of riparian canopy.

While the data is limited, periphyton appear to be a significant factor in the low DO impairment. Periphyton growth and the resulting diurnal fluctuation of dissolved oxygen could indeed be natural, but it could also be greatly influenced by anthropogenic activities resulting in increases in phosphorus in the water column and sediments.

4.2.4.5 Impoundments, Water Temperature and SOD

Impoundments in rivers have a great influence on downstream temperatures (Allen, 2007). It is noteworthy, that immediately upstream of Lac qui Parle River on West Branch Lac qui Parle River there is a low head dam. In addition to increasing water temperatures, impoundments slow flows resulting in deposition and accumulation of organic matter and fine sediment particles which can have an elevated SOD. This dam was replaced with a series of rock weir structures in late 2009. This is expected to increase DO because oxygen diffusion rates are highest in rocky bottomed streams with swift moving, agitated waters. Impoundment effects could also apply to beaver dam structures that create backwater conditions upstream. Impoundments appear to be a factor contributing to the low DO impairment.

4.2.4.6 Canopy Coverage and Water Temperature

Canopy coverage may have an effect on stream dissolved oxygen concentrations. Decreased shading leads to more light penetration which has the potential to increase primary production and raise mean water temperatures, which in turn decreases the solubility of oxygen in water. Shading plays a bigger role in small tributary streams and county ditches, than along the Lac qui Parle River. Losses of streamside vegetation due to agriculture and other human activities can cause increases in in-stream water temperatures (Allen, 2007).

4.2.4.7 In-stream Water Temperature

In-stream water temperatures are summarized in Table 4.7. The maximum daily temperatures are greater than the Northern Glaciated Plains ecoregion range for streams (2.5°C to 22°C).

Table 4.7 – Summary In-Stream Temperatures

Dates	STORET IDs	Number of Samples (N)	Min °C / Max °C	Daily Temperature Fluctuations
August 4, 2005	S003-380, S001-112, S003-676, S003-675, S003-087	5	23.7 / 24.3	na
August 15, 2005	S001-112, S003-676, S003-675, S003-087	4	18.8 / 19.9	na
August 7-9, 2007	S003-676	Continuous	19.7 / 26.9	7.2°C
August 7-9, 2007	S003-675	Continuous	19.7 / 27.1	7.4°C
August 7-9, 2007	S003-087	Continuous	19.7 / 28.0	8.3°C

Daily temperature fluctuations range from 7.2°C to 8.3°C. Vannote and Sweeney (1980) analyzed data collected by the USGS on various streams and found that daily temperature fluctuation in natural streams varied by stream order. Temperature in sixth order streams such as

Lac qui Parle River was found on average to vary by a maximum of 6°C per day to7°C per day. This suggests that Lac qui Parle River temperatures are minimally elevated above the typical range for warm water, sixth order streams in its ecoregion.

Groundwater temperatures were assumed to be 10.1°C, based on the MPCA report "Baseline Water Quality of Minnesota's Principal Aquifers: Southwest Region" dated June 1998. The inflow of cold groundwater has a decreasing effect on temperature.

Only two point sources report temperatures in their DMRs; Madison WTP (MNG550028) and Dawson Ag Processing (MN0040134). A summary of temperature data is provided in Table 4.8.

Table 4.8 – Summary Point Source Temperatures

Point Source	Range of DMR Data	Count of Temperature Measurements Reported	Average Temperature °C	Min °C / Max °C
Madison WTP	Apr 1999 to Jan 2010	173	13.1	0.2 / 48
Dawson Ag Processing	Jul 2008 to Jan 2010	172	37.8	14.4 / 37.8

Point source and diffuse source water temperatures likely play a role in water temperatures, which effect DO concentrations and nutrient cycling in Lac qui Parle River.

4.2.4.8 Stream Geomorphology

Oxygen diffusion rates are highest in rocky bottomed streams with swift moving, agitated waters. Thus, changes to stream morphology such as channelization, deepening/widening, weirs/dams and flow-through wetlands can greatly affect reaeration and DO concentrations.

During periods of very low flows, there may be limited low-flow channel meandering across the streambed. If this occurs in late summer exposed sediments; shallow, stagnant pools; and excessive periphyton growth could contribute to depleted dissolved oxygen.

4.2.5 Linking Pollutant Sources to Water Quality

As discussed with MPCA and based on the information available, the diurnal variation in dissolved oxygen due to periphyton growth appears to be a critical component in the violation of the dissolved oxygen water quality standard. At the time of this study, a stream eutrophication standard for periphyton has not been established, nor is it expected to have an associated nutrient standard. USEPA modeling documentation (USEPA 2001b) states that periphyton are difficult to predict for some of the following reasons:

- They grow in mats that include live algae and detritus,
- They are easily stimulated by nutrients enrichment,
- In stream vegetation may severely limit available light affecting their life cycle,
- High flows may cause sudden sloughing, with instantaneous loss of mats over large areas, and
- Snails and other animals may graze on periphyton.

The monitoring data available upstream of the listed reach is limited. MPCA staff has documented visual evidence that suggest the inflow of anoxic groundwater could contribute to a lower base level of dissolved oxygen in the Lac qui Parle River. It is possible that the hydrogeology of the Coteau Des Prairies could attribute to “natural” low DO conditions. While this does not apply to the listed reach, further investigation in upstream reaches might yield findings that the upstream reaches are impaired for low DO and the resulting study may justify a site specific standard.

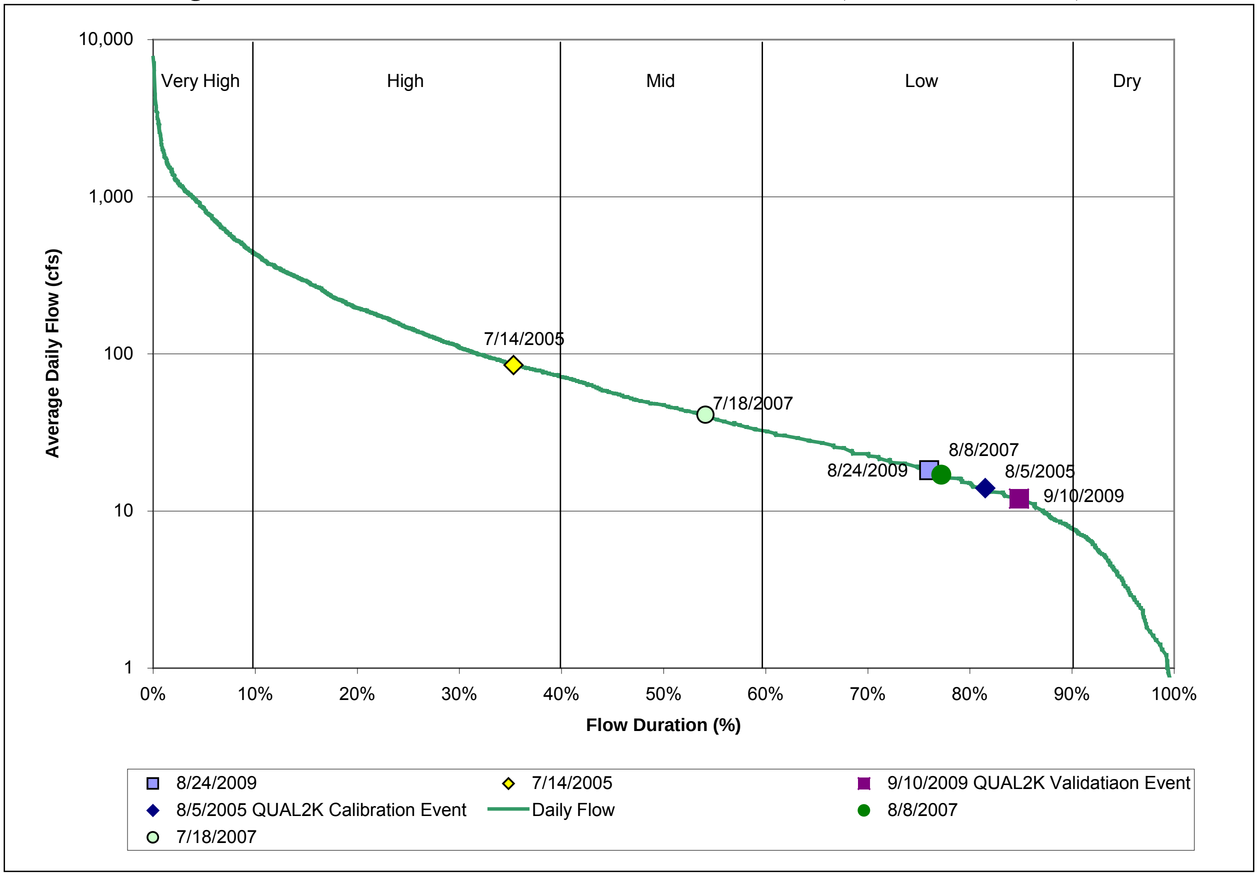
4.3 ALLOCATION METHODOLOGY

4.3.1 Overview of Lac qui Parle River Model Setup and Development

The computational framework, or model, chosen for determining the DO TMDL for Lac qui Parle River was the River and Stream Water Quality Model (QUAL2K). QUAL2K is a public domain model and is widely used and supported by the EPA for TMDL development. This model represents the stream as a well mixed channel and is intended to be applied to steady-state flow conditions. As presented in Section 4.2.3, the critical condition during which significant violations are most likely to occur is the late summer low flow period making this an appropriate model for analyzing DO violation in this system.

The data used to build, calibrate and validate a QUAL2K model for Lac qui Parle River was collected on August 4 and 15, 2005 by Booz Allen Hamilton under contract with the EPA Region 5 (Contract No. 68-W-02-018) and MPCA, August 7-9, 2007 by MPCA, and September 9-10, 2009 by Wenck Associates, Inc. Data for the calibration and validation events can be found in Appendix E. Figure 4.3 shows the flows monitored during these events on the flow duration curve.

Figure 4.3 – Flow Duration Curve for Lac Qui Parle River (AUID 07020003-501)



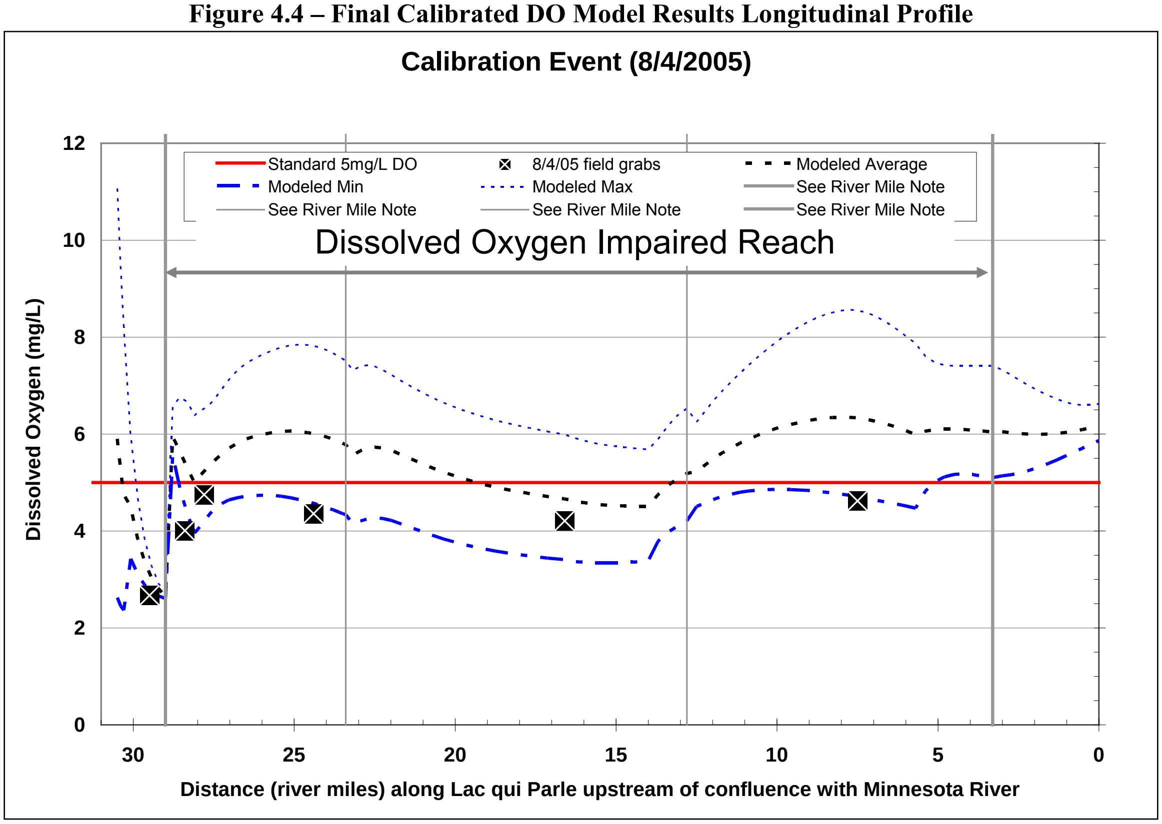
August 4, 2005 is the only event between 2004 and 2009 to show low DO violations throughout the listed reach, and subsequently selected as the DO model calibration event. As illustrated in Figure 4.3, August 5, 2005 is a low flow summer event. Data within the listed reach were limited during the August 5, 2005 data collection effort. Flow, depth, velocity and time of travel data collected on September 9-10, 2009 filled one data gap, and were used to calibrate the hydraulics of the model. As shown in Figure 4.3, September 9-10, 2009 is also a low flow event. MPCA's August 7-9, 2007 continuous monitoring data were used to establish diurnal varying patterns of DO, pH and temperature to be incorporated into the model boundary conditions. The time varying data were adjusted using the time of day, DO, pH, and temperature grab samples collected on August 5, 2005.

The maximum flow monitored during the 3-weeks prior to the calibration event, occurred on July 14, 2005. Figure 4.3 shows July 14, 2005 as a high flow event. Review of rainfall records confirm that the calibration event occurs after a runoff related event. It is possible that the high flows may have caused sudden sloughing of periphyton and detritus resulting in instantaneous loss of mats over large areas. The settling of said detritus results in increased SOD. The upstream boundary conditions of West Branch Lac qui Parle River and South Branch Lac qui Parle River are modeled using monitoring data. The three NPDES permitted treatment facilities and four NPDES permitted feedlots located in the LQPYBWD upstream of the DO impaired reach boundary conditions and not explicitly modeled. Details on how the boundary conditions, point sources, diffuse sources and groundwater were modeled using available information as documented in the Appendix A QUAL2K Technical Memorandum.

Prescribed SOD and diffuse sources of detritus were necessary in many reaches to adequately calibrate the model for both Lac qui Parle River to the observed data. Diffuse sources of detritus were assumed to be 100% CBOD that settles and dissolves as it is transported downstream. This prescribed SOD represents a load that is either unknown or which QUAL2K has difficulty modeling.

Figure 4.4 shows the final calibration results for model-predicted and observed DO concentrations. Field grabs of DO (shown as black boxes with a white “x”) were taken in the early morning on August 4, 2005. The model performs well in predicting average daily DO concentrations (plotted as black dashed line) and the diurnal pattern (daily minimum and maximum, plotted as blue dashed lines) at the monitoring stations.

Figure 4.4 – Final Calibrated DO Model Results Longitudinal Profile



River Mile 29.0 = Km 46.67 = start of listed reach
River Mile 23.4 = Km 37.66 = inflow of tributaries County Ditch 27
River Mile 12.8 = Km 20.60 = inflow of tributaries County Ditch 4
River Mile 3.3 = Km 5.31 = end of listed reach, inflow of tributary Ten Mile Creek

The DO sag just upstream of the impaired reach is due to the monitored DO and diurnal swing of DO of the upstream boundary conditions. The August 4, 2005 DO grab for South Branch Lac qui

Parle River was monitored to be 3.61 mg/L. The August 4, 2005 DO grab for West Branch Lac qui Parle River was monitored to be 2.67 mg/L.

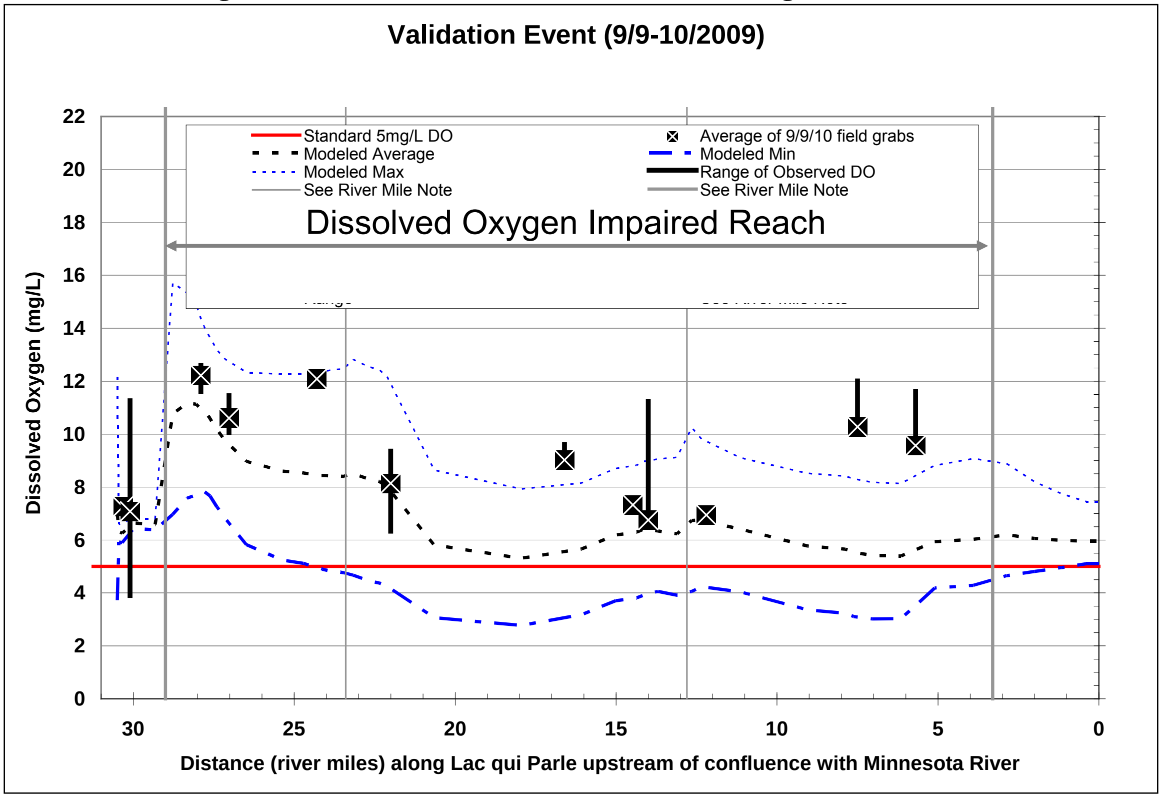
The validation event was based on monitoring conducted on September 9-10, 2009. The maximum flow monitored during the 3-weeks prior to the validation event, occurred on August 24, 2009. Figure 4.3 shows August 24, 2009 as a low flow event. Review of rainfall records confirm that the validation event is preceded with little rainfall. The pre-event conditions of the validation event are quite different than the calibration event.

Boundary conditions, point sources, diffuse sources and groundwater were modeled using available information as documented in the Appendix A QUAL2K Technical Memorandum. Besides changes that were based on monitored data to reflect the validation event, the following modeling changes were incorporated to reflect summer low flow not preceded by a storm event:

- bottom algae coverage was increased,
- prescribed SOD was reduced,
- phytoplankton inflowing from boundary conditions and diffuse sources was increased,
- nutrient release from sediments was reduced since the water column DO was less likely to be anoxic.

Figure 4.5 shows the validation results for model-predicted and observed DO concentrations. The minimum and maximum monitored DO values are shown as a range of DO, the average shown as a black box with a white “x.” None of the DO samples were collected on the listed reach before 9am. It is expected that the actual minimum DO is actually a value lower than the minimum observed. Not all sites were visited multiple times during the sampling period, so not every site shows a range of DO observations. The model predicted average daily DO concentrations (plotted as black dashed line) and the diurnal pattern (daily minimum and maximum, shown plotted as blue dashed lines).

Figure 4.5 – Final Validated DO Model Results Longitudinal Profile



River Mile 29.0 = Km 46.67 = start of listed reach
River Mile 23.4 = Km 37.66 = inflow of tributaries County Ditch 27
River Mile 12.8 = Km 20.60 = inflow of tributaries County Ditch 4
River Mile 3.3 = Km 5.31 = end of listed reach, inflow of tributary Ten Mile Creek

For a complete discussion of the methods and assumptions used to build, calibrate and validate the model refer to the QUAL2K Technical Memorandum provided in Appendix A.

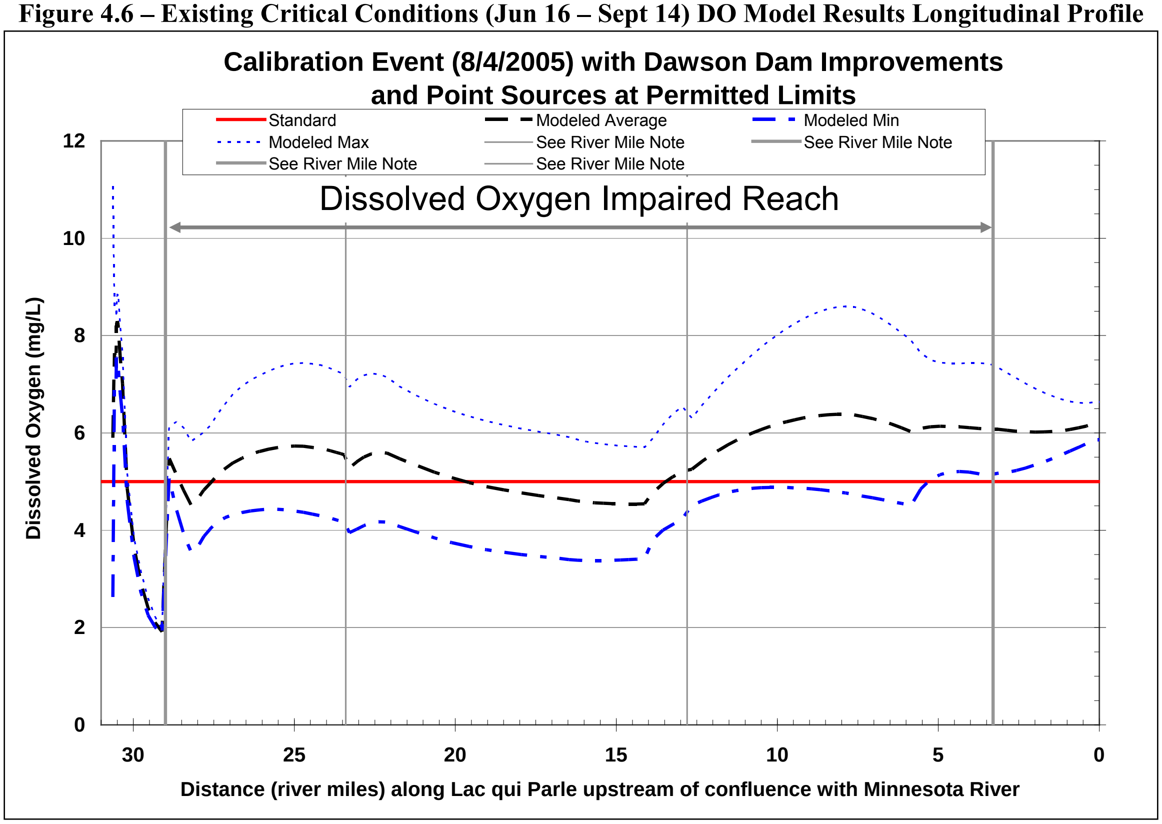
Sensitivity analysis of the calibration event DO model, as discussed in QUAL2K Technical Memorandum provided in Appendix A, show DO levels in Lac qui Parle River are most sensitive sediment geochemical processes (prescribed SOD, diffuse source detritus and prescribed inorganic-phosphorus flux). While not explicitly modeled, the DO in the impaired reach is sensitive to the water quality of the upstream boundary conditions (West Branch Lac qui Parle River and South Branch Lac qui Parle River.) Water column CBOD oxidation and nutrient hydrolysis rates appear less sensitive indicating these processes are not the primary cause of oxygen depletion during the calibration events. Current and historic water column nutrient and chlorophyll-concentrations in Lac qui Parle River are at times high, but usually fall within the range of typical Northern Glaciated Plains ecoregion levels. Thus, it would be very difficult to justify requiring significant individual reductions of these parameters. Moreover, sensitivity analysis suggests reducing these conditions alone would not achieve the 5.0 mg/L DO standard.

The West Branch Lac qui Parle River is the largest tributary to the impaired reach. The Dawson dam was located 1.6 river miles above the confluence of the West Branch and South Branch Lac qui Parle River. In December 2009, the impoundment was removed and replaced with a series of rock weirs. The new structure was expected to have positive reaeration effects on the river. The calibrated model was modified to incorporate representation of the Dawson Dam improvements. The new existing critical condition model is the starting point for the TMDL because:

- The model reflects the Dawson dam replacement,
- The model represents summer low flow conditions and conditions following a runoff related high flow event (two critical conditions when low DO are most expected),
- The model assumes the upstream boundary conditions (South Branch Lac qui Parle River and West Branch Lac qui Parle River) have low DO as monitored on August 4, 2005, and
- The model represents point sources discharging at permitted limits (June 16 – September 14).

Figure 4.6 shows the existing critical condition results for model-predicted DO concentrations. The model predicted average daily DO concentrations (plotted as black dashed line) and the diurnal pattern (daily minimum and maximum, shown plotted as blue dashed lines). The existing critical condition model shows the impaired reach not meeting the 5.0 mg/L DO standard. The TMDL will be based on what needs to be changed to meet the 5.0 mg/L DO standard in the impaired reach.

Figure 4.6 – Existing Critical Conditions (Jun 16 – Sept 14) DO Model Results Longitudinal Profile



River Mile 29.0 = Km 46.67 = start of listed reach
River Mile 23.4 = Km 37.66 = inflow of tributaries County Ditch 27
River Mile 12.8 = Km 20.60 = inflow of tributaries County Ditch 4
River Mile 3.3 = Km 5.31 = end of listed reach, inflow of tributary Ten Mile Creek

4.3.2 Identifying the Appropriate TMDL Parameters

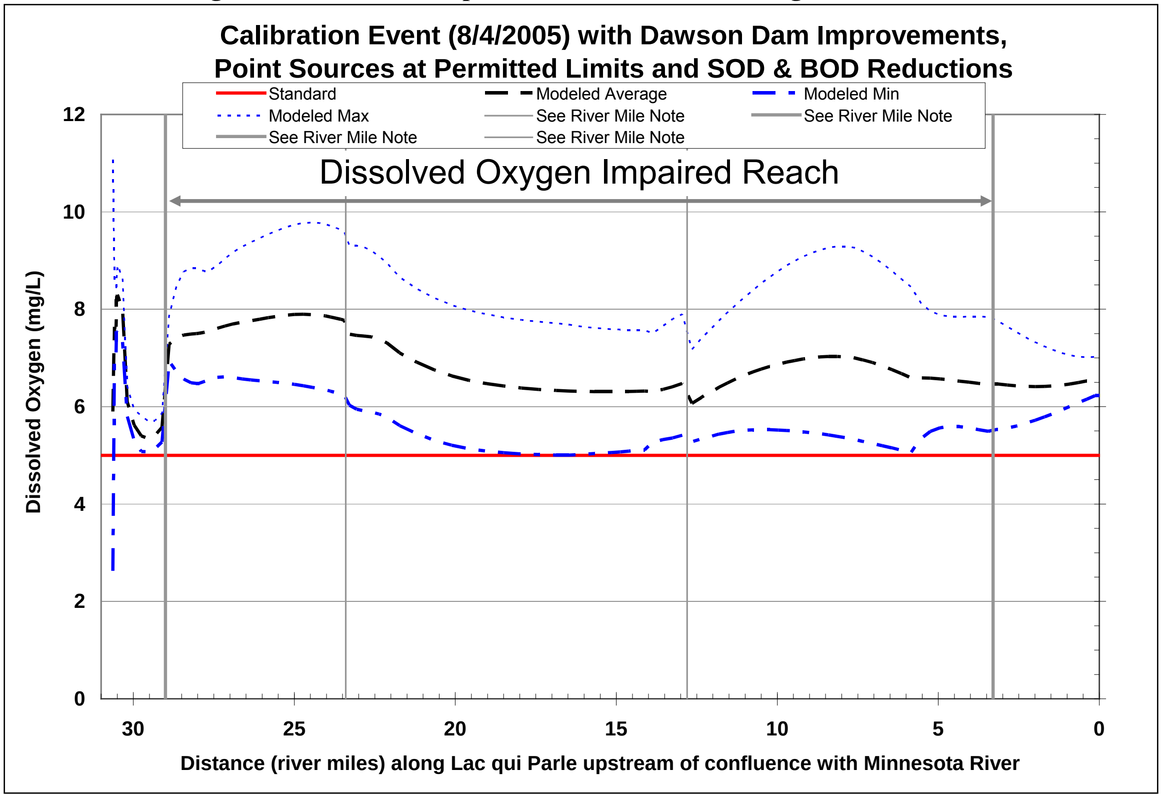
The modeling and monitoring efforts have not established a clear cause–and–effect relationship between sources and the dissolved oxygen impairment. This report selects two prominent parameters to change to meet the 5.0 mg/L DO standard in the impaired reach (SOD and diffuse detritus). The following changes made in the QUAL2K model:

- Impaired Reach reductions in SOD, as a directly related cause of low DO,
- Impaired Reach reductions in diffuse source detritus/nutrients, as an indirectly related cause of periphyton/algae, and
- Upstream Boundary Condition reductions of both SOD and diffuse source detritus/nutrients.

The TMDL model assumes that all point sources are discharging at permitted discharge limits in the existing critical condition model. The load reductions of SOD and diffuse source detritus/nutrients were made to meet the DO requirements throughout the impaired reach.

Figure 4.7 shows the model-predicted DO concentrations with the TMDL reductions. The model predicted average daily DO concentrations (plotted as black dashed line) and the diurnal pattern (daily minimum and maximum, shown plotted as blue dashed lines).

Figure 4.7 – TMDL Endpoint DO Model Results Longitudinal Profile



River Mile 29.0 = Km 46.67 = start of listed reach
River Mile 23.4 = Km 37.66 = inflow of tributaries County Ditch 27
River Mile 12.8 = Km 20.60 = inflow of tributaries County Ditch 4
River Mile 3.3 = Km 5.31 = end of listed reach, inflow of tributary Ten Mile Creek

4.3.3 Total Maximum Daily Load Calculations

The numerical TMDL for Lac qui Parle River, which is its Load Capacity, is the sum of the Wasteload Allocation (WLA), Load Allocation (LA), and the Margin of Safety (MOS). This TMDL is written to solve the TMDL equation for a numeric DO target of a daily minimum of 5.0 mg/L throughout the impaired reach.

4.3.3.1 Oxygen Deficit Terms

Dissolved oxygen is consumed both in the water column and at the sediment interface. This consumption is expressed in terms of the mass of oxygen-demanding substances available per day.

Carbonaceous biological oxygen demand (CBOD) represents the oxygen equivalent (amount of oxygen that micro-organisms require to breakdown and convert organic carbon to CO_2) of the carbonaceous organic matter in a sample.

A second source is nitrogenous biological oxygen demand (NBOD). A wide variety of micro-organisms rapidly transform organic nitrogen (ON) to ammonia nitrogen (NH_3-N). Bacteria then transform NH_3-N to nitrate through an oxygen consuming process called nitrification. For this TMDL, NBOD was calculated by multiplying the sum of organic and ammonia nitrogen by 4.33. The factor 4.33 is the stoichiometric ratio (mass basis) of oxygen demand to nitrogen that is used in the QUAL2K modeling and TMDL calculations.

Finally, sediment oxygen demand (SOD) is the aerobic decay of organic materials in stream bed sediments and in peat soils in wetlands. SOD rates are defined in units of oxygen used per surface area per day (g-O_2/m^2/day). While the tributary areas and WLAs may be sources of oxygen demanding substances for this TMDL, load reductions were only determined for explicitly modeled stream reaches.

4.3.3.2 Load Capacity

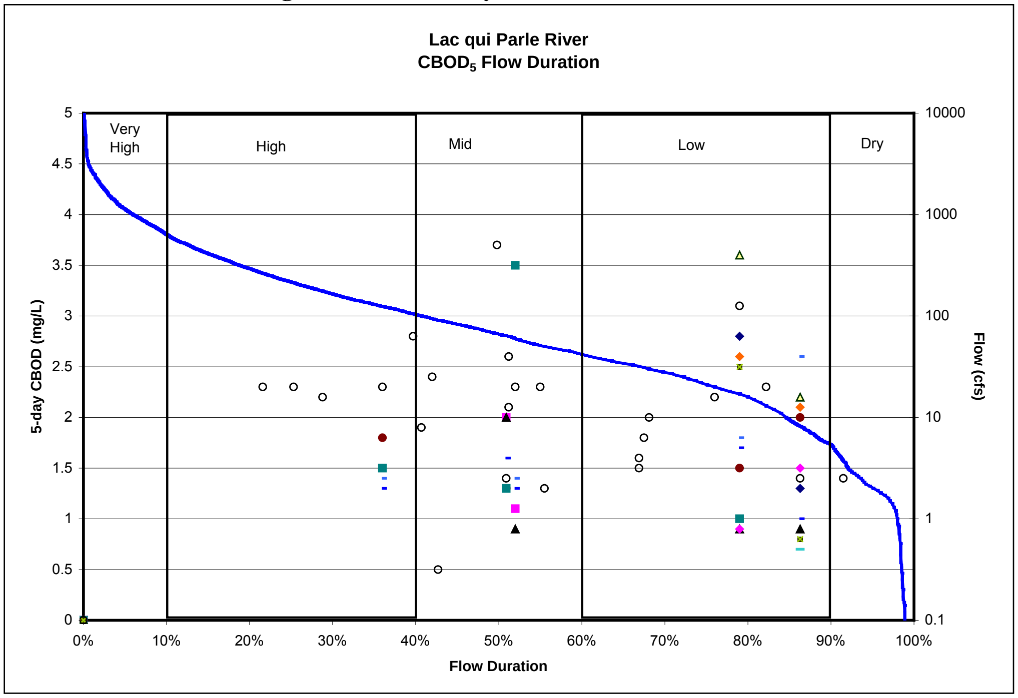
QUAL2K predicts SOD by calculating the delivery and breakdown of particulate organic matter from the water column. Diffuse source detritus loading is user specified. To determine the Load Capacity, the prescribed SOD for each modeled reach was completely removed. Then diffuse source detritus loading was reduced until it was clear model-predicted minimum daily dissolved oxygen did not drop below the 5.0 mg/L standard. Thus, the average SOD rate in each modeled reach after this reduction, which is the model-predicted SOD only, is the TMDL SOD target rate for each modeled reach. The SOD target rate for each modeled reach, represented in mg-O_2/m^2/day, was multiplied within the QUAL2K model by the wetted area of the modeled reach to calculate the SOD TMDL in mg-O_2/day for each modeled reach. Finally the modeled reach loads were summed across all the impaired reach and converted to pounds of oxygen per day. The QUAL2K Technical Memorandum provided in Appendix A contains additional details SOD and diffuse sources (page 42).

4.3.3.3 Wasteload Allocations

The Wasteload Allocation (WLA) includes five sub-categories; treatment facilities requiring NPDES permits, livestock facilities requiring NPDES permits, noncompliant septic systems, NPDES permitted industrial stormwater, and NPDES permitted construction stormwater. WLAs are presented in terms of oxygen demand calculated based on the sum of the permitted oxygen demanding characteristics. The permitted treatment facilities requiring NPDES include industrial or municipal water or wastewater treatment facilities. Livestock facilities requiring an NPDES permit are assigned an allocation of “zero,” since their permits do not allow any discharge from the permitted facility. Noncompliant septic systems are assigned a “zero” allocation as well because they are illegal. There are no entities in the project area subject to Municipal Separate Storm Sewer Systems (MS4) stormwater permit requirements (MNR040000). There are occurrences of both industrial stormwater (MNR50000) and construction stormwater (MNR100001) permitted activities in the watershed. Allocations for both industrial and construction stormwater were set to 0.1% of the loading capacity within the boundary watershed, based on an approximation of the land area covered by those activities. The allocation to this category is made after an explicit MOS (where applicable) is subtracted from the total loading capacity. Treatment facilities requiring NPDES permits are considered in compliance with provisions of the TMDL if they remain in compliance with their permits under the NPDES program.

As shown in Figure 4.8, monitoring data for Lac qui Parle River indicates that CBOD levels do not appear to significantly increase during higher flow runoff related events. As a point of reference the Nationwide Urban Runoff Program (EPA 1983) reports median event mean concentrations (EMCs) of BOD as 10 mg/L for residential land use categories.

Figure 4.8 – Five day CBOD Flow Duration



Therefore, the SOD exerted during summer base-flow conditions is assumed to be the result of in-stream sources such as re-suspension/deposition processes downstream and the result of vegetation/algae/periphyton breakdown in certain reaches. As a result, treatment facilities requiring NPDES permits, permitted industrial and permitted construction stormwater were given a zero wasteload SOD allocation. We acknowledge that point sources likely have SODs, but for the purposes of this TMDL, SOD loads were only determined for explicitly modeled reaches. The QUAL2K Technical Memorandum provided in Appendix A contains additional details on WLA sources (page 41).

4.3.3.4 Load Allocations

The Load Allocation (LA) includes all nonpermitted sources, including in-stream sources. Once wasteload allocations (point sources, construction and industrial stormwater) and the MOS were determined for each reach, the remaining loading capacity was considered the load allocation. The load allocation includes any diffuse source of oxygen demanding substances that are not subject to NPDES permit which may be delivered to Lac qui Parle River. This includes such sources as groundwater, direct wash-off; streambank and riparian sediment and nutrients; organic matter deposited by wind, rain, or directly deposited into the stream; breakdown of pelagic and benthic vegetation; and SOD inputs from riparian or in-line wetlands.

4.3.3.5 Margin of Safety

The purpose of the margin of safety (MOS) is to account for uncertainty that the allocations will result in attainment of water quality standards. The MOS may be implicit, that is, incorporated into the TMDL through conservative assumptions in the analysis. The MOS may also be explicit and expressed in the TMDL as a set aside load. The low DO TMDL employs an explicit and implicit MOS. An explicit MOS of 10% was used for the TMDL equation (CBOD and SOD). Loads for this TMDL study were calculated using a model which is based on data collected during two sampling events; late summer low flow after a storm event and late summer low flow. Thus, a 10% MOS accounts for model uncertainty in predicting SOD and detritus loads in Lac qui Parle River; the uncertainty and assumptions in determining channel dimensions and SOD coverage throughout the system, and the uncertainty in how the stream may respond to changes in SOD and detritus loading. The MOS is also implicit by incorporating conservative model assumptions. Most notably, the modeling assumes that each NPDES permitted treatment facility constantly discharges at the design flow rate during critical conditions at permitted water quality limits. Review of DMRs show that discharges are variable in quantity and quality. One of the permitted treatment facilities discharges to Lac qui Parle River from stabilization ponds. Unlike the larger (and some smaller) mechanical treatment systems which have continuous discharges, pond systems typically discharge over a 1-2 week period in the spring and in the fall. A conservative approach is to predict the diurnal DO and make sure that the minimum predicted DO is above 5.0 mg/L incorporates an extra margin of safety that is implicit.

4.4 ALLOCATION FOR LAC QUI PARLE RIVER (AUID 07020003-501)

The impaired reach is the Lac qui Parle River, West Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501) and Map B7 in Appendix B shows the extent of the entire tributary watershed, the location of the impaired reach. The QUAL2K Technical Memorandum provided in Appendix A summarizes the key monitoring site(s) and data for this reach. The 2010 existing critical conditions load is the sum of the wasteload and load, with no margin of safety. The existing load (Table 4.9) is based on existing critical conditions model (reflecting the Dawson dam replacement) and point sources discharging, between June 16 and September 14, at permitted limits (Figure 4.6).

Table 4.9 – Existing Critical Loads represented in pounds per day.

	2010 Existing CBOD *(pounds O_2 per day)*	2010 Existing NBOD *(pounds O_2 per day)*	2010 Existing SOD *(pounds O_2 per day)*	2010 Existing *Total Oxygen Demand (pounds O_2 per day)*
Existing Load = Σ WL + Σ L + MOS	**7,836.0**	**961.3**	**10,417.1**	**19,214.4**
Σ WL				
NPDES Permitted Treatment Facilities	--	--	--	--
Feedlots Requiring NPDES Permits	--	--	--	--
Noncompliant Septic Systems	--	--	--	--
Construction Stormwater	5.0	1.0	--	6.0
Industrial Stormwater	5.0	1.0	--	6.0
Σ L				
Sources of Sediment Flux	--	--	9,688.5	9,688.5
Diffuse Sources	6,052.2	144.6	--	6196.8
Boundary Condition: West Branch Lac qui Parle River (1.50 river miles)	551.5	233.4	728.6	1,513.6
Boundary Condition: South Branch Lac qui Parle River	105.0	131.2	--	236.1
Boundary Condition: County Ditch 27	963.3	250.6	--	1,214.0
Boundary Condition: County Ditch 4	154.0	199.4	--	353.5
MOS	--	--	--	--

The Total Maximum Daily Load (TMDL) is the sum of the wasteload allocations, load allocations and the margin of safety. The TMDL (Table 4.10) is based on existing critical conditions model (reflecting the Dawson dam replacement) and point sources discharging at permitted limits, between June 16 and September 14, with reductions in SOD and detritus to meet the 5.0 mg/L DO standard (Figure 4.7). Detritus loading was modeled as a diffuse source tributary to the listed reach. Detritus was removed starting 1.3 miles upstream of the impaired reach on West Branch Lac qui Parle River continuing downstream the entire impaired reach of the Lac qui Parle River. Reductions in detritus directly result in model predicted SOD reductions. Prescribed SOD was removed from model reaches starting 1.3 miles upstream of the impaired reach on West Branch Lac qui Parle River, along Lac qui Parle River 5.6 miles to the confluence with County Ditch 27, and along County Ditch 27. Table 4.9 shows the existing critical loads for Lac qui Parle River. Table 4.10 shows the TMDL allocations for Lac qui Parle River.

Table 4.10 – TMDL allocations represented in pounds per day.

	TMDL CBOD (*pounds O_2 per day*)	TMDL NBOD (*pounds O_2 per day*)	TMDL SOD (*pounds O_2 per day*)	TMDL Total Oxygen Demand (*pounds O_2 per day*)
TMDL Allocation = Σ WLA + Σ LA + MOS	5,322.9	961.3	8,013.9	14,298.1
Σ WLA				
NPDES Permitted Treatment Facilities	--	--	--	--
Feedlots Requiring NPDES Permits	--	--	--	--
Noncompliant Septic Systems	--	--	--	--
Construction Stormwater	5.0	1.0	--	6.0
Industrial Stormwater	5.0	1.0	--	6.0
Σ LA				
Sources of Sediment Flux	--	--	6,998.9	6,998.9
Diffuse Sources	3,267.1	144.7	--	3,411.8
Boundary Condition: West Branch Lac qui Parle River (1.50 river miles)	459.4	233.4	237.4	930.2
Boundary Condition: South Branch Lac qui Parle River	105.0	131.2	--	236.2
Boundary Condition: County Ditch 27	963.3	250.6	--	1,213.9
Boundary Condition: County Ditch 4	154.0	199.4	--	353.4
MOS	364.1	--	777.7	1,141.8

According to Vermont Agency of Natural Resources Department of Environmental (2010), "Phosphorus entering our lakes and streams acts as a fertilizer, feeding plant and algae growth. In fact, one pound of phosphorus can produce up to 500 pounds of algae." Reductions in phosphorus are expected to reduce periphyton and associated detritus. Diffuse source loading of soluble reactive phosphorus (SRP) is model estimated to be 98 pounds; a reduction in SRP by 5 pound reduction could result in 2,500 pounds of algae reductions.

4.4.1 Load Reductions

This TMDL requires CBOD load reductions of 46 percent to diffuse sources for the listed reach (Lac qui Parle River) and 17 percent for the 1.5 miles upstream of the impaired reach on West Branch Lac qui Parle River.

This TMDL does not require NBOD load reductions for the listed reach (Lac qui Parle River).

This TMDL requires SOD load reductions of 28 percent for the listed reach (Lac qui Parle River) and 67 percent for the 1.5 miles upstream of the impaired reach on West Branch Lac qui Parle River. SOD load reductions can be achieved by reducing sources of particulate organic matter, as well as reducing wetted perimeter as part of a channel form scenario.

4.5 SEASONAL AND ANNUAL VARIATION

Seasonal variation is accounted for by establishing the TMDL for the critical low flow condition. By selecting the most sensitive conditions for the stream, dissolved oxygen concentrations in all seasons will be protected.

4.6 CRITICAL CONDITION

The critical condition for this TMDL is the summer low flow season. During summer low flow, stream temperatures are at their maximum resulting in minimal holding capacity for stream dissolved oxygen. Stream velocities are typically low, reducing reaeration of the stream. As a result, summer low flow represents the most sensitive conditions for stream dissolved oxygen.

4.7 RESERVE CAPACITY

The population of Lac qui Parle County was estimated to be 7,756 people in 2004. This represents a four percent decrease from the year 2000, and a 13.1 percent decrease from 1990 (U.S. Census Bureau, 2006).

Table 4.11 – Population in 1990, 2000, and 2004 (U.S. Census Bureau, 2006)

Location	Number of People in 1990	Number of People in 2000	Number of People in 2004	Percentage Change in Population 2000 - 2004
Lac qui Parle County	8,924	8,067	7,756	-3.86
Town of Dawson	1,626	1,539	1,480	-3.83

The population in the town of Dawson was approximately 1,480 people in the year 2004. From 2000 to 2004, the town of Dawson experienced a 3.8 percent decrease in population, and a nearly 9 percent decrease from 1990 (U.S. Census Bureau, 2006). If this trend continues, populations in these areas are expected to continually decrease.

No new NPDES point sources are anticipated in this watershed. There are no Wasteloads identified in this TMDL, and therefore no portion of the Wasteload Allocation is being held in reserve. With negative population trends no portion of the Wasteload Allocation is being held in reserve.

5.0 Implementation

5.1 BACTERIA, TURBIDITY AND LOW DISSOLVED OXYGEN STRATEGIES

Since the impairments of bacteria, turbidity and low DO have several sources and some common delivery pathways, most of the implementation strategies have multiple water quality benefits in terms of load reductions. As the LQPYBWD coordinates with its stakeholders on the details of the TMDL implementation plan, some of the following BMPs may be selected to achieve the bacteria, turbidity, low DO TMDLs. These actions will be further developed in the TMDL implementation plan to be developed within one year of EPA's approval this TMDL report. The estimated total cost of implementing these and other potential BMPs ranges from $8 million to $10 million. The following provides an overview of implementation options to be considered.

5.1.1 BMP Guidance Based on Agroecoregion

The portion of LQPYBWD located within Minnesota is predominately comprised of two agroecoregions, the Coteau and the Dryer Blue Earth Till (Figure 1.1). Dr. David Mulla of the University of Minnesota developed matrices to provide general planning-level guidance on the application of BMPs within each agroecoregion. The BMPs were developed through a focus group process that included experts from the University of Minnesota, Minnesota Pollution Control Agency, Minnesota Department of Agriculture, and the Minnesota Board of Water and Soil Resources. Four broad categories of management practices discussed include nutrient management, vegetative practices, tillage practices, and structural practices. Selection of appropriate management practices for the pollutant(s) of concern depends on site-specific conditions, stakeholder attitudes and knowledge, and on economic factors. This information is intended to be used as a starting point in the development of a custom set of BMPs to reduce sources of pollution generation and transport through improved management of uplands and riparian land within the TMDL project area. Reducing sediment generation and transport will also lead to decreases in turbidity, bacteria concentrations, and improve DO in downstream reaches.

A brief summary of each of the broad categories of management practices as it applies to the TMDL watershed follows.

5.1.1.1 Nutrient Management Practices

Nutrients have an effect upon algal and periphyton growth and subsequent death, decay, and development of SOD; and well as periphyton–developed diurnal swings in dissolved oxygen. Therefore, fertilization management is an important BMP component of the Dissolved Oxygen Implementation Plan.

5.1.1.2 Vegetative Management Practices

Vegetative practices include those focusing on the establishment and protection of crop and non-crop vegetation to minimize sediment mobilization from agricultural lands and decrease sediment transport to receiving waters. The recommended cropping practices are designed in part to slow the speed of runoff over bare soil to minimize its ability to entrain sediment. Grassed waterways and grass filter strips provide settling of entrained sediment which gets incorporated into both the soil and vegetation. Other practices, such as alternative crop rotations and field windbreaks are designed to minimize exposure of bare soils to wind and water which can transport soil off-site. Pasture management often emphasizes rotational grazing techniques, where pastures are divided into paddocks, and the livestock moved from one paddock to another before forage is over-grazed. As livestock are moved frequently, forage is able to survive. Maintaining the vegetation, as opposed to bare soil, allows for greater water infiltration, reducing runoff and associated sediment transport.

The Natural Resources Conservation Service offices or Soil and Water Conservation Districts facilitate Environmental Quality Incentives Program (EQIP) or other cost-share programs to put Best Management Practices into place. There are a number of programs available to compensate land owners for moving environmentally sensitive cropland out of production for varying periods of time. These include the Conservation Reserve Program (CRP), Re-Invest in Minnesota (RIM) Reserve Program, and the Conservation Reserve Enhancement Program (CREP) or similar programs. Anticipated benefits in reducing soil erosion and improving water quality are key considerations in deciding what lands can be enrolled in each program. Throughout the LQPYBWD 81,055 acres are in easement programs, which comprise about 13 percent of the land area. These easements are either Conservation Reserve Enhancement Program (CREP), Reinvest in Minnesota (RIM), Wetland Preservation Areas (WPA) and Wildlife Management Areas (WMA).

Vegetative Practices

- Grassed waterways
- Grass filter strip for feedlot runoff
- Buffers
- Wetland restoration
- Alternative crop in rotation
- Field windbreak
- Pasture management, intensive rotation grazing (IRG)
- Conservation Reserve Program (CRP) or Conservation Reserve Enhancement Program (CREP) or similar programs

5.1.1.3 Primary Tillage Practices

Certain kinds of tillage practices can significantly reduce the generation and transport of soil from fields. Conservation tillage techniques emphasize the practice of leaving at least some vegetation cover or crop residue on fields as a means of reducing the exposure of the underlying soil to wind and water which leads to erosion. If it is managed properly, tillage management can reduce soil erosion on active fields by up to two-thirds (Randall et. al. 2008). The Natural Resources Conservation Service offices or Soil and Water Conservation Districts facilitate Environmental Quality Incentives Program (EQIP) or other cost-share programs to put Best Management Practices into place.

Primary Tillage Practices

- Chisel Plow
- One pass tillage
- No-till
- Strip-till
- Ridge till

5.1.1.4 Structural Practices

Structural practices emphasize elements that generally require a higher level of site-specific planning and engineering design. Most structural practices focus on watershed improvements to decrease sediment loading to the receiving water. For example, restoration of wetlands can create a natural method of slowing overland runoff and storing runoff water, which can both reduce channel instability and flooding downstream. In addition, the quiescent conditions of a wetland mean that they can be effective at settling out sediment particles in the runoff that reaches them, although accumulation of too much sediment too rapidly can compromise other important functions of the wetland. Livestock exclusion involves fencing or creating other structural barriers to limit or eliminate access to stream by livestock, and may involve directing livestock to an area that is better designed to provide limited access with minimal impact. Sediment load reduction structures such as basins, diversions and terraces trap sediment from migrating downstream into channels and ditches. The Natural Resources Conservation Service offices or Soil and Water Conservation Districts facilitate Environmental Quality Incentives Program (EQIP) or other cost-share programs to put Best Management Practices into place.

Structural Practices

- Wetland creation
- Livestock exclusion
- Liquid manure waste facilities
- Water and sediment control basins
- Diversions
- Terraces

5.1.2 Feedlot Runoff Reduction

This strategy is presently under implementation through the MPCA's Open Lot Agreement (OLA) established in October 2000. The OLA has a Full Compliance goal to meet effluent limits in Minn. R. 7053.0305 by October 1, 2010. This program encourages producers to seek information and assistance for practical solutions to treat feedlot runoff that discharges into waters of the state from feedlots that do <u>not</u> require NPDES permits. There are a variety of options for improving open lot runoff problems that reduce diffuse source loading of bacteria and turbidity, including:

- Move Fences/Change Lot Area
- Eliminate Open Tile Intakes and/or Feedlot Runoff to the Intake
- Install Clean Water Diversions and Rain Gutters
- Install Grass Buffers
- Maintain Buffer Areas
- Construct a Solids Settling Area(s)
- Prevent Manure Accumulations
- Manage Feed Storage
- Manage Watering Devices
- Total Runoff Control and Storage
- Roofs
- Runoff Containment with Irrigation onto Cropland/Grassland
- Vegetated Infiltration Area
- Tile-Drained Vegetated Infiltration Area with Secondary Vegetated Filter Strip
- Sunny Day Release on to Vegetated Infiltration Area or Filter Strip
- Vegetated Filter Strip

5.1.3 Manure Management Planning

Continued cooperation between the Counties and the MPCA through the County Feedlot Program ensures that feedlot owners get assistance to remain compliant with their permits. The Natural Resources Conservation Service offices or Soil and Water Conservation Districts facilitate Environmental Quality Incentives Program (EQIP) or other cost-share programs to put Best Management Practices into place. The development and update of manure management plans continue to reduce bacteria in runoff.

5.1.4 Stream and Channel Restoration

Other practices which may be considered for the project area involve making improvements to the structure of the receiving water to improve stability and decrease in-stream sources of sediment. In-stream structures need to be carefully designed to direct flow where appropriate under a wide range of discharge conditions and make sure that solution of one channel stability problem doesn't create another elsewhere. Also important is, where possible, making sure that the main stream channel can overflow into its floodplain at high flows to allow the stream to temporarily store water outside the streambank, reducing flow velocity and excessive scouring of the channel. Intact natural vegetation in the floodplain also acts to slow flow velocities and encourages deposition and permanent capture of sediment.

5.1.5 Upstream Sources

As presented in Section 2.3.3 and Section 3.3.3, South Dakota applies less stringent standards to water classified to support indirect contact recreation. If South Dakota does not meet Minnesota standards for streamflows discharged across the border, exceedances of Minnesota's bacteria standards in Minnesota are likely even if Minnesota sources are complying with the allocations set out in this TMDL. Individual states have the right and authority to protect its people and resources, USEPA facilitation of an agreement between Minnesota and South Dakota to protect water quality over state boundaries should be pursued.

5.1.6 Waste Water Treatment Facilities

Counties, Regional Development Commissions and MPCA staff will work with Waste Water Treatment Facilities to ensure continued compliance.

5.1.7 Subsurface Sewage Treatment Systems (SSTS)

Low interest loan dollars are available to aid landowners in upgrading SSTS through the Soil and Water Conservation Districts and Clean Water Partnership, and State Revolving Fund (SRF) through the Minnesota Department of Agriculture and the Minnesota Pollution Control Agency.

5.1.8 Headwaters

Specific to the low DO impairment, the headwaters of the listed Lac qui Parle River are the West Branch Lac qui Parle River and the South Branch Lac qui Parle River. The water discharged from the headwaters often contains less than the 5.0 mg/L DO standard. The reaches downstream are not able to provide reaeration to lift the DO content above 5.0 mg/L. Additional study is necessary to fully understand the specific mechanism or mechanisms accounting for these upstream boundary conditions not meeting the DO standard, and determine the most feasible mitigation approach. Some options might include synoptic surveys to better understand the sources. It is not possible to accurately estimate the cost of implementing any of these or other strategies without more study, but the cost is likely in the range of $200,000 to $400,000. Further assessment of dissolved oxygen in the headwaters is recommended.

5.1.9 Stormwater

The wasteload allocation for stormwater discharges from sites where there is construction activities reflects the number of construction sites greater than 1 acre expected to be active in the watershed at any one time, and the Best Management Practices (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.

The wasteload allocation 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 coverage under the appropriate NPDES/SDS General Stormwater 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.

There are currently no permitted MS4 communities in the Lac qui Parle River or Yellow Bank River watersheds. Future transfer of loads in this TMDL may be necessary if any of the following scenarios occur within the watershed:

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be given additional WLA to accommodate 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 an urban area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an Urban Area at the time the TMDL was completed, but are now inside a newly expanded urban area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related point source is identified and is covered under a NPDES permit. In this situation, a transfer must occur from the LA.

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

5.2 MONITORING

5.2.1 Monitoring Plan

A long term monitoring station is maintained at the outlet of each watershed (S003-087 and S003-091) by the MPCA. The MPCA will also be conducting intensive watershed monitoring in both watersheds every 10 years starting in 2015 (subject to change). Additional monitoring sites are maintained by the LQPYBWD as funding permits. This monitoring data will be utilized in determining the effectiveness of BMP implementation in progress toward meeting the water quality goals in this TMDL report.

Targeted sampling should occur in watersheds where high bacteria concentrations were observed during low flow conditions. This is indicative of septic systems, overgrazed pastures with direct access to streams, and/or wildlife as probable sources. In addition to comparing geometric monthly means to the standard, a comparison of samples collected during low flow is necessary to monitor effectiveness. These watersheds are generally upstream on the Lac qui Parle River above Lazarus Creek, Lazarus Creek itself, and the North and South Fork of the Yellow Bank River.

Monitoring water quality and quantity at the Minnesota and South Dakota border is needed to clearly understand South Dakota's contribution to the bacteria and turbidity impairments in the Yellow Bank River and Lac qui Parle River watersheds. At the time this report was being written, a cooperative effort to determine South Dakota's contribution to the Yellow Bank River was led by the East Dakota Water Development District through funding from the South Dakota Department of Environment and Natural Resources with assistance from the MPCA, LQPYBWD, and the Upper Minnesota River Watershed District. Similar endeavors should be sought for the Lac qui Parle River watershed.

5.2.2 Flow Monitoring

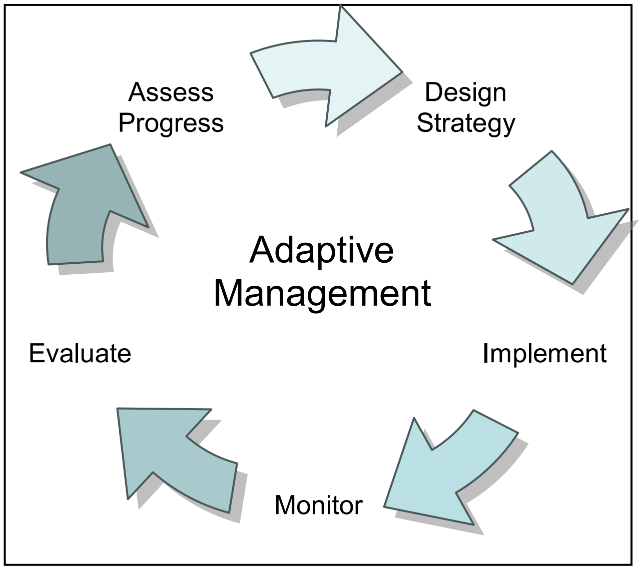
The LQPYBWD has partnered with the USGS and United States Army Corps of Engineer for flow monitoring and will continue to partner with them.

5.3 ADAPTIVE MANAGEMENT

Adaptive management is an iterative implementation process that makes progress toward achieving water quality goals while using any new data and information to reduce uncertainty and adjust implementation activities. It is an ongoing process of evaluating and adjusting the strategies and activities that will be developed to implement the TMDL. The implementation of practicable controls should take place even while additional data collection and analysis are conducted to guide future implementation actions. Adaptive management does not include changes to water quality standards or loading capacity. Any changes to water quality standards or loading capacity must be preceded by appropriate administrative processes; including public notice, and an opportunity for public review and comment.

A detailed implementation plan will be prepared from the management strategies and activities listed in Section 5.1 following EPA's approval of this TMDL assessment report. The implementation plan focuses on adaptive management (Figure 5.1) to evaluate project progress as well as to determine if the implementation plan should be amended. Implementation of TMDL related activities can take many years, and water quality benefits associated with these activities can also take many years. As the pollutant source dynamics within the watershed are better understood, implementation strategies and activities will be adjusted and refined to efficiently meet the TMDL and lay the groundwork for de-listing the impaired reaches. The follow up water monitoring program outlined in Section 5.2 will be integral to the adaptive management approach, providing assurance that implementation measures are succeeding in attaining water quality standards.

Figure 5.1 – Adaptive Management



6.0 Reasonable Assurance

6.1 INTRODUCTION

When establishing a TMDL, reasonable assurances must be provided demonstrating the ability to reach and maintain water quality endpoints. Several factors control reasonable assurance, including a thorough knowledge of the ability to implement BMPs (presented in Section 5.1) as well as the overall effectiveness of the BMPs. This TMDL report establishes aggressive goals for improving the water quality of the aquatic life and recreation for the impaired reaches in the Lac qui Parle-Yellow Bank Watershed District (LQPYBWD).

TMDL implementation will be carried out on an iterative basis so that implementation course corrections based on periodic monitoring and reevaluation can adjust the strategy to meet the standard. Reevaluation every five years will determine whether the plan is working or identify those activities that need to be strengthened or other activities that need to be implemented to reach the standards.

Various technical and funding sources will be used to execute measures detailed in the implementation plan that will be developed within one year of approval of this TMDL report. Technical resources include the LQPYBWD, County Soil and Water Conservation Districts (SWCDs), Natural Resources Conservation Service (NRCS), County Water Plans, as well as the Minnesota Department of Natural Resources. Funding resources include a mixture of state and federal programs, including (but not limited to) the following:

- Conservation Reserve Program,
- Federal Section 319 program for watershed improvements,
- Funds ear-marked to support TMDL implementation from the Clean Water, Land, and Legacy constitutional amendment, approved by the state's citizens in November 2008.
- LQPYBWD program funds,
- Local government cost-share funds,
- CWP Grants, and
- CWP (SRF Loan Funds)

A partnership between the State of Minnesota and the USEPA has been developed to implement a new program called the Minnesota Agricultural Water Quality Certification Program. The program has yet to be developed; however, a Memorandum of Understanding has been signed to start the process. The goal of the program is to accelerate voluntary implementation of on-farm conservation practices that will certify farms in meeting their water quality goals. More information regarding this program can be found at http://www.mda.state.mn.us/en/protecting/waterprotection/awqcprogram.aspx.

Finally, it is a reasonable expectation that existing regulatory programs such as those under NDPES will continue to be administered to control discharges from industrial, municipal, and construction sources as well as large animal feedlots that meet the thresholds identified in those regulations.

Following is a discussion of the key agencies at the local level that will help assure that implementation activities proposed under this TMDL report will be executed.

6.2 THE LAC QUI PARLE-YELLOW BANK WATERSHED DISTRICT

The Watershed Act in 1955, the Minnesota Legislature passed the Watershed Act in order to better address water related issues and concerns at a watershed level. Watershed districts are special purpose units of government created to solve water resource issues on a watershed basis. The LQPYBWD is one of forty-six watershed districts established in Minnesota since 1955. On April 19, 1971, the LQPYBWD was established and the first district board of managers was appointed. The LQPYBWD came to the aid of local citizens who had requested help in controlling flooding in the watershed.

The LQPYBWD mission is to:

> *Serve as a partner in water planning and management with the state agencies, counties, cities, and Soil and Water Conservation Districts, and assist with the management of water quality and quantity within Lac qui Parle-Yellow Bank Watershed boundaries.*

Minnesota Rules Chapter 8410 requires watershed management plans to address eight management areas and to include specific goals and policies for each. Strategies and policies for each goal were developed to serve as a management framework as part of the LQPYBWD's Watershed Management Plan covering the years 2009-2019. That Plan includes 63 outcome based strategies to progress toward meeting water quality goals through implementation estimated to cost approximately $8.4 million over the next ten years. Cost-share, Clean Water Legacy funding, 319 funding, low interest loan programs and opportunities from the Clean Water, Land and Legacy Amendment will be pursued to assist plan implementation. The philosophy of the LQPYBWD is that the Management Plan establishes certain common goals and standards for water resources management in the watersheds, agreed to by stakeholders of the watershed, and implemented as a cooperative effort by those at the local level.

All Watershed Management Plans have a Plan Amendment Procedure to incorporate revisions to policies, programs, and activities, such as those identified in the TMDL report and implementation plan.

6.3 SUSTAINED STATE – LOCAL COOPERATION

Numerous projects have been completed cooperatively through the LQPYBWD, SWCDs, NRCS and other state and local agencies resulting in 692 BMPs implemented over three counties; Lac qui Parle, Yellow Medicine and Lincoln County. The following Table 6.1 is from LQPYBWD's Watershed Management Plan.

Table 6.1 – BMPs within LQPYBWD

Best Management Practices within the Lac qui Parle – Yellow Bank Watershed			
Practice	**Number**	**Practice**	**Number**
Abandoned well sealing	267	Fence	1
Water and sediment control basin	140	Diversion	10
Roof runoff management	1	Drainage system modification	5
Windbreak/Shelterbelt establishment	60	Residue management – mulch	5
Erosion control	2	Cover and green manure crop	1
Terrace	51	Sediment basin	7
Septic system improvement	82	Waste storage facility	1
Grassed waterway	29	Field border	2
Conservation cover easement	1	Septage management	5
Filter strip	13	Underground outlet	3
Streambank and shoreline protection	1	Wildlife habitat management	2
Grade stabilization structure	2	Road construction practices	1
		Total	**692**

Lac qui Parle, Yellow Medicine and Lincoln Counties have Water Management Plans that articulate goals and objectives for water and land-related resource management initiatives, including impaired waters. All three plans identify completion of the TMDL assessments of impaired waters within the county as a top three priority in the plan. The LQPYBWD supports the water plans and cooperates with the local water plan coordinators. In turn, the water plan coordinators require the support of the District to accomplish the plan goals for each county.

The purpose of the SWCDs is to plan and execute policies, programs, and projects which conserve the soil and water resources within its jurisdictions. It is particularly concerned with erosion of soil due to wind and water. The SWCDs are heavily involved in the implementation of practices that effectively reduce or prevent erosion, sedimentation, siltation, and agricultural-related pollution in order to preserve water and soil as resources. The SWCDs frequently provides cost share for many types of projects, including grassed waterways, on-farm terracing, erosion control structures, and flow control structures.

7.0 Public Participation

7.1 INTRODUCTION

The Lac qui Parle-Yellow Bank Clean Water Partnership (CWP) organized partnering agencies to provide direction and guidance for water quality grants. They meet monthly and are referred to as TEAM meetings. TEAM stands for "Together Everyone Achieves More." A broad base of knowledgeable stakeholders was developed through voluntary sign up and with the help of TEAM members by suggesting names of citizens and landowners. The stakeholders participate and share their concerns, interests, and questions regarding the development of the TMDL report. Meeting notes from the public meetings can be found on Lac qui Parle-Yellow Bank Watershed District website (www.lqpybwatershed.org).

TEAM members include representatives from:

- Lac qui Parle, Yellow Medicine and Lincoln County Soil and Water Conservation Districts
- Lac qui Parle, Yellow Medicine and Lincoln County Water Plans
- Lac qui Parle, Yellow Medicine and Lincoln County Natural Resources Conservation Service
- Lac qui Parle County Environmental Office
- Area II Minnesota River Basin Projects, Inc.
- Prairie Country Resource Conservation & Development
- Board of Water and Soil Resources
- Minnesota Department of Natural Resources
- U.S. Fish & Wildlife Service
- East Dakota Water Development District
- Minnesota Pollution Control Agency

7.2 STAKEHOLDER COMMITTEE

The stakeholder committee was established so that interested stakeholders could be involved in key decisions during the development of the TMDL report. They are asked to comment on drafts of the report.

The stakeholder committee includes representatives from:

- TEAM members
- Livestock Producers
- Corn and Soybean Producers
- City Employees/Residents

- Lake Associations
- Environmental Groups

7.2.1 Stakeholder Meetings

Two public meetings were held on November 24, 2009 with Stakeholder members from 1:30 pm to 3:30 pm at the Canby Community Center, 110 Oscar Avenue North, Canby MN 56220. The second meeting was from 7:00 pm to 10:15 pm at the Madison VFW, 711 2nd Street, Madison MN 56256. These meetings reviewed the TMDL process, local water quality concerns and requested attendees to participate in the Stakeholder Committee.

Two Stakeholder meetings were held on April 14, 2010. The first meeting included TEAM members and was from 1:00 p.m. to 3:00 p.m. at the Lac qui Parle County Multi Media Room, 422 5th Avenue, Madison MN 56256. The second meeting was from 7:00 pm to 10:15 pm at the Lac qui Parle County Multi Media Room, 422 5th Avenue, Madison MN 56256. This meeting included a TMDL refresher and information on bacteria and turbidity impairments in the Lac qui Parle-Yellow Bank watershed.

One Stakeholder meeting was held on June 29, 2010 with Stakeholder members from 6:00 p.m. to 10:15 p.m. at the Lac qui Parle County Multi Media Room, 422 5th Avenue, Madison MN 56256. This meeting reviewed the low dissolved oxygen impairment and the Pollutant Source Inventory for bacteria and turbidity in the Lac qui Parle-Yellow Bank watershed.

One Stakeholder meeting was held on Friday, November 19, 2010 with Stakeholder members from 8:30-11:30 a.m. at the Lac qui Parle County Multi Media Room 422 5th Avenue, Madison MN 56256. This meeting reviewed the draft TMDL report before submission to the MPCA.

7.3 PUBLIC COMMENT PERIOD

The official TMDL public comment period was held from May 29, 2012 through June 27, 2012. Five public comment letters were received on the Draft TMDL. These public comment letters were considered and resulted in minor clarifications and revisions to the TMDL report.

An information public meeting was held on June 4, 2012 at 7:00 p.m. at the Lac qui Parle County Multi Media Room 422 5th Avenue, Madison MN 56256 and was open to the general public. This meeting reviewed the draft TMDL, the public comment period process, and provided an opportunity to allow the citizens to ask questions and make comments regarding the report.

8.0 Literature Cited

Allan. J. D. 1995. *Stream Ecology: Structure and Function of Running Waters*. The Netherlands: Springer. Pp70-71.

Cleland, B.R. 2002. *TMDL Development From the "Bottom Up" – Part II: Using Duration Curves to Connect the Pieces*. National TMDL Science and Policy – WEF Specialty Conference. Phoenix, AZ.

Cleland, B.R. March 2011. *Zumbro River Watershed TMDL: WLA Linkage Analysis*. Prepared for the US EPA.

Duan, N., 1983, *Smearing estimate -- a nonparametric retransformation method*: Journal of the American Statistical Association, 78, 383, p. 605-610

Ferguson, R.I., 1986, *River loads underestimated by rating curves*: Water Resources Research, 22, 1, p. 74-76.

Hatch, L.K., A.P. Mallawatantri, D. Wheeler, A. Gleason, D.J. Mulla, J.A. Perry, K.W. Easter, P. Brezonik, R. Smith, and L. Gerlach. 2001. *Land Management at the major watershed – agroecoregion intersection*. J. Soil Water Conservation. 56:44-51.

Ishii, S., W. B. Ksoll, R. E. Hicks, and M. J. Sadowsky. 2006. *Presence and Growth of Naturalized Escherichia coli in Temperate Soils from Lake Superior Watersheds*. Applied and Environmental Microbiology, January: 612-621.

Lac qui Parle County, 2003. *Lac qui Parle County Local Water Management Plan 2003-2012.*

Lac qui Parle - Yellow Bank Watershed District, 2009, *Watershed Management Plan.* <<http://www.lqpybwatershed.org/>>

Lincoln County, 2010. *Lincoln County Water Management Plan*. April, 2, 2010

Minnesota Pollution Control Agency. 1998. *Baseline Water Quality of Minnesota's Principal Aquifers: Southwest Region*. June 1998 <http://www.pca.state.mn.us/index.php/water/water-types-and-programs/groundwater/groundwater-monitoring-and-assessment/statewide-baseline-study.html>

Minnesota Pollution Control Agency. 2002. *Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota*. October 2002.

Minnesota Pollution Control Agency. 2005. *The Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment*. <<http://www.pca.state.mn.us/publications/manuals/tmdl-guidancemanual04.pdf>>

Minnesota Pollution Control Agency. 2006. *Revised Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota.*

Minnesota Pollution Control Agency. 2007. *Statement of Need and Reasonableness (SONAR) in the Matter of Proposed Revisions of Minnesota Rules Chapter 7050, Relating to the Classification and Standards for Waters of the State*. Book III of III. July 2007.

Minnesota Pollution Control Agency. 2007. *Turbidity TMDL Protocols and Submittal Requirements*. <http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/project-resources/tmdl-policy-and-guidance.html>

Minnesota Pollution Control Agency. 2007. *Bacteria TMDL Protocols and Submittal Requirements*. <http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/project-resources/tmdl-policy-and-guidance.html>

Minnesota Pollution Control Agency. 2008. *Pipestone Creek Fecal Coliform Bacteria and Turbidity Total Maximum Daily Load Report*.

Minnesota Pollution Control Agency. 2010. *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List. 2010 Assessment Cycle*. <http://www.pca.state.mn.us/publications/wq-iw1-04.pdf>.

Mulla, D.J., and A.S. Birr, G. Randall, J. Moncrief, M. Schmitt, A. Sekely, and E. Kerre. 2001. *Technical Work Paper: Impacts of Animal Agriculture on Water Quality*. Department of Soil, Water, and Climate, University of Minnesota. Prepared for the Minnesota Environmental Quality Board and Citizen Advisory Committee, April 3, 2001.

Mulla, D.J. 2002. *Relationship between Agro-ecoregions and Water Quality.* Minnesota River Research Forum presentation.

Randall, G. Wagar, T., Senjem, N., Busman, L., and Moncrief, J. 2008. *Tillage Best Management Practices for Water Quality Protection in Southeastern Minnesota*, University of Minnesota Extension Service, St. Paul, Revised 2000, Order# WW-07694. http://www.extension.umn.edu/distribution/cropsystems/DC7694.html

Sandowsky M. and Matteson S., 2010, *Growth, Survival, and Genetic Structure of E. coli found in Ditch Sediments and Water at the Seven Mile Creek Watershed*, Minnesota Department of Agriculture, St. Paul. http://www.mda.state.mn.us/protecting/cleanwaterfund/cwfresearch/7milecreek.aspx

Spiehs, M. and Goyal, S., 2007. Best Management Practices for Pathogen Control in Manure Management Systems. University of Minnesota Extension, St. Paul, MN.

U. S. Environmental Protection Agency. 1983. *Results of the Nationwide Urban Runoff Program, Vol.1 Final Report*. NTIS PB84-185552. << http://www.epa.gov/npdes/pubs/sw_nurp_vol_1_finalreport.pdf>>

U. S. Environmental Protection Agency. 1999. *Preliminary Data Summary of Urban Stormwater Best Management Practices*. EPA 821-R-99-012. Washington, D.C. (August 1999)

U. S. Environmental Protection Agency. 2001a. *Protocol for Developing Pathogen TMDLs*. EPA 841-R-00-002. Office of Water (4503F). United States Environmental Protection Agency, Washington, D.C.

U. S. Environmental Protection Agency. 2001b. *AQUATOX for Windows. A Modular Fate and Effects Model for Aquatic Ecosystems. Release 1.1. Volume 3: Model Validation Reports Addendum*. EPA 823-R-01-008. Office of Water (4305). United States Environmental Protection Agency, Washington, D.C.

U. S. Environmental Protection Agency. 2009. *River and Stream Water Quality Model (QUAL2K)*. << http://www.epa.gov/athens/wwqtsc/html/qual2k.html>>

Vannote, R. and B. Sweeney. 1980. *Geographic analysis of thermal equilibria: A conceptual model for evaluating the effect of natural and modified thermal regimes on aquatic insect communities*. The American Naturalist. 115(5):667-695.

Yellow Medicine County, 2005. *Yellow Medicine County Comprehensive Local Water Plan January 2005–December 2014.*

9.0 Acronyms

AUID	Assessment Unit ID
BOD5	5-Day Biochemical Oxygen Demand
CBOD	Carbonaceous BOD
$CBOD_5$	5-Day Carbonaceous BOD
$CBOD_{20}$	20-Day Carbonaceous BOD
$CBOD_u$	Ultimate Carbonaceous BOD
CE	Computational Element (QUAL-2K)
cfs	cubic feet per second
cfu	colony-forming unit
CRP	Conservation Reserve Program
CREP	Conservation Reserve Enhancement Program
CREP-II	Conservation Reserve Enhancement Program-Minnesota II
CWA	Clean Water Act
CWP	Clean Water Partnership
DEM	Digital Elevation Model
DMR	Discharge Monitoring Reports
DO	Dissolved oxygen
DOQ	Digital Ortho Quadrangle
DRG	Digital Raster Graphic
EPA	Environmental Protection Agency
GIS	Geographical Information System
g O_2/sec	grams of oxygen per second
g O_2/m^2 – day	grams of oxygen per square meter per day
HUC	Hydrologic Unit Code: 8-digit HUC fourth-level (cataloguing unit)

IRG	intensive rotation grazing
LqP-##.#	Lac qui Parle River: River Mile ##.# (e.g. LqP-27.9)
LQPYBWD	Lac qui Parle River Yellow Bank Watershed District
LA	Load Allocation
lbs/day	pounds per day
LC	Loading Capacity
LCC	Land Cover Category
MDNR	Minnesota Department of Natural Resources
MGD	million gallons per day
mg/L	milligrams per liter
mg/ft^3	milligrams per cubic foot
mg/sq ft - day	milligrams per square foot per day
mg O_2/ mg Chl a / day	milligrams of Oxygen per milligram chlorophyll-*a* per day
mg N/ mg Chl a / day	milligrams of Nitrogen per milligram chlorophyll-*a* per day
mg P/ mg Chl a / day	milligrams of Phosphorus per milligram chlorophyll-*a* per day
mi^2	square miles
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NASS	National Agricultural Statistics Service
NBOD	Nitrogenous Biochemical Oxygen Demand
NGP	Northern Glaciated Plains
NH_3-N	Total Ammonia-Nitrogen
NO_2/ NO_3-N	Nitrate/ Nitrite- Nitrogen
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
ON	Organic Nitrogen
QA	Quality Assurance
QC	Quality Control

QUAL2E	Enhanced Stream Water Quality Model
QUAL-2K	Modernized Enhanced Stream Water Quality Model
RM	River Mile
RIM	Reinvest in Minnesota
7Q10	Seven day low flow average based on a minimum of ten years of data
SCS	Soil Conservation Service
SOD	Sediment Oxygen Demand
SONAR	Statement of Need and Reasonableness
STATSGO	State Soil Geographic
SSURGO	Soil Survey Geographic
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total phosphorus
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
Wenck	Wenck Associates, Inc.
WPA	Wetland Preservation Areas
WMA	Wildlife Management Areas
WLA	Wasteload Allocation
WQBELs	Water Quality Based Effluent Limits
WWTF	Waste Water Treatment Facility

Appendix A

Wenck Associates, Inc.
1802 Wooddale Drive, Suite 100
Woodbury, MN 55125

(651) 294-4580
Fax (651) 228-1969
E-mail: wenckmp@wenck.com

TECHNICAL MEMORANDUM

TO: Mary Homan, Lac qui Parle/Yellow Bank Watershed Clean Water Partnership
Katherine Pekarek-Scott, MPCA Regional Impaired Waters Coordinator

FROM: Rich Brasch
Pamela Massaro, P.E.

DATE: October 6, 2010, revised November 22, 2010

SUBJECT: Lac qui Parle/Yellow Bank (LQPYB) Watershed
Bacteria Loading by Source: Methodology and Estimates of Relative Contribution

---

This memo is intended to summarize the major assumptions underlying the bacteria accounting summary presented in the main body of the Lac qui Parle/Yellow Bank (LQPYB) watershed bacteria TMDL report. The methodology outlined here is adapted from the 2002 version of the "Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota" (MPCA 2002). It represents a means to estimate the loadings from various bacteria sources. It is only a very rough approximation for the following reasons:

1. The method uses only very general percentages to represent the availability and delivery of bacteria to receiving waters based largely on professional judgment rather than research-derived information.
2. The dynamics of bacteria growth and die-off in the environment and such factors as re-suspension and survival in the receiving water are not factored in to the methodology.
3. The effect of streamflow is not specifically accounted for.

Because of these factors, the results of the analysis are expressed in qualitative terms (low, medium, high) that attempt to capture the relative contributions from the various sources rather than precise loads. Despite these shortcomings, this method can help to understand the general magnitude of the various contributing sources and potentially help understand delivery mechanisms that can assist in focusing implementation efforts. It is important to note that the analysis does not affect the allocations of the TMDL itself. Finally, it is also important to note that the methodology is based on fecal coliform bacteria accounting, but that the relative proportions hold for *E. coli* bacteria as well.

Following are an explanation of the steps and a summary of the results for the LQPYB TMDL project area.

Step 1: Estimating fecal coliform produced per animal per day

One of the first steps is to identify estimates of fecal production by animal type. Table A.1 provides numbers obtained from the literature for the major animal categories in the project area.

Table A.1: Fecal Coliform Bacteria Produced per Animal per Day

	FC orgs/animal/day		
	Source 1*	Source 2*	Average
Dairy cattle		1.00E+11	1.00E+11
Beef cattle		1.00E+11	1.00E+11
Swine	8.90E+09	1.10E+10	9.95E+09
Chickens	2.40E+08	1.40E+08	1.90E+08
Turkeys	1.30E+08	9.50E+07	1.13E+08
Horses		4.20E+08	4.20E+08
Sheep	1.80E+10	1.20E+10	1.50E+10
Deer**	5.00E+08		5.00E+08
Geese***	1.04E+07		1.04E+07
People	5.00E+09		5.00E+09
Dogs/cats****	5.00E+09		5.00E+09

*Source 1: Metcalf and Eddy 1991; Source 2: ASAE, 1998
**Interpolated from Metcalf and Eddy, 1991 (in Dry Creek Watershed TMDL, Alabama, 2001)
***from Alderisio, K.A. and N. DeLuca, 1999. Applied and Env. Microbio. (assumes 1.5 lbs. waste/goose/day)
****from Horsley and Witten, 1996

Tables A.2 through A.12 summarize the total fecal coliform bacteria production estimated for all types of animals in the watersheds within Minnesota of each of the 11 listed reaches. Livestock numbers were determined based on level 1 feedlot inventories conducted in 2009 by environmental staff from Lac qui Parle, Yellow Medicine, and Lincoln Counties. That inventory data was separated into the respective subwatersheds for each of the listed reaches. (Note: The inventory data did not differentiate between dairy and beef cattle, so cattle numbers and fecal production from cattle are not differentiated either). Human population numbers and persons per household for each subwatershed was based on the 2000 census block data. Based on this information, we assumed a figure of 2.8 persons per household for the project subwatersheds. These numbers were used to estimate households served by on-site septic systems in the rural portions of each watershed as well as populations served by municipal wastewater systems in incorporated areas. The failure rate for on-site septic systems was set at 56% based on inventory data and information from the Lincoln County portion of the Lac qui Parle River watershed. In the absence of other data, this failure rate was applied to septic systems serving rural areas in the remainder of the TMDL project area. Based on information from Curt Vacek, Minnesota DNR Wildlife Division, we assigned a deer density of 5 deer per square mile and a goose population of 18.7 geese per square mile over each subwatershed. Finally, we assumed the bacteria loading for urban stormwater based on the number of dogs and cats per household in urban areas. These figures were based on American Veterinary Medicine Association data nationwide that indicates there are 0.58 dogs and 0.73 cats per household.

Table A.2: Total Fecal Coliform Bacteria Produced per Animal Type in the Subwatershed Draining to Florida Creek (AUID 07020003-521, South Dakota border to W. Branch Lac qui Parle River)

Category	Subcategory	Numbers	FC produced/day	Total FC produced per day	% of Total
Livestock	Cattle	4967	1.00E+11	4.97E+14	
	Swine	6387	9.95E+09	6.36E+13	
	Poultry	70580	1.90E+08	1.34E+13	
	Other	190	4.20E+08	7.98E+10	99.57%
Humans	Rural Populations	448	5.00E+09	2.24E+12	
	Population served by WWTF	0	5.00E+09	0.00E+00	0.39%
Wildlife	Deer	381	5.00E+08	1.91E+11	
	Geese	1426	1.04E+07	1.48E+10	0.04%
Urban	Dogs and cats in cities	0	5.00E+09	0	0.00%
TOTAL				5.76E+14	100%

Table A.3: Total Fecal Coliform Bacteria Produced per Animal Type in the Subwatershed Draining to Lazarus Creek (AUID 07020003-508, Canby Creek to Lac qui Parle River)

Category	Subcategory	Numbers	FC produced/day	Total FC produced per day	% of Total
Livestock	Cattle	7776	1.00E+11	7.78E+14	
	Swine	4349	9.95E+09	4.33E+13	
	Poultry	231	1.90E+08	4.39E+10	
	Other	325	4.20E+08	1.37E+11	98.05%
Humans	Rural Populations	634	5.00E+09	3.18E+12	
	Population served by WWTF	1761	5.00E+09	8.80E+12	1.43%
Wildlife	Deer	491	5.00E+08	2.46E+11	
	Geese	1836	1.04E+07	1.91E+10	0.03%
Urban	Dogs and cats in cities	824	5.00E+09	4.12E+12	0.49%
TOTAL				8.37E+14	100%

Table A.4: Total Fecal Coliform Bacteria Produced per Animal Type in the Subwatershed Draining to West Branch Lac qui Parle River (AUID 07020003-512, Unnamed ditch to Unnamed creek)

Category	Subcategory	Numbers	FC produced/day	Total FC produced per day	% of Total
Livestock	Cattle	8711	1.00E+11	8.71E+14	
	Swine	23665	9.95E+09	2.35E+14	
	Poultry	71345	1.90E+08	1.36E+13	
	Other	1925	4.20E+08	8.09E+11	98.90%
Humans	Rural Populations	749	5.00E+09	3.75E+12	
	Population served by WWTF	1099	5.00E+09	5.49E+12	0.82%
Wildlife	Deer	1205	5.00E+08	6.03E+11	
	Geese	4507	1.04E+07	4.69E+10	0.05%
Urban	Dogs and cats in cities	514	5.00E+09	2.57E+12	0.23%
TOTAL				1.13E+15	100%

Table A.5: Total Fecal Coliform Bacteria Produced per Animal Type in the Subwatershed Draining to West Branch Lac qui Parle River (AUID 07020003-516, Lost Creek to Florida Creek)

Category	Subcategory	Numbers	FC produced/day	Total FC produced per day	% of Total
Livestock	Cattle	1503	1.00E+11	1.50E+14	
	Swine	0	9.95E+09	0	
	Poultry	60	1.90E+08	1.14E+10	
	Other	10	4.20E+08	4.2E+9	99.64%
Humans	Rural Populations	93	5.00E+09	4.66E+11	
	Population served by WWTF	0	5.00E+09	0	0.31%
Wildlife	Deer	134	5.00E+08	6.70E+10	
	Geese	501	1.04E+07	5.21E+09	0.05%
Urban	Dogs and cats in cities	0	5.00E+09	0	0.00%
TOTAL				1.51E+14	100%

Table A.6: Total Fecal Coliform Bacteria Produced per Animal Type in the Subwatershed Draining to Lac qui Parle River (AUID 07020003-505, Headwaters to Lazarus Creek)

Category	Subcategory	Numbers	FC produced/day	Total FC produced per day	% of Total
Livestock	Cattle	5972	1.00E+11	5.97E+14	
	Swine	7550	9.95E+09	7.51E+13	
	Poultry	107	1.90E+08	2.03E+10	
	Other	85	4.20E+08	3.57E+10	98.70%
Humans	Rural Populations	428	5.00E+09	2.14E+12	
	Population served by WWTF	867	5.00E+09	4.34E+12	0.96%
Wildlife	Deer	484	5.00E+08	2.42E+11	
	Geese	1809	1.04E+07	1.88E+10	0.04%
Urban	Dogs and cats in cities	406	5.00E+09	2.03E+12	0.30%
TOTAL				6.81E+14	100%

Table A.7: Total Fecal Coliform Bacteria Produced per Animal Type in the Subwatershed Draining to Lac qui Parle River (AUID 07020003-506, Lazarus Creek to W. Branch Lac qui Parle River)

Category	Subcategory	Numbers	FC produced/day	Total FC produced per day	% of Total
Livestock	Cattle	16265	1.00E+11	1.63E+15	
	Swine	17113	9.95E+09	1.70E+14	
	Poultry	393	1.90E+08	6.27E+09	
	Other	688	4.20E+08	2.89E+11	98.49%
Humans	Rural Populations	1504	5.00E+09	7.52E+13	
	Population served by WWTF	2628	5.00E+09	1.31E+13	1.13%
Wildlife	Deer	1383	5.00E+08	6.92E+11	
	Geese	5173	1.04E+07	5.38E+10	0.04%
Urban	Dogs and cats in cities	1230	5.00E+09	6.15E+12	0.34%
TOTAL				1.82E+15	100%

Table A.8: Total Fecal Coliform Bacteria Produced per Animal Type in the Subwatershed Draining to Lac qui Parle River (AUID 07020003-501, W. Branch Lac qui Parle River to Ten Mile Creek)

Category	Subcategory	Numbers	FC produced/day	Total FC produced per day	% of Total
Livestock	Cattle	26320	1.00E+11	2.63E+15	
	Swine	65188	9.95E+09	6.49E+14	
	Poultry	71338	1.90E+08	1.36E+013	
	Other	2613	4.20E+08	1.10E+12	98.08%
Humans	Rural Populations	3285	5.00E+09	1.64E+13	
	Population served by WWTF	6109	5.00E+09	3.05E+13	1.44%
Wildlife	Deer	3134	5.00E+08	1.57E+12	
	Geese	11721	1.04E+07	1.22E+11	0.05%
Urban	Dogs and cats in cities	2858	5.00E+09	1.43E+13	0.43%
TOTAL				3.36E+15	100%

Table A.9: Total Fecal Coliform Bacteria Produced per Animal Type in the Subwatershed Draining to Ten Mile Creek (AUID 07020003-511, Headwaters to Lac qui Parle River)

Category	Subcategory	Numbers	FC produced/day	Total FC produced per day	% of Total
Livestock	Cattle	997	1.00E+11	9.97E+13	
	Swine	56863	9.95E+09	5.66E+14	
	Poultry	0	1.90E+08	0.00	
	Other	143	4.20E+08	6.01E+10	99.33%
Humans	Rural Populations	618	5.00E+09	3.09E+12	
	Population served by WWTF	0	5.00E+09	0	0.63%
Wildlife	Deer	579	5.00E+08	2.90E+11	
	Geese	2167	1.04E+07	2.25E+10	0.04%
Urban	Dogs and cats in cities	0	5.00E+09	0	0.00%
TOTAL				6.70E+14	100%

Table A.10: Total Fecal Coliform Bacteria Produced per Animal Type in the Subwatershed Draining to North Fork Yellow Bank River (AUID 07020001-510, South Dakota Border to Yellow Bank River mainstem)

Category	Subcategory	Numbers	FC produced/day	Total FC produced per day	% of Total
Livestock	Cattle	160	1.00E+11	1.60E+13	
	Swine	0	9.95E+09	0.00	
	Poultry	0	1.90E+08	0.00	
	Other	0	4.20E+08	0.00	99.31%
Humans	Rural Populations	20	5.00E+09	9.86E+10	
	Population served by WWTF	0	5.00E+09	0	0.62%
Wildlife	Deer	22	5.00E+08	1.11E+10	
	Geese	83	1.04E+07	8.86E+08	0.07%
Urban	Dogs and cats in cities	0	5.00E+09	0	0.00%
TOTAL				1.61E+13	100%

Table A.11: Total Fecal Coliform Bacteria Produced per Animal Type in the Subwatershed Draining to South Fork Yellow Bank River (AUID 07020001-526, South Dakota Border to Yellow Bank River mainstem)

Category	Subcategory	Numbers	FC produced/day	Total FC produced per day	% of Total
Livestock	Cattle	1874	1.00E+11	1.87E+14	
	Swine	0	9.95E+09	0.00	
	Poultry	3485	1.90E+08	3.47E+13	
	Other	140	4.20E+08	5.58E+10	99.20%
Humans	Rural Populations	190	5.00E+09	1.70E+12	
	Population served by WWTF	150	5.00E+09	0	0.76%
Wildlife	Deer	193	5.00E+08	9.67E+10	
	Geese	723	1.04E+07	7.52E+09	0.04%
Urban	Dogs and cats in cities	0	5.00E+09	0	0.00%
TOTAL				2.24E+14	100%

Table A.12: Total Fecal Coliform Bacteria Produced per Animal Type in the Subwatershed Draining to Yellow Bank River (AUID 07020001-525, North Fork Yellow Bank River to Minnesota River)

Category	Subcategory	Numbers	FC produced/day	Total FC produced per day	% of Total
Livestock	Cattle	4213	1.00E+11	4.21E+14	
	Swine	3585	9.95E+09	3.57E+13	
	Poultry	0	1.90E+08	0.00	
	Other	140	4.20E+08	5.88E+10	99.74%
Humans	Rural Populations	513	5.00E+09	2.57E+12	
	Population served by WWTF	0	5.00E+09	0	0.22%
Wildlife	Deer	393	5.00E+08	1.96E+11	
	Geese	1470	1.04E+07	1.53E+10	0.04%
Urban	Dogs and cats in cities	0	5.00E+09	0	0.00%
TOTAL				4.60E+14	100%

Step 2: Estimating bacteria produced within livestock subcategories that is potentially available for transport by runoff.

A number of assumptions were made in order to assess potential contributions of bacteria from livestock. These assumptions were made based on where the bacteria from livestock were either deposited or otherwise resided on the landscape and a judgment as to how susceptible to transport to the receiving water the bacteria would therefore be. The possibilities considered as to where manure would be deposited during various times of the year in the project area watershed were:

- Pastures near streams (with direct access to the stream)
- Feedlots without runoff controls
- Surface-applied manure
- Incorporated manure

Table A.13 summarizes these assumptions for the various livestock categories. (Note: Livestock in the "other" category were not considered in this and future steps because of their generally small numbers).

Table A.13: Livestock Source Area Assumptions by Livestock Category

Source	**Category**		
	Cattle	Swine	Poultry
Pasture near streams	1%	None	1%
Feedlots w/o runoff controls	1%	None	99%
Surface-applied manure	64%	10%	None
Incorporated manure	34%	90%	None
TOTAL	100%	100%	100%

For example, Table A.13 above outlines assumptions that:

- 1% of the bacteria produced by cattle is in pastures near streams

- 1% of the bacteria produced by cattle are in feedlots without controls
- 64% of the bacteria produced by cattle is in surface applied manure
- 90% of the bacteria produced by swine is in incorporated manure

For human populations, the following assumptions were made

1. All bacteria produced from noncompliant septic systems were assumed to be potentially available for transport. We assumed the failure rate was 56% of all systems based on information supplied to us from inspections in Lincoln County.
2. Bacteria potentially available for transport from municipal wastewater treatment plants was estimated directly from plant permit or discharge monitoring data.

For wildlife populations, the following assumptions were made:

1. It was assumed that all bacteria produced by deer and geese were potentially available for transport.
2. To be conservative, the bacteria potentially available for transport from deer and geese were doubled to account for all other wildlife.

Each bacteria source was assigned a percentage that attempts to predict the likelihood of that animal's bacteria reaching the streams and tributaries within the LQPYB TMDL project area (Table A.14). These assumptions are gross approximations that were first developed as part of the Southeast Regional TMDL (MPCA, 2002), and reviewed by knowledgeable experts coordinated through the LQPYB Clean Water Partnership staff for applicability in this project area.

Table A.14 Assumptions Used to Estimate the Amount of Daily Fecal Coliform Production Available for Potential Runoff or Discharge into the Streams and Rivers of the Lac qui Parle Yellow Bank TMDL Project Area

Category	Source	Assumption
Livestock	Overgrazed Pasture near Streams or Waterways	1% of Dairy Manure 1% of Beef Manure
	Feedlots or Stockpiles without Runoff Controls	1% of Dairy 5% of Beef Manure 1% Poultry Manure
	Surface Applied Manure	64% of Dairy Manure 94% of Beef Manure 99% of Poultry Manure 10% Swine Manure; 20% of this manure applied in Spring 20% of this manure applied in Summer 60% of this manure applied in Fall
	Incorporated Manure	34% of Dairy Manure 90% of Swine Manure; 20% of this manure applied in the Spring 80% of this manure applied in Fall
Human	Noncompliant Septic Systems and Unsewered Communities	All waste from noncompliant septic systems and unsewered communities
	Municipal Wastewater Treatment Facilities (excluding bypasses)	Calculated directly from WWTP discharge limits
Wildlife	Deer	All fecal matter produced by deer in basin
	Geese	All fecal matter produced by geese in basin
	Other Wildlife	The equivalent of all fecal matter produced by deer and geese in basin
Urban Stormwater Runoff	Improperly Managed Waste from Dogs and Cats	10% of waste produced by estimated number of dogs and cats in basin

Step 3: Estimating bacteria delivery potential

To estimate actual delivery from the various sources to the surface water of each subwatershed, a second set of assumptions was applied.

Table A.15 shows estimated bacteria "delivery potential" expressed in both a qualitative and quantitative manner. Sources of bacteria and delivery potential vary with both season and weather. The percentages applied reflect assumptions regarding bacteria available by season (spring, summer, fall) and by whether the season is wet (when runoff-driven transport processes dominate) or dry (when they don't). Table A.14 presents these assumptions.

Table A.15: Estimate of Bacteria Potentially Available For Transport That May Be Delivered by Source Area

Source	*Estimated Delivery Potential*					
	Spring (wet)	**Spring (dry)**	**Summer (wet)**	**Summer (dry)**	**Fall (wet)**	**Fall (dry)**
Over-grazed pasture near streams or waterways	4% (High)	1% (low)	4% (high)	1% (low)	4% (high)	1% (low)
Feedlots/manure stockpiles without runoff controls	4% (High)	None	4% (High)	none	4% (High)	none
Surface-applied manure	1% (low)	None	1% (low)	none	1% (low)	none
Incorporated manure	0.1% (Very low)	None	0.1% (Very low)	none	0.1% (Very low)	none
Noncompliant septic systems	6% (Very high)	6% (Very high	6% (Very high	6% (Very high	6% (Very high	6% (Very high
Municipal wastewater treatment facilities	Contribution estimated directly from permits and discharge reports					
Deer	1% (low)	1% (low)	1% (low)	1% (low)	1% (low)	1% (low)
Geese	4% (high)	4% (high)	4% (high)	4% (high)	4% (high)	4% (high)
Other wildlife	1% (low)	1% (low)	1% (low)	1% (low)	1% (low)	1% (low)
Urban stormwater runoff	4% (high)	4% (high)	4% (high)	4% (high)	4% (high)	4% (high)

The delivery potential rating summarized in this table came from Mulla, et. al (2001), which should be referred to for a more detailed explanation of the risk categories. Discussion of the estimated delivery and likely delivery mechanisms with each of the sources is provided below.

<u>Livestock</u>

Because of the well-drained nature of the landscape and the at times close proximity of many feedlots to creeks and waterways, runoff from "feedlots and stockpiles without runoff controls" under wet conditions is assigned a "high" rating during the spring. The estimate from summer is reduced to account for the filtering effect of vegetation growth. A high delivery potential is assigned during wet conditions for "over-grazed pasture near streams or waterways" because of limited protected cover that can result from overgrazing. Under dry conditions, a low delivery potential is assumed by direct deposit of manure from livestock standing in the water.

Land application of manure can be a significant source of bacteria loading. Even for large operations which are regulated as Concentrated Animal Feedlot Operations (CAFOs) and not allowed to discharge from the feedlot itself, the manure is still usually spread on the landscape. The locations of CAFOs are shown in Figure A.12. The delivery of land-applied manure to receiving waters is greatly dependent on management, including:

- The rate, timing, and method of application
- Observance of setbacks from surface water or surface tile intakes
- Timely incorporation of the manure to avoid transport following a major rainfall
- Prevalence of riparian buffer strips along the transport route
- Residue management to reduce surface runoff

Large scale transport of applied manure can only occur during runoff from precipitation events. Unlike some feedlots and overgrazed pastures, there is usually some separation between fields and streams/waterways, though surface tile intakes can provide more direct routes to surface waters. Consequently, the delivery potential is considered low relative to some other manure sources, though the large volume of manure disposed of in this manner still means it can be a large potential source of delivered load under certain conditions. Compared to surface-applied manure, the delivery potential of injected or incorporated manure is considered very low.

Humans

Noncompliant septic systems are estimated to have a high delivery potential during both wet and dry conditions. This estimate assumes waste delivery via runoff and that there are relatively few "straight pipe" septic connections to tile systems. The higher the incidence of straight-pipe connections, the higher the delivery potential however. Contributions from wastewater treatment plants are based on discharge limits, a somewhat conservative assumption since the WWTP's (especially those with continuous discharges that occur over the April-October period) often perform better than their discharge limit.

Wildlife

The estimated delivery potential of deer and other wildlife is assumed to be low during all conditions. It is assumed that deer waste is usually deposited in well-vegetated areas, though they spend some time near streams and waterways as well, where there is likely to be some delivery of their fecal matter. The estimated delivery potential of geese is assumed to be high because they spend much of their time in or around water.

Pets

The delivery of pet waste is assumed to occur only during wet conditions. For dogs and cats in urban areas, a high delivery is assumed due to stormwater runoff from impervious and pervious surfaces which is conveyed efficiently to receiving waters by storm sewers. Pet waste outside urban areas is ignored for the purposes of this analysis because of the small amount and the general lack of efficient delivery mechanisms.

Step 4: Estimating Relative Bacteria loading by Source, Season, and Moisture Condition

While the information on loading is quantitative based on the previously explained assumptions, its primary importance is to assess relative potential contributions from the different sources under various seasonal and moisture conditions. Analysis for all eleven reaches were conducted using the outline methodology. Figures A.1 through A.11 show graphically by season and moisture condition for each impaired reach the relative contribution by source for the Minnesota portion of the watershed to each reach. The following general conclusions can be drawn for every impaired reach except Ten Mile Creek based on this analysis:

1. Overgrazed pastures near streams (especially where cattle have direct access to the stream) and noncompliant septic systems are the most likely significant sources of bacteria during dry conditions in all three seasons. This is because runoff-driven

processes of transport for bacteria are largely absent, and point source discharges are generally meeting their discharge limits, which are at the standard.

2. During wet conditions in the spring and summer, the most likely significant sources of bacteria delivered to receiving waters are surface-applied manure, over-grazed pastures near streams, and feedlots without runoff controls. All three are largely dependent on runoff processes to move large loads of bacteria to receiving waters.
3. During wet conditions in the fall, bacteria loads from surface-applied manure represent the largest potential source of loading to receiving waters. This is largely because 60% of the surface-applied manure spread over any given year is assumed to occur in the fall.

For Ten Mile Creek, the high numbers and therefore bacteria production of swine and the assumption that swine manure is generally injected into the soil with a very low potential for delivery means that other sources dominate. Specifically, the analysis indicates that noncompliant septic systems and surface-applied manure from the few cattle in the watershed are the largest potential sources of bacteria in this watershed.

Figure A.1: Estimated Relative Delivered Bacteria Load by Source, Season, and Moisture Condition in the Watershed Draining to Florida Creek (AUID 07020003-521, South Dakota Border to W. Branch Lac qui Parle River)

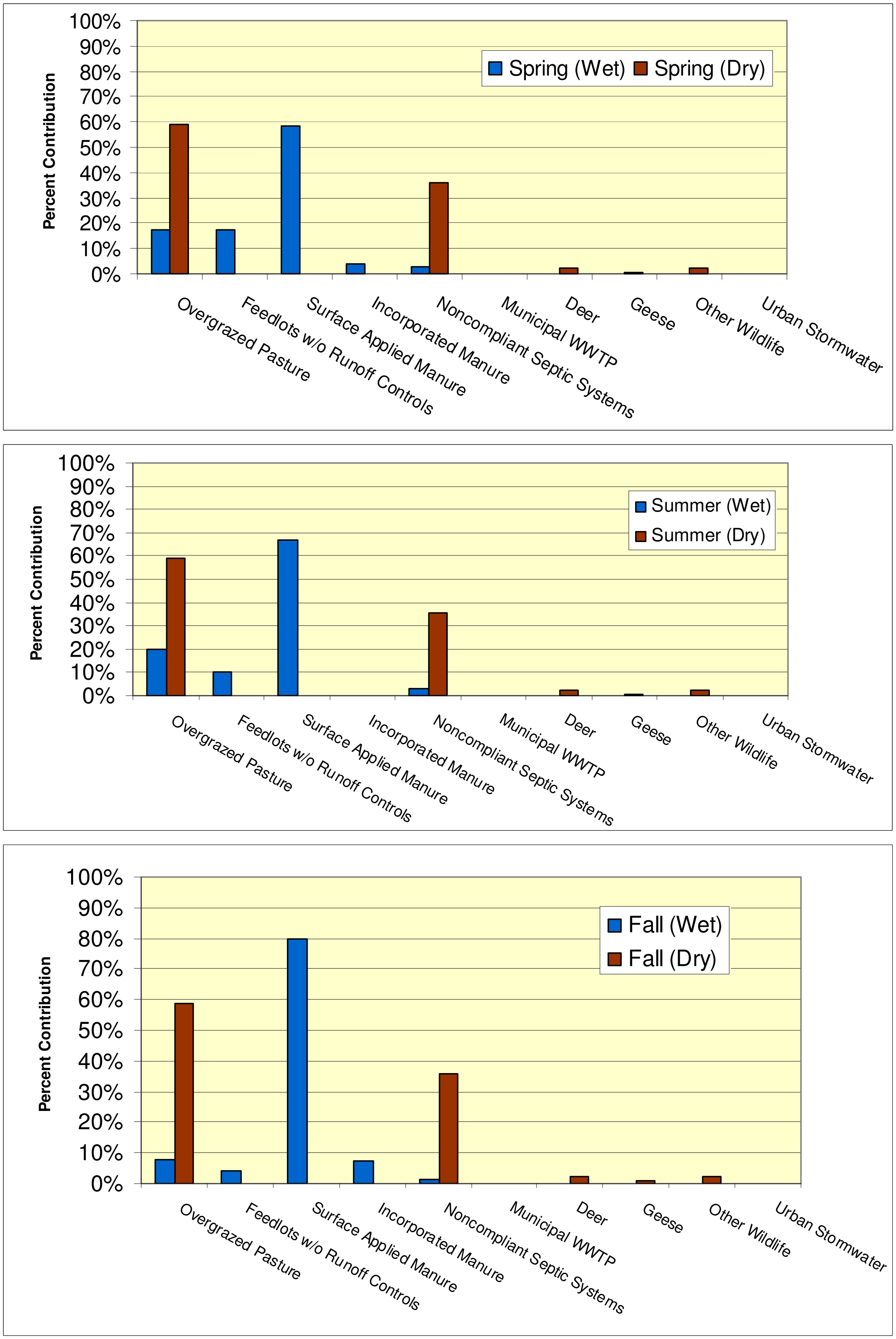
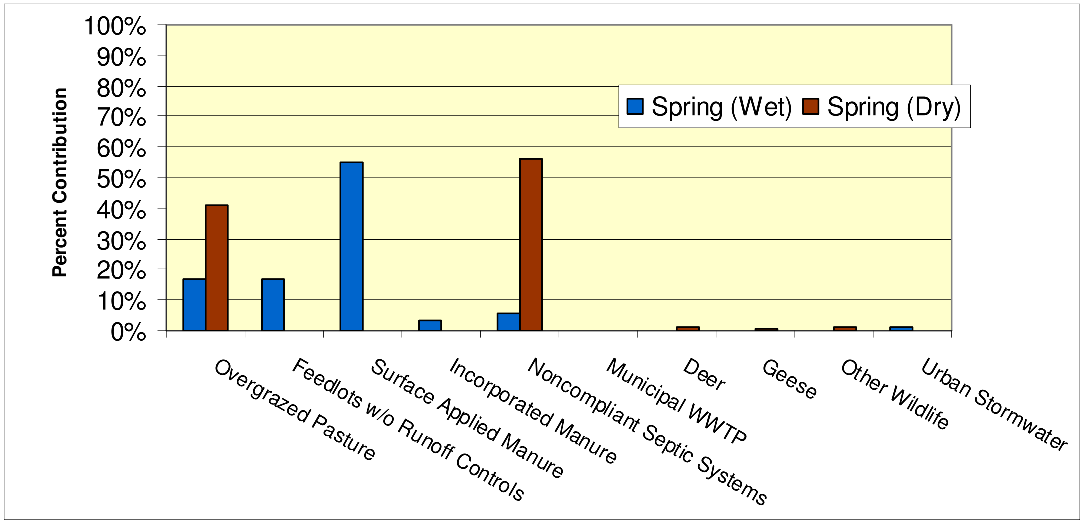
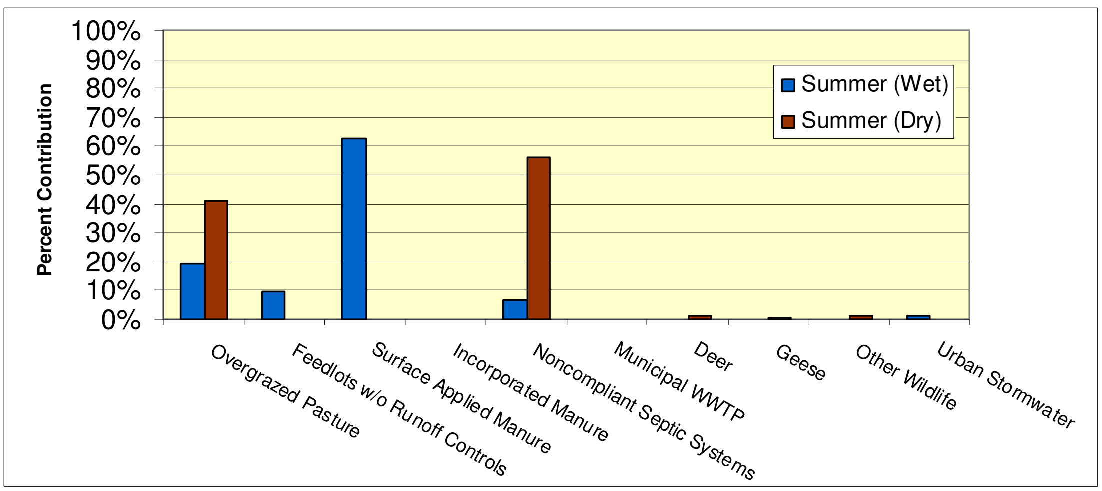


Figure A.2: Estimated Relative Delivered Bacteria Load by Source, Season, and Moisture Condition in the Watershed Draining to Lazarus Creek (AUID 07020003-508, Canby Creek to Lac qui Parle River)





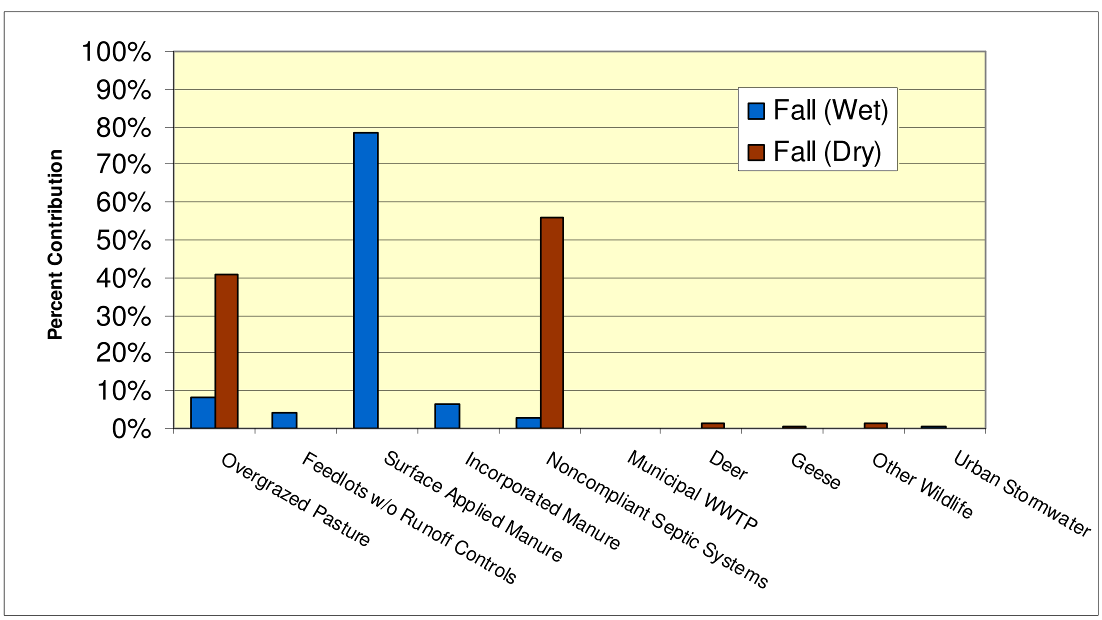
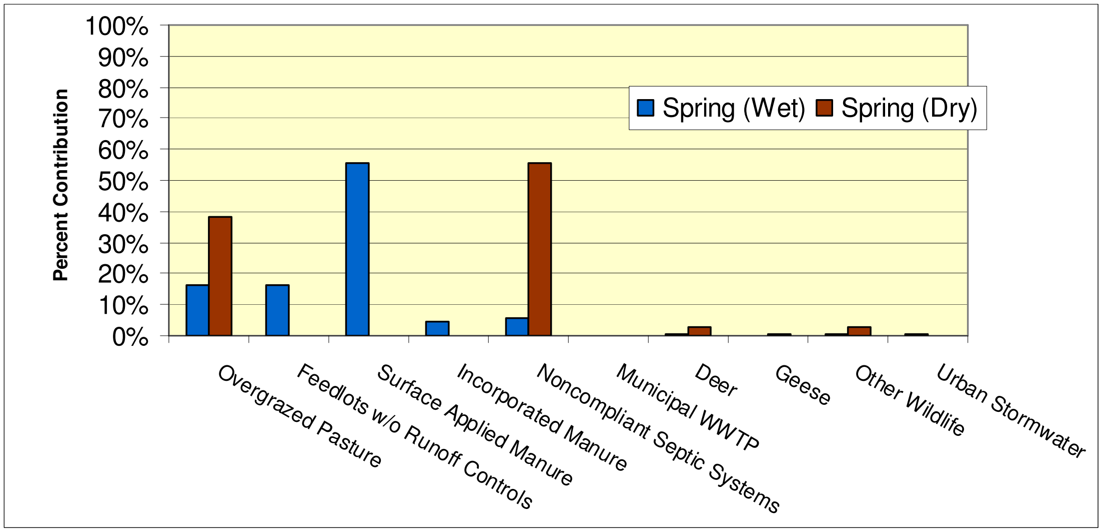
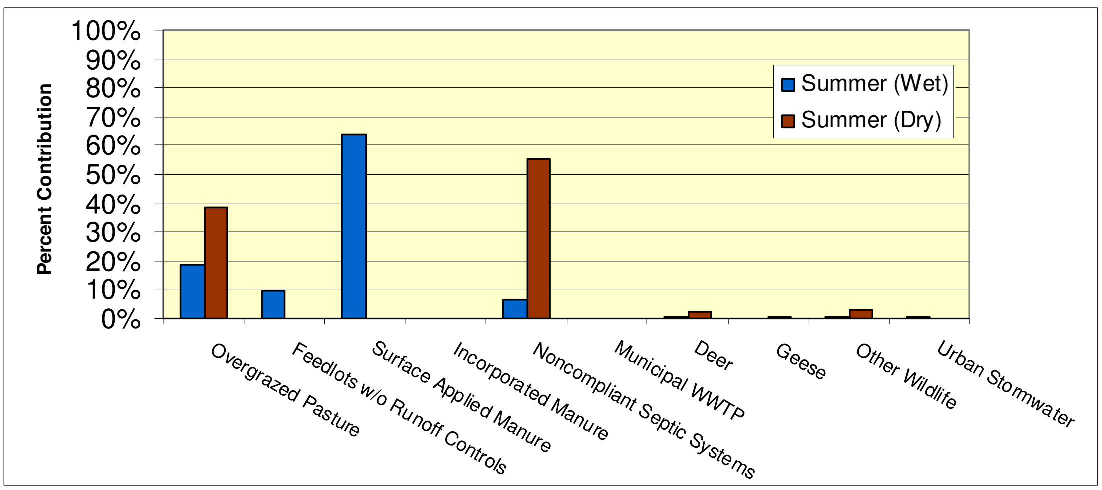


Figure A.3: Estimated Relative Delivered Bacteria Load by Source, Season, and Moisture Condition in the Watershed Draining to West Branch Lac qui Parle River (AUID 07020003-512, Unnamed ditch to Unnamed creek)





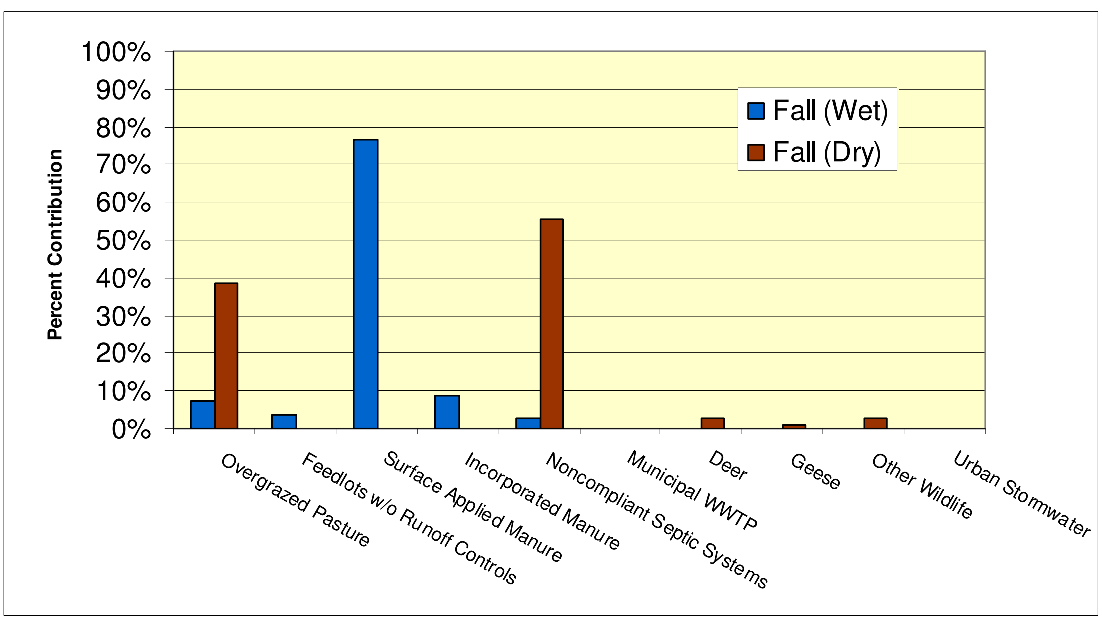
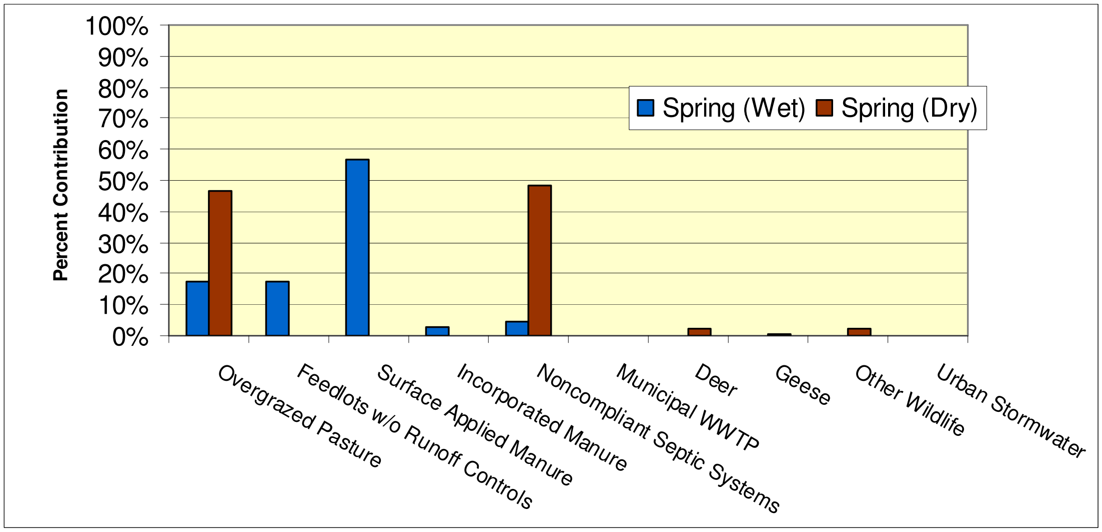
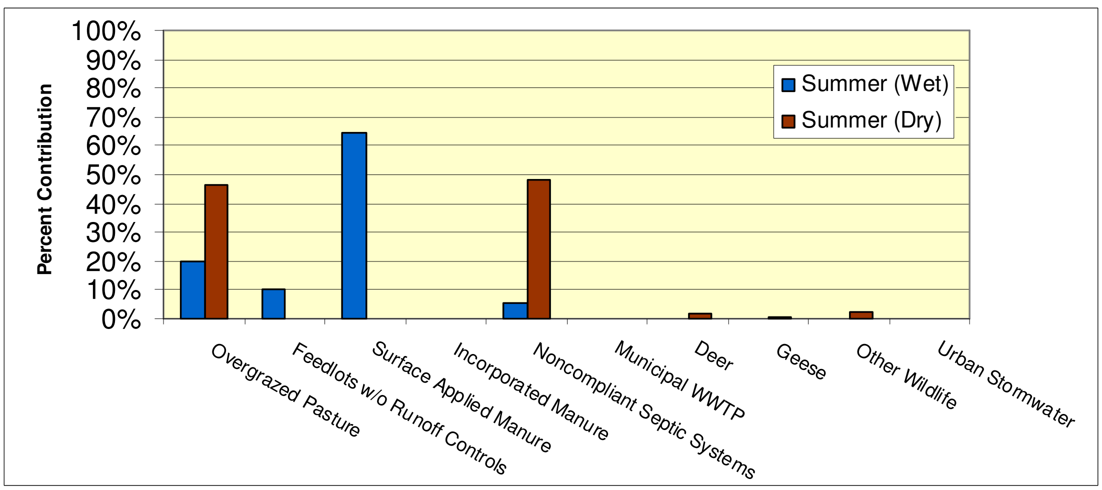


Figure A.4: Estimated Relative Delivered Bacteria Load by Source, Season, and Moisture Condition in the Watershed Draining to West Branch Lac qui Parle River (AUID 07020003-516, Lost Creek to Florida Creek





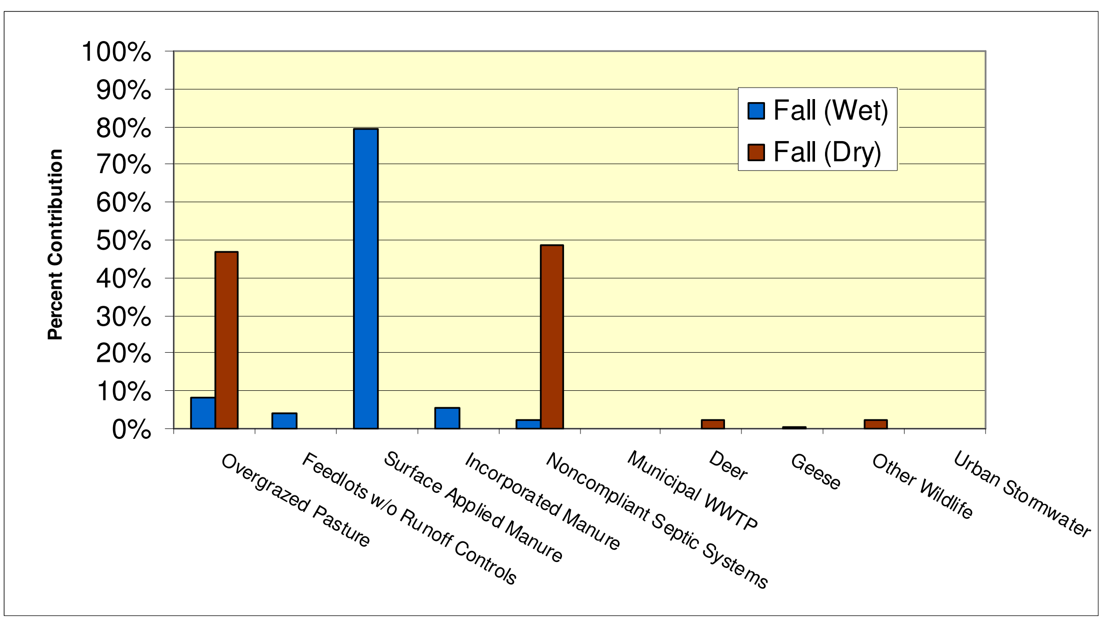
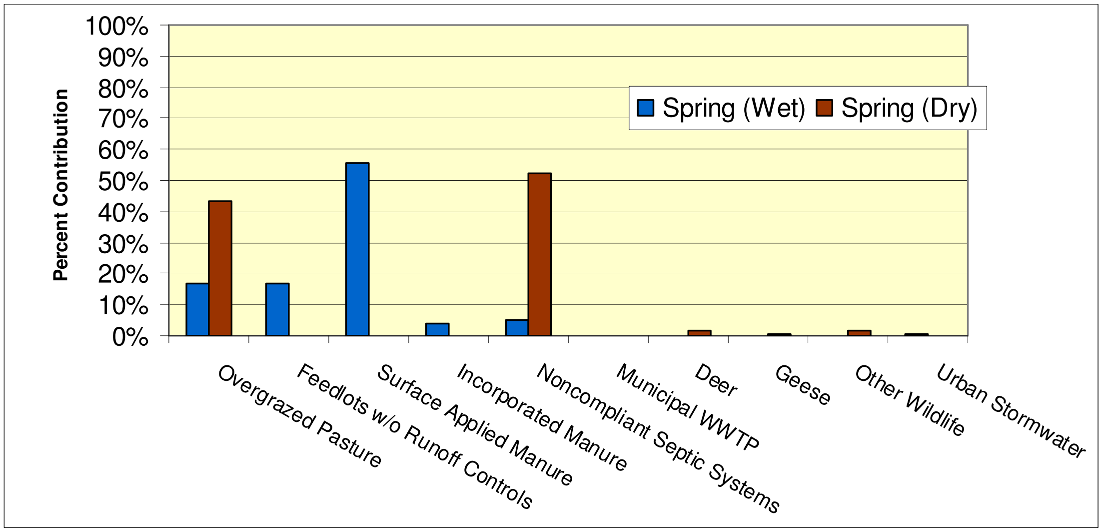
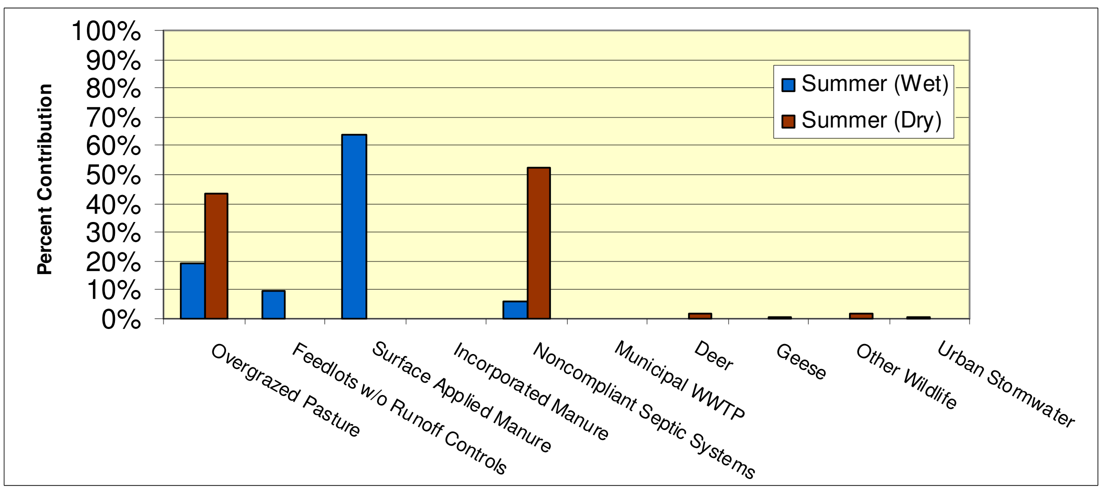


Figure A.5: Estimated Relative Delivered Bacteria Load by Source, Season, and Moisture Condition in the Watershed Draining to Lac qui Parle River (AUID 07020003-505, Headwaters to Lazarus Creek)





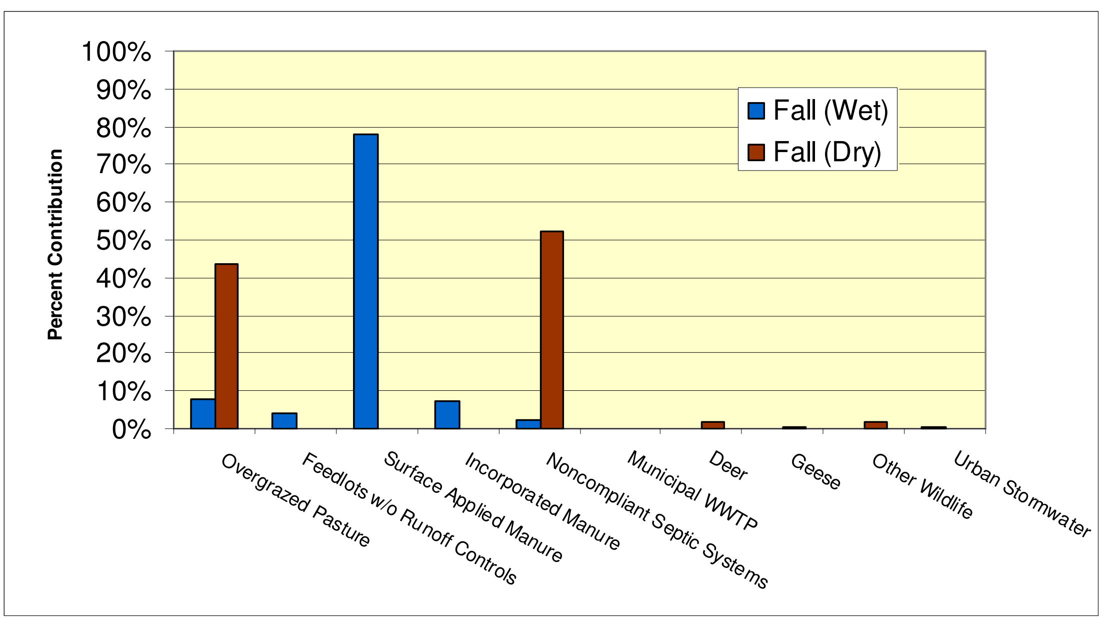
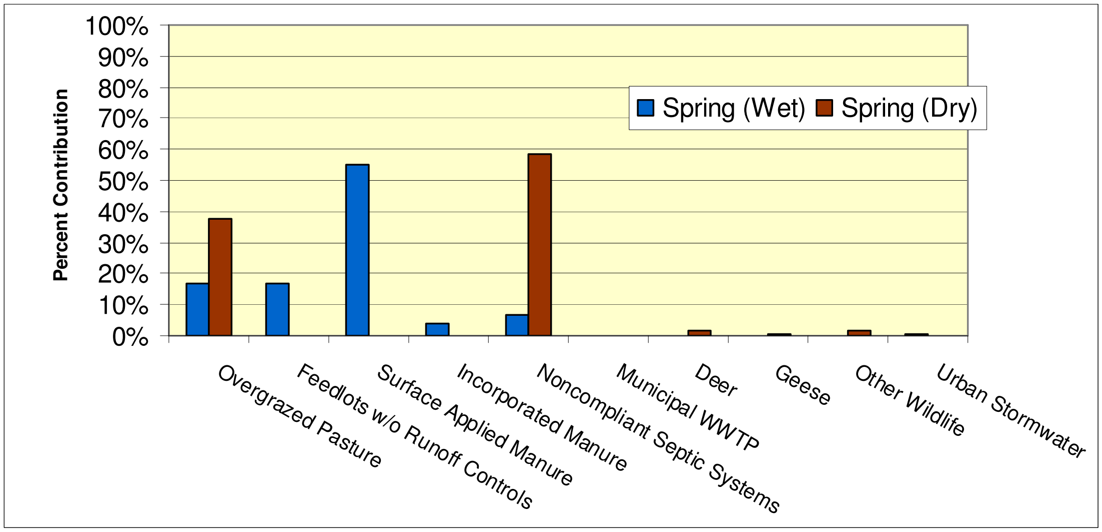
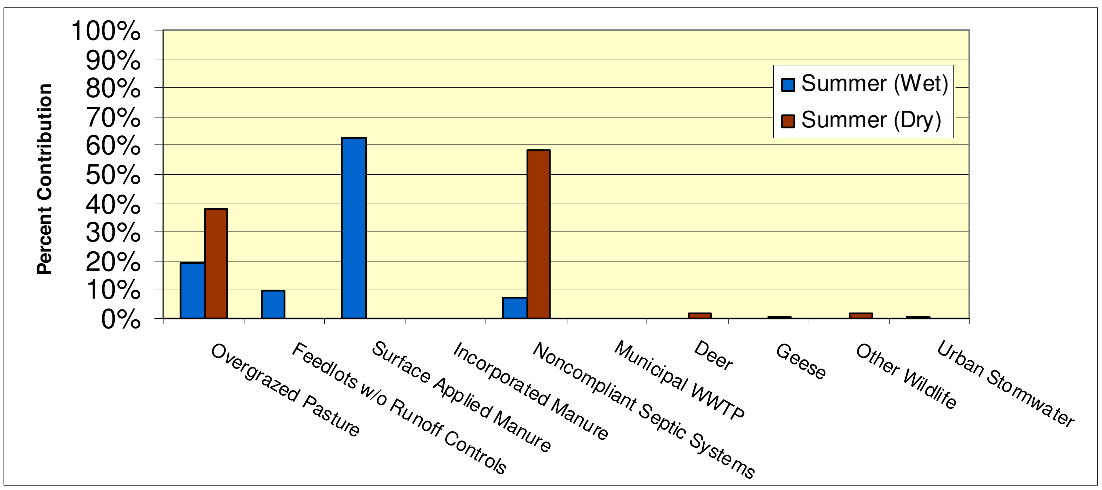


Figure A.6: Estimated Relative Delivered Bacteria Load by Source, Season, and Moisture Condition in the Watershed Draining to Lac qui Parle River (AUID 07020003-506, Lazarus Creek to W. Branch Lac qui Parle River)





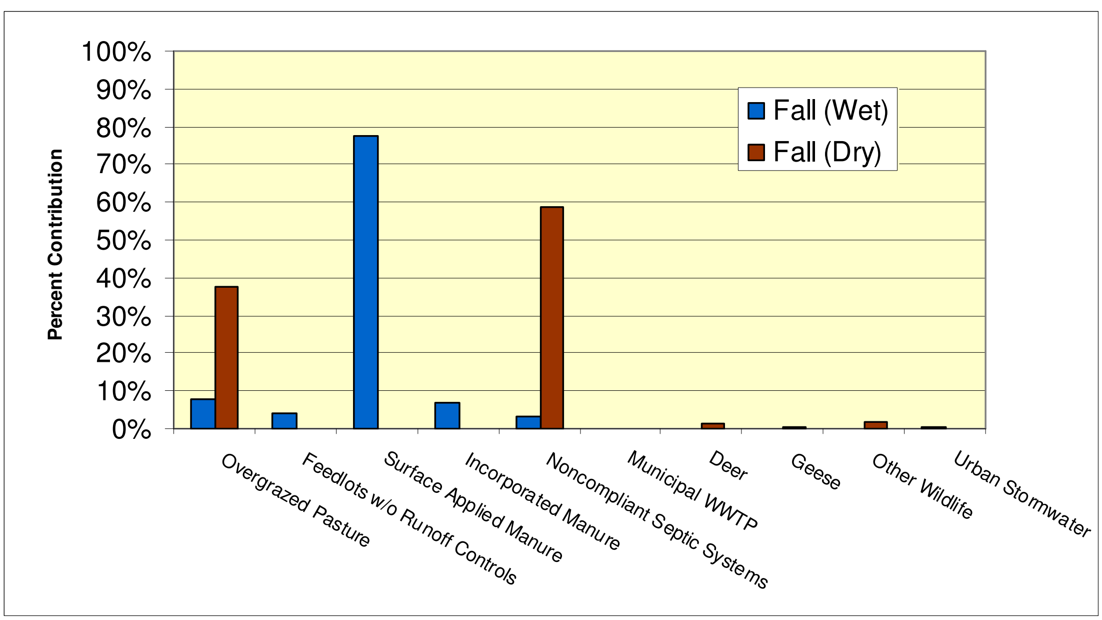
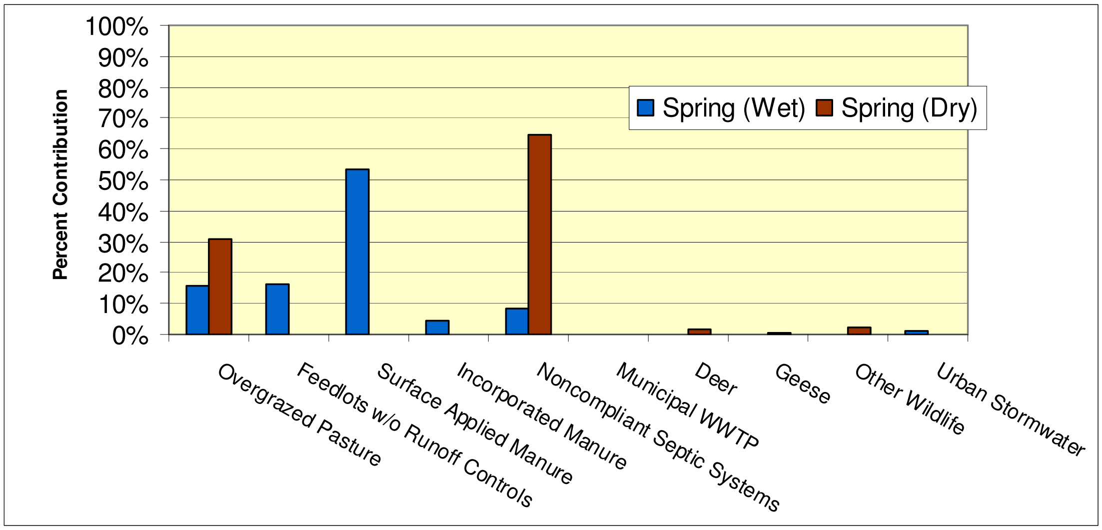
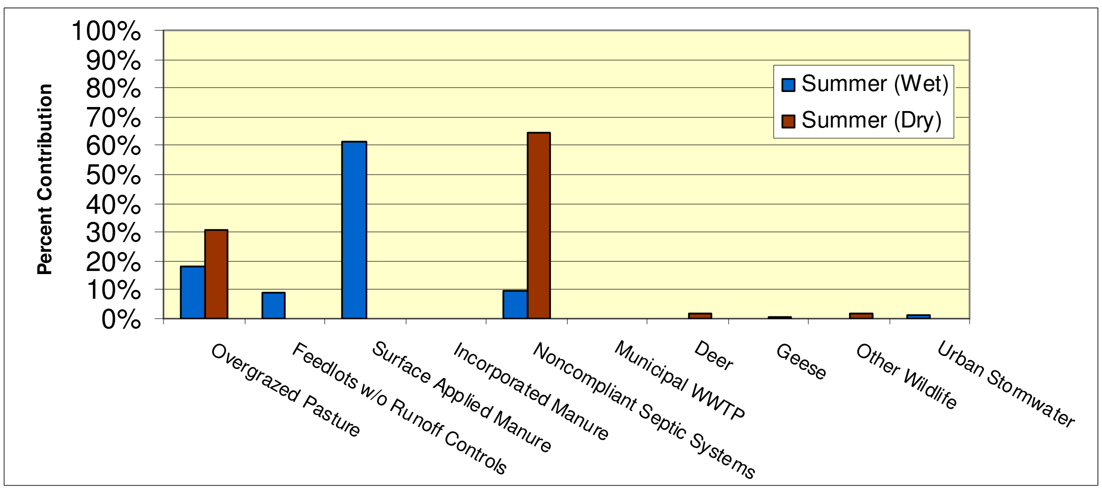


Figure A.7: Estimated Relative Delivered Bacteria Load by Source, Season, and Moisture Condition in the Watershed Draining to Lac qui Parle River (AUID 07020003-501, W. Branch Lac qui Parle River to Ten Mile Creek)





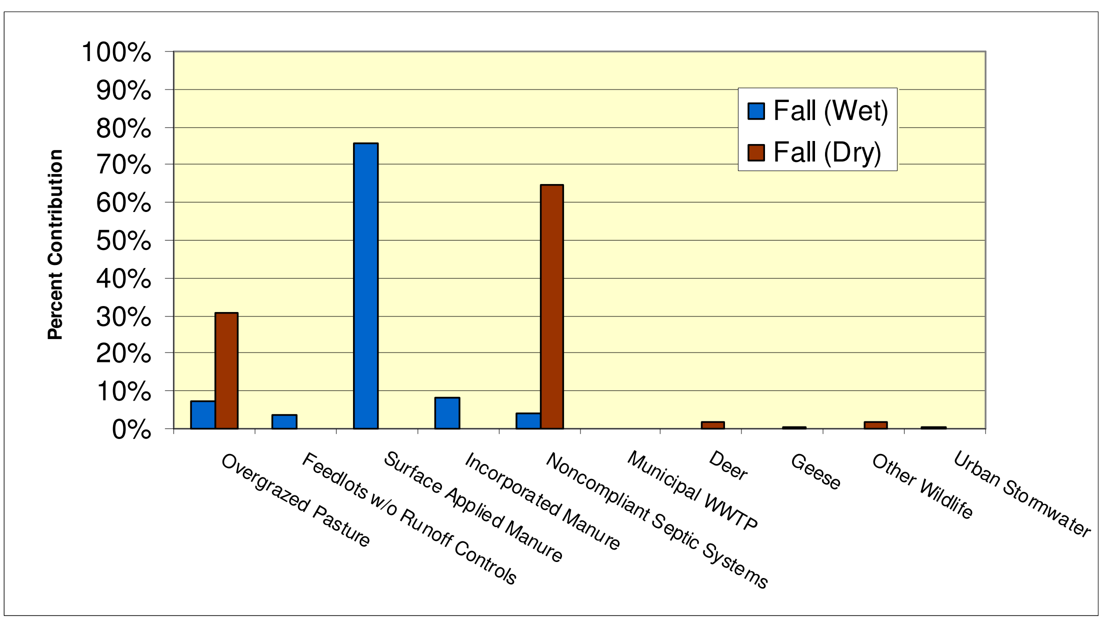
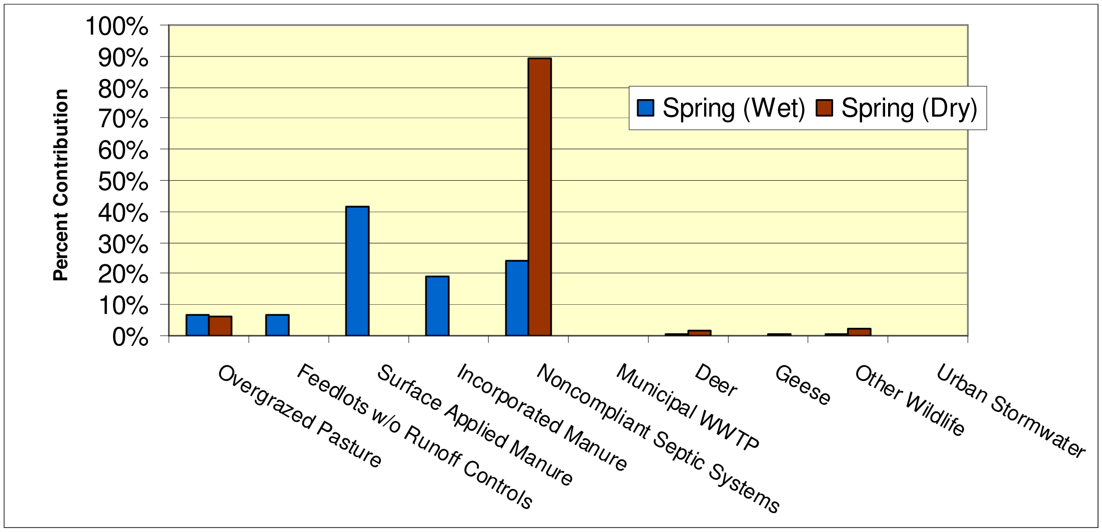
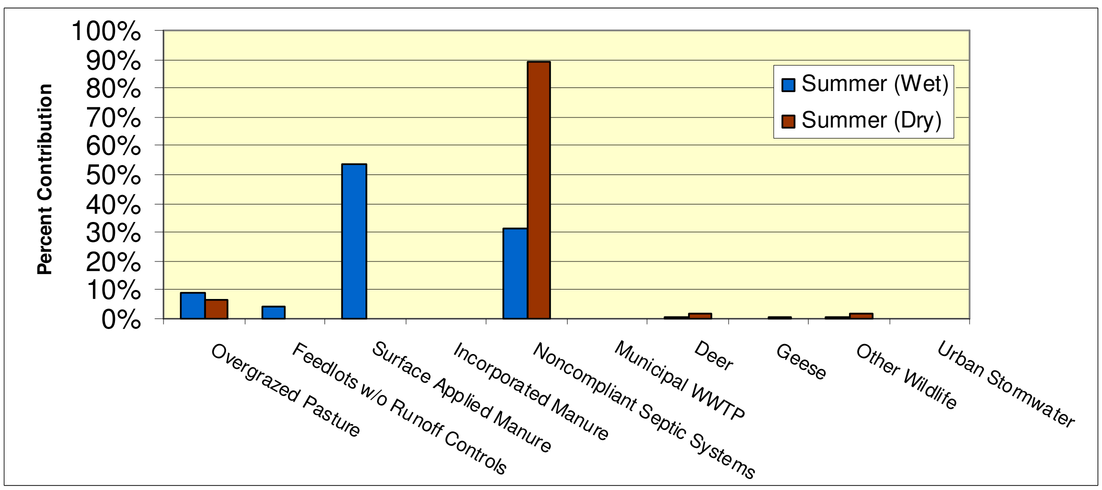


Figure A.8: Estimated Relative Delivered Bacteria Load by Source, Season, and Moisture Condition in the Watershed Draining to Ten Mile Creek (AUID 07020003-511, Headwaters to Lac qui Parle River)





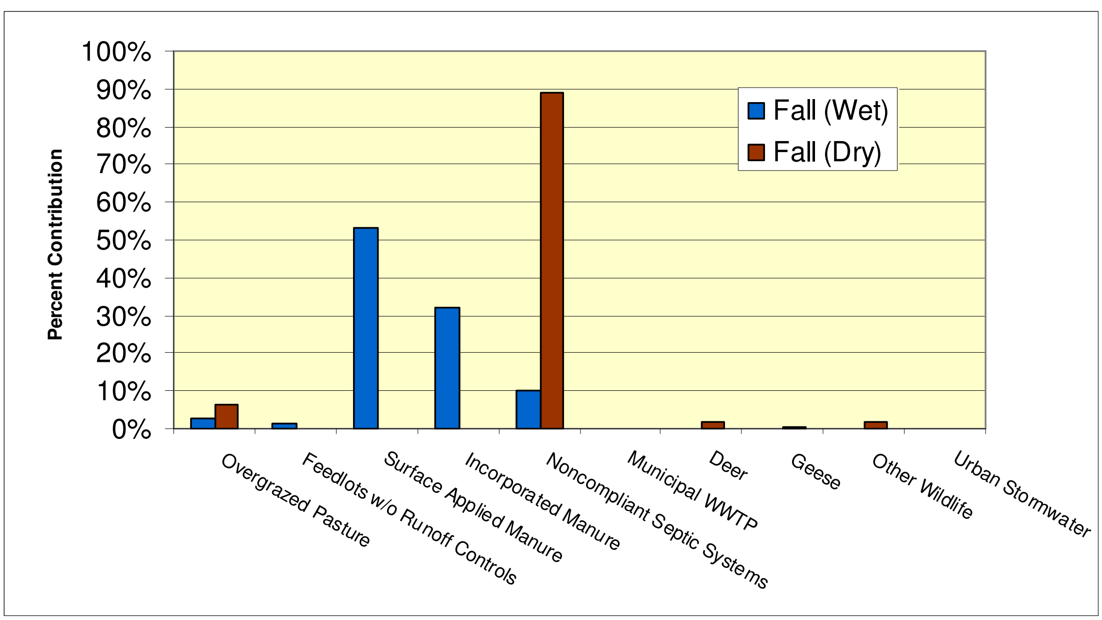
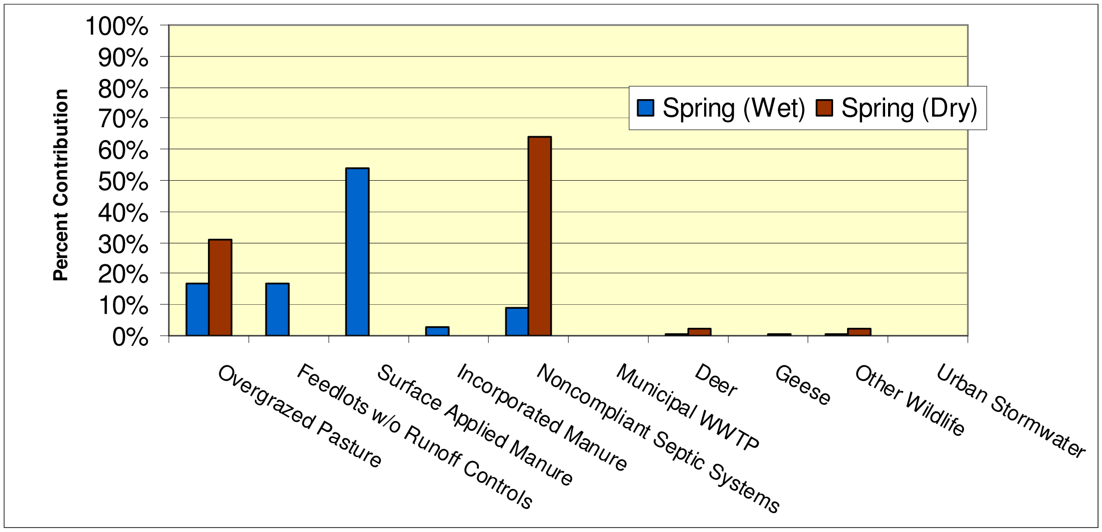
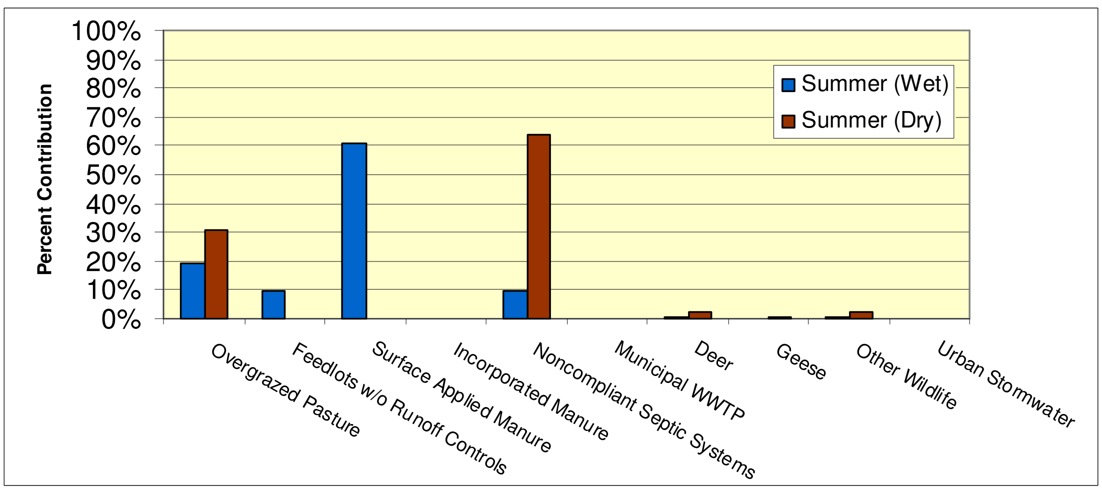


Figure A.9: Estimated Relative Delivered Bacteria Load by Source, Season, and Moisture Condition in the Watershed Draining to North Fork Yellow Bank River (AUID 07020001-510, South Dakota Border to Yellow Bank River mainstem)





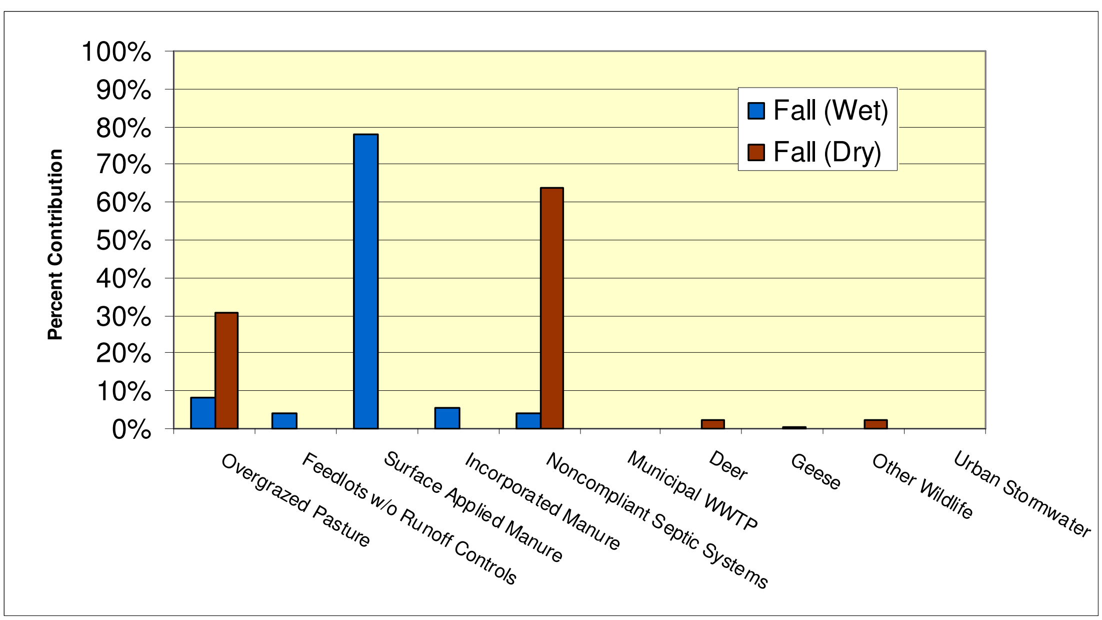


Figure A.10: Estimated Relative Delivered Bacteria Load by Source, Season, and Moisture Condition in the Watershed Draining to South Fork Yellow Bank River (AUID 07020001-526, South Dakota Border to Yellow Bank River mainstem

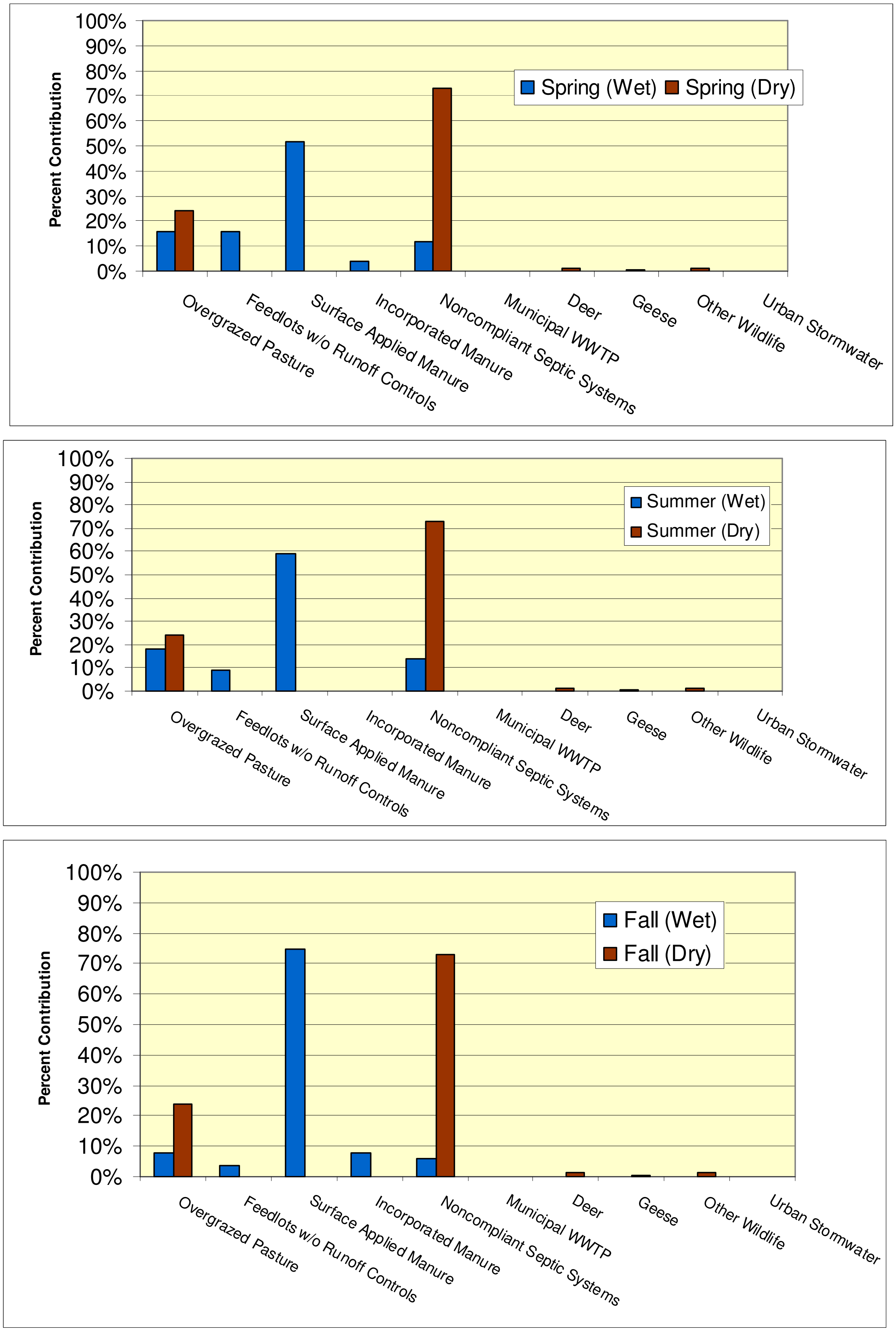
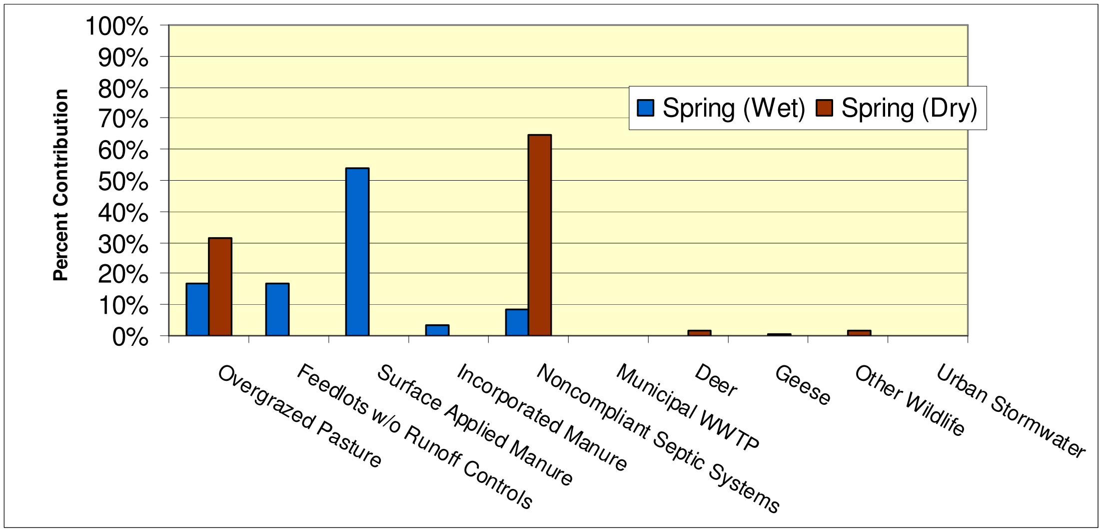
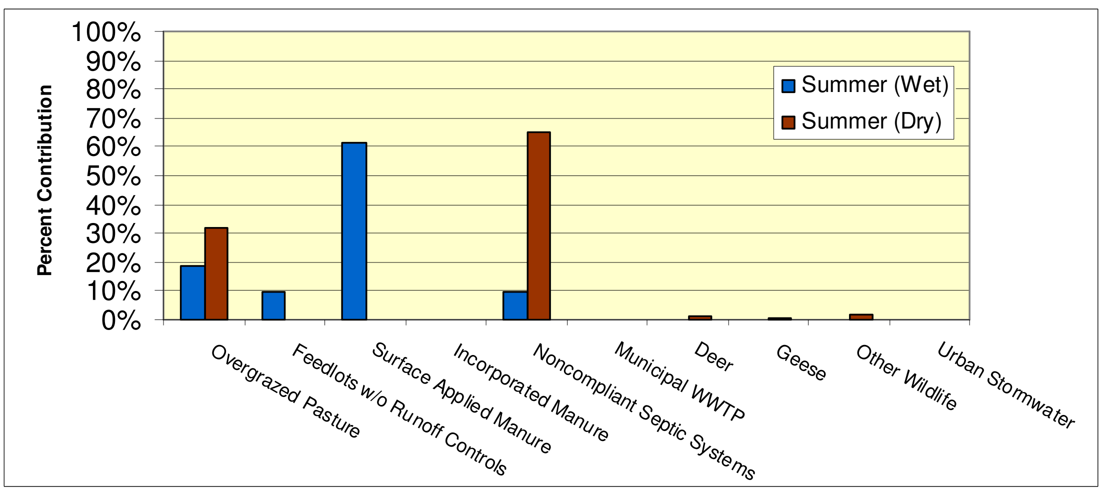


Figure A.11: Estimated Relative Delivered Bacteria Load by Source, Season, and Moisture Condition in the Watershed Draining to Yellow Bank River (AUID 07020001-525, North Fork Yellow Bank River to Minnesota River)





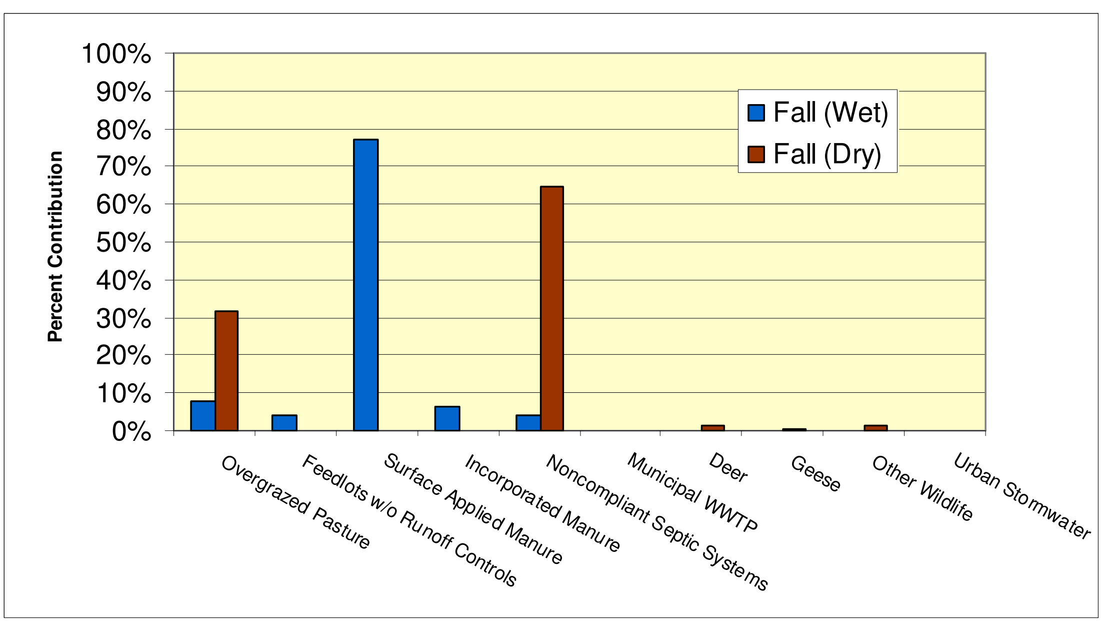
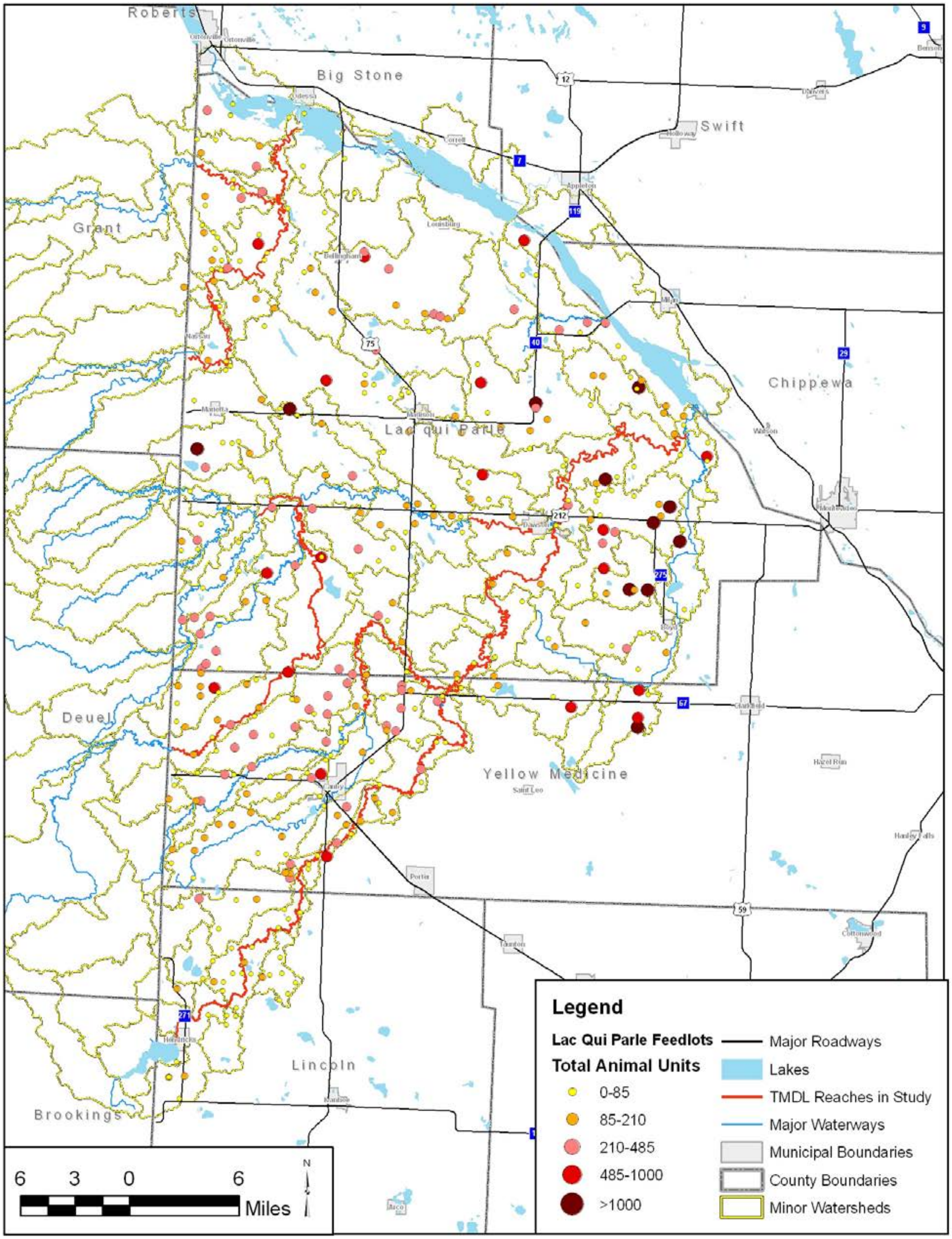


Figure A.12 – Confined Animal Feeding Operations (CAFOs) and Registered Feedlots in the Lac qui Parle/Yellow Bank Watershed Project Area



Wenck Associates, Inc.
1802 Wooddale Drive, Suite 100
Woodbury, MN 55125

(651) 294-4580
Fax (651) 228-1969
E-mail: wenckmp@wenck.com

TECHNICAL MEMORANDUM

TO: Katherine Pekarek-Scott, MPCA Regional Impaired Waters Coordinator

CC: Mary Homan, Lac qui Parle – Yellow Bank (LQPYB)
Clean Water Partnership (CWP) Project Coordinator

FROM: Pamela Massaro, P.E.

DATE: October 29, 2010
Revised: November 5, 2010, November 24, 2010, & June 23, 2011

SUBJECT: Lac qui Parle River Dissolved Oxygen TMDL
Description of QUAL2K Modeling Methods and Results

Wenck Associates, Inc. has developed and calibrated a QUAL2K model for Lac qui Parle River to model dissolved oxygen from the confluence of the West and South Branches of the Lac qui Parle River to the inflow of Ten Mile Creek. The purpose of this technical memorandum is to describe the methods and assumptions used to create and calibrate the QUAL2K model.

1.0 INTRODUCTION

1.1 Background

This modeling effort was undertaken in an effort to provide a technical basis for resolving the low dissolved oxygen (DO) impairment for a lower reach of the Lac qui Parle River in Lac qui Parle County, MN. The affected reach was listed in 1994. The objective of the modeling approach was to make use of currently available data to develop a model adequate to make the allocations and provide the framework for implementation necessary for an "approvable" TMDL assessment to address the impairment. As part of an earlier (Phase 1) effort to address this and other TMDLs in the Lac qui Parle and Yellow Bank River system, the data collected on impaired reaches was examined and Wenck conducted an abbreviated field data collection effort in September 2009 to fill some critical hydrologic/hydraulic data gaps. This memo builds on the summary of data collected provided in the technical memorandum to Mary Homan dated

December 4, 2009. Key conclusions from the December 4, 2009 memo relating to the DO impairment were as follows:

- Periodic monitoring within the designated impaired reach has not recorded a violation of the 5 mg/l DO standard since August 4, 2005
- The data collection effort on August 4, 2005 indicates that the degree of impairment within the listed reach appears relatively minor, with no readings below 4 mg/l even though the measurements documenting the violations were for the most part taken before 9:00 a.m. and can therefore be considered daily minimums.
- Based on the information presented, we would conclude that the critical condition during which significant violations are most likely to occur is the late summer low flow period. Note that the only data that show violations throughout the listed reach occurred at a flow of about 17 cubic feet per second (cfs) at Station S003-087 (lower end of impaired reach), well within the low flow regime
- Based on guidance from MPCA TMDL project staff, the preferred strategy is to proceed with the preparation of the DO TMDL and supporting modeling, then let the monitoring that will be completed as part of the basin-wide ("One Waters") approach starting in 2012 address whether the reach is still impaired.
- It is appropriate to try to match the level of effort in completing a credible analytical basis for the DO TMDL to the relatively minor severity of the impairment, if that is possible.
- The DO modeling effort in Phase 2 should aim to make the best use of the existing data to represent violating conditions, then see if there is a compelling need to generate additional monitoring data to better define boundary conditions. Note that any additional data collection will be conducted under conditions which could be significantly changed relative to historical conditions because of the replacement of the Dawson Dam with an overflow weir/fish ladder (in 2009).

This memo summarizes the results of the DO modeling effort for Phase 2 of the project.

1.2 Model Selection

The U.S. EPA River and Stream Water Quality Model (QUAL2K) version 7 is a modernized version of the QUAL2E model developed by Dr. Steven Chapra with Tufts University and Greg Pelletier with Washington State. It was selected to analyze Lac qui Parle River because it is a relatively simple surface water quality model that can be used during steady-state conditions to model nutrient, algal and DO dynamics.

1.3 General Overview of the Model

The model was built using primarily survey data sets collected on August 4, 2005, August 7-9, 2007 and September 9-10, 2009. As will be explained later in this memo, none of the data sets generated by the above efforts provided a complete suite of the high priority parameters desired to build a model. Thus, we combined monitoring information from the data collection efforts on the different dates to build a composite model for the system.

Stream locations and physical features were built into the model first before proceeding to hydraulic calibration. The model was hydraulically calibrated using both the August 4, 2005 and September 9-10, 2009 data sets. With the diffuse flow inputs incorporated, the conservative water quality parameters (such as water temperature, pH, alkalinity, and conductivity) were adjusted to match the August 4, 2005 monitored observations. Then, chlorophyll-*a* (phytoplankton production), nutrients (phosphorus and nitrogen components), and ultimate carbonaceous biological oxygen demand (UCBOD) were calibrated by adjusting tributary/diffuse source/groundwater contributions and/or kinetic coefficients within the range of published values. In some cases, reach-specific kinetic rates and in-stream nutrient fluxes were assigned to model geochemical processes believed to be unique to certain reaches. Then, sediment oxygen demand was adjusted for each reach to match observed DO data. Finally, the water quality adjustments used to calibrate to the August 4, 2005 water quality data were validated using the September 9-10, 2009 DO, pH and temperature observations.

2.0 MODEL SETUP AND INPUTS

The QUAL2K model covers the main stem of Lac qui Parle River from the confluence of the West and South Branches of the Lac qui Parle River (just south of where US Hwy 212 crosses near Dawson, MN) to the inflow of Ten Mile Creek. Figure 2.1 shows the drainage areas by tributary. The heavy red line in Figure 2.1 shows the reach of the mainstem of the Lac qui Parle River impaired for low DO, and the colored shaded areas show the various subwatersheds draining to both the mainstem itself and tributaries entering this reach of the mainstem.

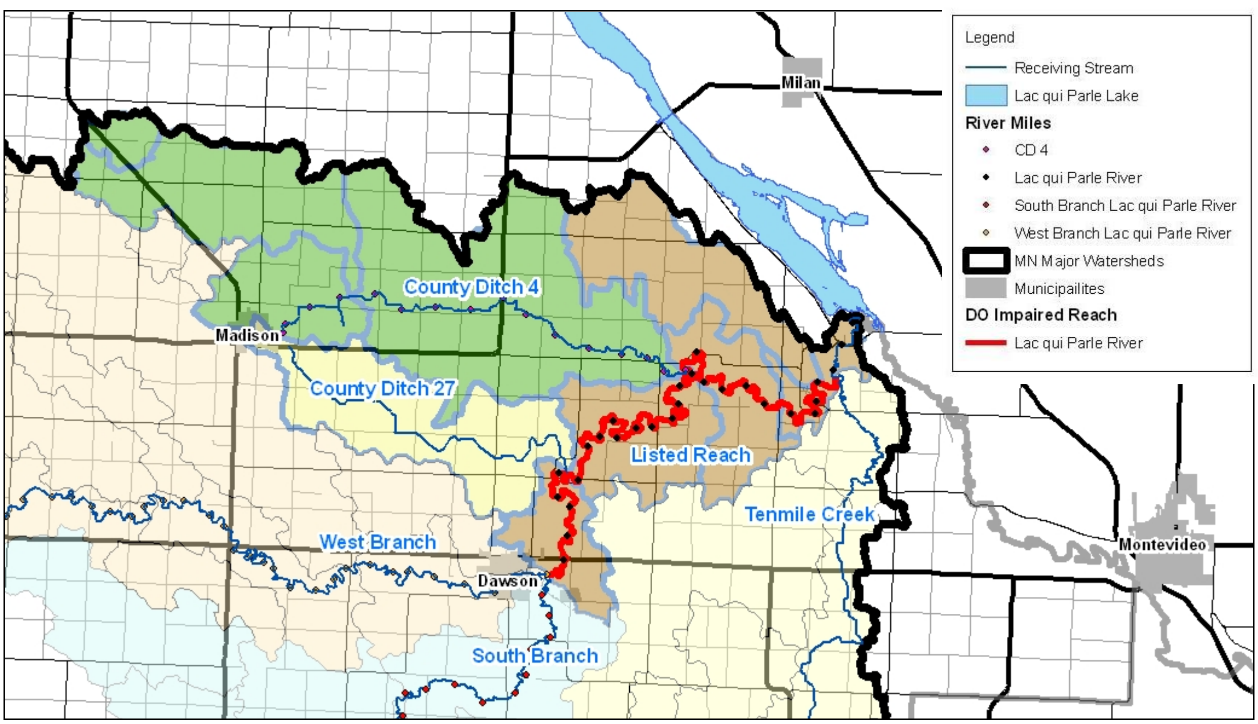


Figure 2.1: Direct Drainage Areas and Tributaries to the Lac qui Parle River QUAL2K Model.

The stretch of Lac qui Parle River, explicitly modeled, represents approximately 25.7 miles (41.4 km) represented in QUAL2K as 19 individual reaches. The start of each reach correlates with a monitoring location or tributary inflow location. Modeled slope (summarized in Table 3.3) was determined using GPS channel bottom elevations surveyed on September 9-10, 2009 and USGS contours. Provided at the end of this memorandum are Figure 1 and Figure 2 to aid visualization of the model river system (QUAL2K network diagrams). These figures identify the QUAL2K reaches, headwater boundaries, point sources, diffuse sources, downstream boundaries, and tributaries.

2.1 Tributaries

The headwater of the Lac qui Parle River is the confluence of two tributaries; the West Branch Lac qui Parle River and South Branch Lac qui Parle River. The QUAL2K model for Lac qui Parle River starts at the confluence of the West and South Branches of the Lac qui Parle River and ends at the inflow of Ten Mile Creek. The model required setting the boundary conditions for six streams, namely (in upstream to downstream order) the West Branch Lac qui Parle, Judicial Ditch 4, South Branch Lac qui Parle, County Ditch 27, County Ditch 4, and Ten Mile Creek. There is one point source (AMPI, MN0048968) discharging directly to the listed reach at Lac qui Parle River Mile 28.1 in Dawson.

2.1.1 West Branch Lac qui Parle

The West Branch Lac qui Parle River is the largest tributary to the mainstem and originates on the Coteau des Prairies in eastern South Dakota. The South Dakota/Minnesota border is 55 river miles upstream of the West Branch Lac qui Parle River's confluence with South Branch, which is 29 river miles upstream of the Minnesota River. There is only one permitted point source upstream of Dawson. That source is the City of Marrietta's stabilization pond, which discharges to a ditch tributary to West Branch. The discharge occurs approximately 37.5 miles upstream of the confluence and was not modeled explicitly in this effort. One notable feature of this reach of the West Branch is the Dawson dam, which was located about 1.6 river miles above the confluence of the West Branch and South Branch Lac qui Parle River. During the September 9-10, 2009 sampling event, the water level behind the Dawson Dam was below the spill crest as shown in Figure 2.2. Dissolved oxygen was monitored from the pool (6.68 mg/L 8:42am) and just downstream (7.26mg/L 8:44am).

Figure 2.2 Photo Dawson Dam (tLqP-29.0 WB1.6) September 10, 2009 at 8:40am.

It should be noted that the Dawson dam pictured in Figure 2.2 has now been replaced with a series of rock weir structures (shown in Figure 2.3). Installation of the rock weirs was completed in December 2009 and is likely to have some positive re-aeration effect on this reach of river compared to the original dam configuration. Note that all data being used to build the QUAL2K model was collected before the dam was replaced with the rock weir structures.

Figure 2.3 Photo Dawson Dam (tLqP-29.0 WB1.6) received by email on March 29, 2010.

2.1.2 Judicial Ditch 4

Judicial Ditch 4 originates approximately 1 mile West of County Road 67 west of Dawson. The ditch is contained in a storm sewer in Dawson that daylights to a concrete lined ditch south of Lindon Street east of 1st Street (by the ball fields). At the time of this study, two point sources are permitted to discharge to Judicial Ditch 4 before it joins the West Branch Lac qui Parle River approximately 1.3 miles upstream of the West Branch's confluence with the South Branch and 0.3 miles below the Dawson Dam site. Permitted point sources discharging to JD-4 are the Dawson WWTP (MN0021881) and AGP (MN0040134), both of which have continuous discharges. Each of these point sources was represented explicitly in the modeling effort.

2.1.3 South Branch Lac qui Parle

The South Branch Lac qui Parle River originates in South Dakota. The Minnesota border is 90 river miles upstream of South Branch Lac qui Parle River's confluence with West Branch, which is 29 river miles upstream of the Minnesota River. There is only one permitted point source upstream of Dawson. That source is the City of Canby's stabilization pond, which discharges to Canby Creek approximately 56.5 river miles upstream of the confluence of the West and South Branches. This discharge was not modeled explicitly in this effort.

2.1.4 County Ditch 27

County Ditch 27 originates east of Madison, MN south of State Trunk Hwy 40 and is extends for about 10.5 miles before joining the Lac qui Parle River, 23.4 river miles upstream of the Minnesota River. Two point sources in Madison, MN were explicitly modeled in the modeling effort. The point sources are Madison WWTP (MNG550028) and Madison WTP (MN0061077) both of which are authorized to discharge continuously to County Ditch 27 at the headwaters, approximately 10 miles upstream of the confluence with Lac qui Parle River.

2.1.5 County Ditch 4

County Ditch 4 originates east of Madison, MN North of State Trunk Hwy and is extend for approximately 15 miles before joining the Lac qui Parle River, 12.8 river miles upstream of the Minnesota River. No point sources are permitted to discharge directly to County Ditch 4.

2.1.6 Ten Mile Creek

Ten Mile Creek originates North of Boyd, MN and is extends about 31 miles before it joins the Lac qui Parle River just north of Lac qui Parle, MN, 3.3 river miles upstream of the Minnesota River. Again, there are no permitted point sources discharging to this reach.

3.0 DATA SOURCES

3.1 Weather and Physical Processes

Hourly weather measurements of temperature, cloud conditions, relative humidity and wind speed were downloaded from the National Weather Service (NWS) NOAA Montevideo Airport, Montevideo, MN and input into the model for August 4, 2005 and September 9-10, 2009. Wind speed was adjusted down to calibrate to the in-stream temperatures. Stream canopy coverage and shading was set to 0 percent for all reaches.

The USGS station 05300000 located at Lac qui Parle River Mile 7.5 has a tributary drainage area of 983 square miles (according to USGS.) For Water Year 2009, the annual mean is 178 cfs and the annual mean for Water Years 1910 to 2009 is 161 cfs. For Water Year 2009, the annual runoff is 129,000 acre-ft and the annual runoff for Water Years 1910 to 2009 is 116,400 acre-ft.

Table 3.1 summarizes the daily flows for a period of approximately 3 weeks prior to the two data collection efforts being used for calibration and validation of the DO model. It is apparent from these flow records that while the conditions during the event are similar, the conditions prior to the model events are slightly different, with higher river flows immediately preceding the August 2005 effort.

Table 3.1: USGS daily mean flows at USGS gauge prior to model events.

Date	Mean of Daily Flow (cfs)	Date	Mean of Daily Flow (cfs)
7/14/2005	85	8/19/2009	8.0
7/15/2005	81	8/20/2009	9.7
7/16/2005	77	8/21/2009	12
7/17/2005	75	8/22/2009	10
7/18/2005	65	8/23/2009	10
7/19/2005	57	8/24/2009	18
7/20/2005	57	8/25/2009	16
7/21/2005	54	8/26/2009	14
7/22/2005	46	8/27/2009	13
7/23/2005	41	8/28/2009	9.4
7/24/2005	37	8/29/2009	6.8
7/25/2005	36	8/30/2009	5.3
7/26/2005	38	8/31/2009	5.1
7/27/2005	34	9/1/2009	6.3
7/28/2005	30	9/2/2009	7.6
7/29/2005	28	9/3/2009	7.7
7/30/2005	27	9/4/2009	7.2
7/31/2005	25	9/5/2009	7.4
8/1/2005	22	9/6/2009	7.2
8/2/2005	21	9/7/2009	6.5
8/3/2005	18	9/8/2009	6.7
8/4/2005	17	9/9/2009	8.5
8/5/2005	**14**	**9/10/2009**	**12**

Figure 3.1 shows the daily rainfall data recorded before, during, and after the 8/4/2005 "critical condition" monitoring effort, shown by the vertical shaded bar. During the 14-day period before the event, a total of 0.71 inches of rainfall was recorded, with the maximum daily rainfall depth less than 0.5 inches approximately one week before the monitoring effort. Thirteen-hundredths of an inch rainfall was recorded on 8/4/2005. These rainfall conditions seem unlikely to have generated any significant amounts of surface runoff in the watershed.

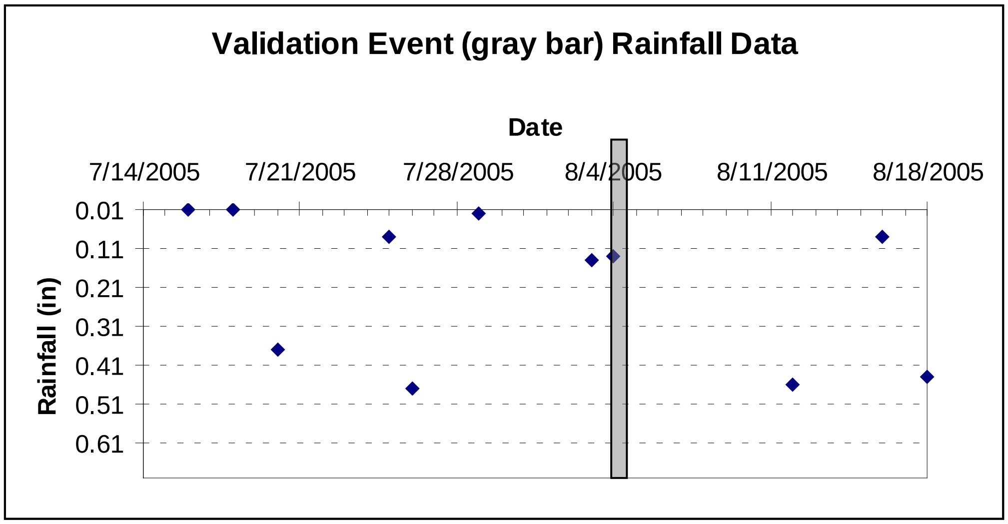


Figure 3.1 Rainfall recorded around the 8/4/2005 event.

No rainfall was recorded during the 14-day period before the 9/9-10/2009 "critical condition" event (shown as a shaded vertical bar), as illustrated in Figure 3.2. A trace amount of rainfall occurred before water quality samples were collected. Again, the rainfall amounts recorded seem unlikely to have generated a significant surface runoff in the watershed.

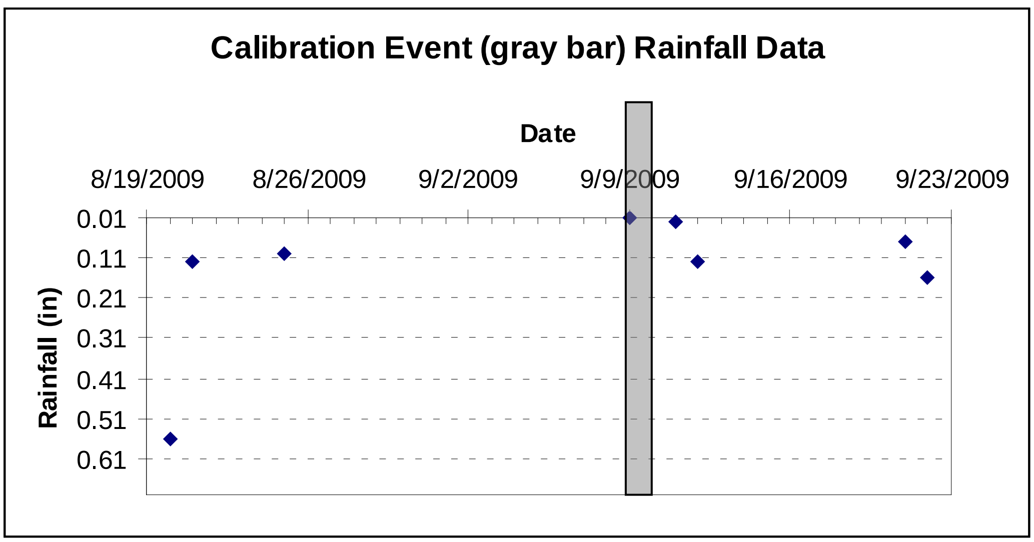


Figure 3.2 Rainfall recorded around the 9/9-10/2009 event.

3.2 2009 Dye Study

A slug of a tracer (Rhodamine WT dye) was injected at four separate points in Lac qui Parle River during the September 9-10, 2009 field survey. Dye injection points and monitoring locations for the September 9-10, 2009 field survey are summarized in Table 3.3 using the following notations in the descriptions; DD# = Dye dump location; and DD#M = Dye monitoring location. Dye samples were collected as grabs by field personnel or ISCO automatic samplers. Fixed stations downstream of the injection point were sampled until the dye cloud passed. The concentration of the dye in each sample was measured using an Aquafluor handheld fluorometer ("Measurement and Computation of Streamflow: Volume 1. Measurement of Stage and Discharge" page 214.) Dye study data was used to determine the time of travel in between stations. Figures 3.4 and 3.5 in a following section (Section 3.4 Water Quality Sampling) show the locations of the time of travel study for the 2009 data collection effort.

Figure 3.3 Photo taken LqP-14.5 Dye Dump #1 September 9, 2009 11:26am.

3.3 Flow Gauging

Historical streamflow gauging data from intensive field efforts undertaken on July 28, 1987, August 10, 1987, August 4, 2005, and August 15, 2005 was considered while developing the hydrologic and hydraulic basis for the QUAL2K model for the impaired reach. To supplement this data and support the time of travel measurements described in the previous section, additional instantaneous flow data at multiple sites within the listed reach was collected during the September 9-10, 2009 field data collection effort. Flow was recorded using a SonTek Flow Tracker handheld digital velocity meter with an accuracy of 0.001 cfs. Velocity measurements were taken at 60 percent of the total depth for shallow reaches (less than 2.5 feet deep) and at 20 percent and 80 percent of the total depth for deeper reaches. Horizontal spacing of velocity measurements was set so less than 10 percent of total discharge is accounted for by any single velocity measurement. Flow gauging was conducted at each dye injection and monitoring station. Figures 3.4 and 3.5 in the next section (Section 3.4 Water Quality Sampling) show the locations of the flow gauging points for the 2009 data collection effort. It should be noted that during the 2009 gauging efforts, our gauged flows were less than those reported by the USGS real time data web site as shown in Table 3.2. The USGS real time flow data is provisional, and we sent our gauging information to the USGS to refine the rating curve during low flow.

Table 3.2: USGS flows at USGS gauge compared to 9/9-10/2009 field gauging effort.

Date & Time	Wenck Gauged Flow (cfs)	USGS Flow (cfs)
9/9/2009 17:24	4.1	21
9/10/2009 11:18	1.4	24
9/10/2009 15:05	2.1	24

Table 3.3 uses “Q” notations in the descriptions to document the location of flow gauging (depth, velocity and discharge) data collected. Flow gauging data is presented in the hydraulic calibration section of this memo.

Table 3.3: Model Reach Characteristics.

	Reach	Description	Distance (miles)	Slope (m/m)
Tributary Reaches	1	West Branch Lac qui Parle River (downstream of Dawson Dam)	0.20	0.00004
	2	Judicial Ditch 4 downstream of Storm Culvert upstream of WWTP (PS AGP & Dawson WWTF)	0.33	0.01024
	3	West Branch LqP (downstream of JD4 inflow)	1.30	0.00004
	4	South Branch LqP	0.90	0.00414
Main Stem LqP	5*	LqP River Mile 29.0 (downstream of confluence of SB & WB LqP)	0.90	0.00004
	6*	LqP 28.1 (downstream of PS AMPI inflow)	0.20	0.00728
	7*	LqP River Mile 27.9 (DD3, Q)	0.37	0.00047
	8*	LqP River Mile 27.5 (DD3M)	0.50	0.00047
	9*	LqP River Mile 27.0 (DD3M)	2.17	0.00047
	10*	LqP River Mile 24.86	0.55	0.00183
	11*	LqP River Mile 24.3 (Q)	0.69	0.00061
	12*	LqP River Mile 23.61	0.21	0.00095
Tributary Reach	13	County Ditch 27 near Madison, MN to LqP (PS Madison WWTF & WTP)	10.63	0.00107
Main Stem LqP	14*	LqP River Mile 23.4 (downstream of CD27 inflow)	0.91	0.00095
	15*	LqP River Mile 22.5 (DD2)	0.49	0.00001
	16*	LqP River Mile 22.0 (DD2M, Q)	5.40	0.00066
	17*	LqP River Mile 16.6 (Q)	2.13	0.00049
	18*	LqP River Mile 14.5 (DD1)	0.48	0.00002
	19*	LqP River Mile 14.0 (DD1M, Q)	1.20	0.00017
Tributary	20	County Ditch 4 near Madison, MN to LqP	15.00	0.00097
Main Stem LqP	21*	LqP River Mile 12.8 (downstream of CD4 inflow)	0.60	0.00002
	22*	LqP River Mile 12.2 (DD1M, Q)	4.18	0.00061
	23*	LqP River Mile 8.0 (DD4)	0.52	0.00061
	24*	LqP River Mile 7.5 (USGS, DD4M, Q)	1.80	0.00364
	25*	LqP River Mile 5.7 (DD4M, Q)	2.40	0.00364
Tributary	26	Ten mile Creek to LqP	7.00	0.00195
Main Stem LqP	27	LqP River Mile 3.3 (downstream of Ten mile Creek inflow)	1.75	0.00364
	28	LqP River Mile 1.55	1.55	0.00364

* denotes modeled reach listed for DO (AUDID 07020003-501)
Reach break notations included in descriptions are by River Mile

LqP = Lac qui Parle River; WB = West Branch; JD4 = Judicial Ditch; SB = South Branch
CD27 = County Ditch 27; CD4 = County Ditch 4
PS = Point Source; WWTF = Wastewater Treatment Facility; WTP = Water Treatment Plant
USGS = United States Geological Survey Monitoring Station

3.4 Water Quality Sampling

This section provides an overview of the water quality data used to develop the QUAL2K model. Figure 3.4 shows some of the sampling locations within and outside the listed reach and referred to in the following narrative Figure 3.5 shows a close-up of key sampling locations in the Dawson area at the upper end of the listed reach.

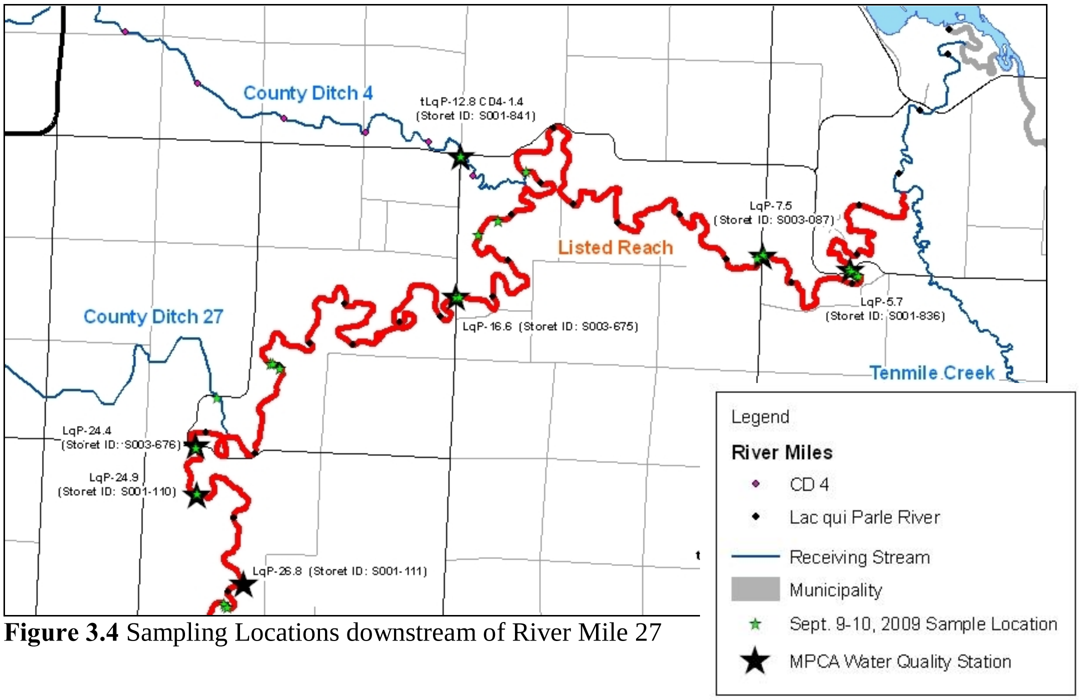


Figure 3.4 Sampling Locations downstream of River Mile 27

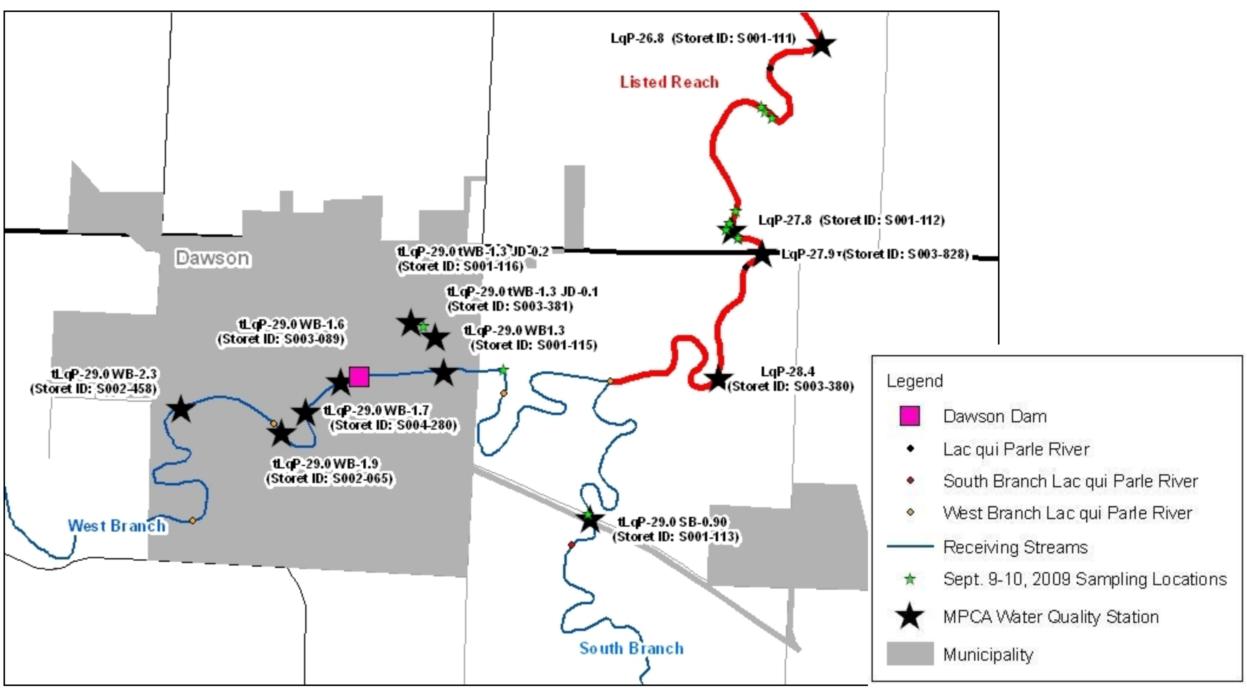


Figure 3.5 Detail of Sampling Locations in and near Dawson, MN.

3.4.1 August 4, 2005

Water quality data from three key monitoring efforts were used to develop the calibration and validation models for the DO-impaired reach. Table 3.4 summarizes the type and location of water quality data collected during the August 4, 2005 field effort when the listed reach was actually recorded as being in a violating condition with respect to the DO standard of 5 mg/l. The locations at which data was collected are described by modeling reach for the current effort as well as by river mile, MPCA's STOrage and RETrieval (STORET) identification number, and the monitoring station descriptor used by Booze Allan Hamilton, the firm that collected the 2005 data. This data set provides the primary source of synoptic field data (ph, DO, temperature, transparency, algal coverage, etc.)) and chemical water quality data (including total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_2-N), 5-day carbonaceous biological oxygen demand ($CBOD_{5\text{-day}}$), total phosphorus (TP), and ortho-phosphorus/soluble reactive phosphorus) during critical conditions to support the development of this model. Table 2 provided in Appendix E of the TMDL report summarizes the data collected. The QUAL2K water quality modeling Section 5.0 figures display the data longitudinally.

Table 3.4: August 4, 2005 monitoring locations considered in calibration.

Reach	Reach Start Monitoring Location ID	Description	Data Collected
2	tLqP-29.0 WB1.3C JD4 (us WWTP) (BAHID: LS07; Storet ID: S003-381)	Judicial Ditch 4; South of Gravel Road	Grab, Field
3	tLqP-29.0 WB-1.1 (BAHID: LS05; Storet ID: S001-114)	West Branch LqP; End of Private Road in SW Qtr of NW Qtr of S 22 (T117N/R43W)	Grab, Field
4	tLqP-29.0 SB-0.90 (BAHID: LS11; Storet ID: S001-113)	South Branch LqP; Dawson's Diagonal Road	Q, Grab, Field
6*	LqP-28.4 (BAHID: LS04; Storet ID: S003-380)	Main Stem LqP; Backyard of Ervin Kostad Property's canoe landing	Grab, Field, Chla
7*	LqP-27.8 (BAHID: LS03; Storet ID: S001-112)	Main Stem LqP; End of private drive SE Qtr of SE Qtr of S15 (T117N/R43W) north of US Hwy 212 1-mile east of Dawson	Grab, Field, Chla
10*	LqP-24.4 (BAHID: LS18; Storet ID: S003-676)	Main Stem LqP; CSAH 16	Grab, Field, Chla
13	tLqP-23.4 CD27-0.4 (BAHID: LS02; Storet ID: S003-379)	County Ditch 27; CSAH 39	Q, Grab, Field, Chla
17*	LqP-16.6 (BAHID: LS17; Storet ID: S003-675)	Main Stem LqP; CSAH 27	Grab, Field, Chla
20	tLqP-12.8 CD4-1.4 (BAHID: LS16; Storet ID: S001-841)	County Ditch 4; CR 20 & CR 27	Grab, Field, Chla
24*	LqP-7.5 (BAHID: LS01; Storet ID: S003-087)	Main Stem LqP; CSAH31, USGS	Q_{USGS}, Grab, Field, Chla

Q = Flow gauged.

Grab = Water quality grab sample collected and lab analyzed for typical pollutants (total kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_2-N), 5-day carbonaceous biological oxygen demand ($CBOD_{5\text{-day}}$), total phosphorus (TP), and ortho-phosphorus (soluble reactive phosphorus).

Chla = Water quality grab sample collected and lab analyzed for chlorophyll-*a*.

Field = In-field measurement of temperature, pH, and dissolved oxygen (DO, t-tube, depth estimate, algae growth percentage, vegetation percentage).

BAHID Booze Allen Hamilton data collection site identification.

Storet Id MPCA's STOrage and RETrieval database of sampling data.

3.4.2 August 7-9, 2007

The second data set used was from the August 7-9, 2007 continuous DO monitoring by MPCA. The continuous DO data provided by this effort is important because it documents a pronounced diurnal variation in DO (as well as ph and water temperature) both in the listed reach of the Lac qui Parle River as well as upstream of the listed reach. The information was essential in credibly representing diurnal swings in DO and several other parameters at the modeling boundaries as well as in the impaired reach itself, as will be explained later in this memo. It should be noted that this effort was conducted during a summer low flow period, but did not capture any violations of the 5 mg/l standard at any time in the 2-day continuous monitoring. Table 3.5 summarizes the location of the data collected using the same format as Table 3.4. The QUAL2K water quality modeling Section 5.0 figures display the data longitudinally.

Table 3.5: August 7-9, 2007 monitoring locations considered in calibration.

Reach	Reach Start Monitoring Location ID	Description	Data Collected
n/a	tLqP-29.0 WB-8.9 (BAHID: LS15; Storet ID: S003-674)	West Branch LqP; CSAH21, also 155th Street	DO
3	tLqP-29.0 WB-1.2 (Storet ID: S004-554)	West Branch LqP; off the Right Angle Turn on SE 3rd Street	DO
4	tLqP-29.0 SB-0.90 (BAHID: LS11; Storet ID: S001-113)	South Branch LqP; Dawson's Diagonal Road	DO
10*	LqP-24.4 (BAHID: LS18; Storet ID: S003-676)	Main Stem LqP; CSAH 16	DO
17*	LqP-16.6 (BAHID: LS17; Storet ID: S003-675)	Main Stem LqP; CSAH 27	DO
24*	LqP-7.5 (BAHID: LS01; Storet ID: S003-087)	Main Stem LqP; CSAH31, USGS	DO

DO = Data sondes deployed to collect continuous measurements of dissolved oxygen, temperature, pH and conductivity.

3.4.3 September 9-10, 2009

Finally, field water quality data were collected in conjunction with the time of travel dye study and streamflow measurements during the September 9-10, 2009 monitoring effort under Phase 1 of this project. As was mentioned previously, this field effort was undertaken largely to fill critical data needs to build the hydrologic/hydraulic basis for the model. However, field parameters (DO, ph, water temperature, and specific conductivity) were also measured using a data sonde (YSI Model 6920 V2). Multiple data points were recorded at each sampling location while wading from right bank to left bank and upstream and downstream of the flow gauging location. Table 3.6 summarizes the DO statistics for the monitoring effort. Again, there were no DO readings below the 5 mg/l standard recorded within the listed reach during this data collection effort. Table 1 provided in Appendix E of the TMDL report summarizes the data collected. The QUAL2K water quality modeling Section 5.0 figures display the data longitudinally.

Table 3.6: September 9-10, 2009 DO data considered in calibration.

	River Mile (RM)	Count	Average	Maximum	Minimum
West Branch Lac qui Parle River	tLqP-29.0 WB-1.32	1	7.26	---	---
West Branch Lac qui Parle River	tLqP-29.0 WB-1.10	11	7.08	11.26	3.90
Lac qui Parle River	27.90	5	12.21	12.59	11.61
Lac qui Parle River	27.03	6	10.60	11.45	10.06
Lac qui Parle River	24.30	7	12.09	12.17	12.04
Lac qui Parle River	22.00	16	8.14	9.36	6.33
Lac qui Parle River	16.60	6	9.02	9.61	9.02
Lac qui Parle River	14.48	3	7.33	7.40	7.33
Lac qui Parle River	14.00	14	6.75	11.24	6.75
Lac qui Parle River	12.20	5	6.94	7.04	6.94
Lac qui Parle River	7.50	16	10.27	12.01	10.27
Lac qui Parle River	5.70	5	9.56	11.60	9.56
Judicial Ditch 4	tLqP-29.0 tWB-1.3 JD 0.20	1	4.78	---	---
South Branch Lac qui Parle River	tLqP-29.0 SB-0.87	4	10.14	11.72	10.14
County Ditch 27	tLqP-23.4 CD 0.40	2	9.23	9.23	9.23
County Ditch 4	tLqP-12.8 CD 1.40	1	3.61	---	---

3.5 Conversion of 5-day CBOD to Ultimate CBOD

Some of the LQPYB water quality samples were analyzed for 5-day CBOD. The 5-day CBOD, oxygen demand exerted after 5 days, is the common laboratory measurement of CBOD. Small subsets of samples were analyzed for both 5-day CBOD and 20-day CBOD. 20-day CBOD is assumed representative of the Ultimate CBOD (UCBOD). The QUAL2K model requires that all CBOD be entered into the model as UCBOD. By using a ratio of 5-day CBOD to UCBOD all the 5-day CBOD samples were converted to UCBOD.

3.5.1 Groundwater and Riverine Ratios

All the groundwater and in-stream CBOD values used in the QUAL2K model were adjusted using the 5-day CBOD to UCBOD ratio of 0.407. This is the average of data available. The Lac qui Parle River was sampled twice for CBOD and the resulting ratios were 0.382 and 0.432.

3.5.2 Wastewater Ratios

All the NPDES permitted point sources CBOD values used in the QUAL2K model were adjusted using the 5-day CBOD to UCBOD ratio of 0.3085. Dawson WWTP was sampled twice for

CBOD and the resulting ratios were 0.383 and 0.234. These values are in the range expected, since the ratio of 0.39 is based on (15) effluent wastewater samples from WWTFs of similar sizes as Dawson's WWTF.

4.0 HYDRAULIC CALIBRATION

Modeled hydraulic inputs were derived from the flow gauging data. Total discharge was calibrated prior to calibrating travel time. All hydraulic inputs and calibration adjustments are described in the following sections.

4.1 Hydraulic Rating Curves

QUAL2K hydraulics may be modeled using power function rating curves, weirs (dam/drop structures) or Manning's equations. Hydraulics for all Lac qui Parle River reaches were represented using power function rating curves based on flow gauging data. The rating curve option relates mean velocity and depth to flow in each reach. QUAL2K uses coefficients and exponents (a, b, c, d) to define reach hydraulics for depth and velocity rating curves, as follows:

- Velocity (m/sec) = $a\ Q^b$
- Depth (m) = $c\ Q^d + e$

in which Q is flow in cubic meters per second. It is assumed that at zero depth there is zero flow, thus the "e" is equal to zero. Gauging stations with similar channel dimensions and flow characteristics were combined in one rating curve to provide more robust velocity/depth versus flow relationships. Applying the principals of hydraulic geometry (Leopold and Maddock, 1953), there is one additional power function that defines channel width:

- Width (m) = $f\ Q^g$

Because the width, depth and velocity are a function of discharge, the following rules apply to the coefficients and exponents of these power functions. The sum of the exponents equal one ($b + d + g = 1.0$), and the product of the coefficients equal one ($a \times c \times f = 1.0$). The representative hydraulic rating curves for each reach were selected based on proximity to gauging stations and typical channel dimensions throughout the reach. The hydraulic gauging data, hydraulic coefficients and exponents for each QUAL2K reach were entered into the model. Figures 4.1 and 4.2 show the final values used compared to flow gauging data and model runs simulating the August 4, 2005 and September 9-10, 2009 events.

4.2 Flow Calibration

The West and South Branches of the Lac qui Parle River were monitored. The monitored changes in flow between gauging stations were built in to the model as diffuse inflows or abstractions attributed to either groundwater or diffuse source inflows.

4.2.1 Diffuse Source Flow

Diffuse source flow is assumed to be the same for both the calibration and validation events (Table 4.1). This assumption is based on the USGS daily mean flows being similar for both events (14 cfs vs. 12 cfs in Table 3.1) and the judgment that precipitation directly preceding the events produces little, if any, runoff. However, based on the USGS daily mean flows prior to the events, the diffuse loading of the calibration event (August 4, 2005) may be an over estimate of the diffuse loading of the validation event (September 9-10, 2009). Figure 4.1 presents QUAL2K estimates of diffuse inflows for the 2005 and 2009 monitored events.

Table 4.1 QUAL2K diffuse source inflows.

	Location upstream (RM)	Location downstream (RM)	8/4/2005 In/outflow (cfs/RM)	9/9/2009 In/outflow (cfs/RM)
West Branch Lac qui Parle River to Lac qui Parle River (inflow of tributary Ten Mile Creek)	tLqP-29.0 WB-1.50	3.30	0.29	0.29
County Ditch 27	tLqP-23.4 CD 10.63	tLqP-23.4 CD 0.40	0.60	0.60
County Ditch 4	tLqP-12.8 CD 15.00	tLqP-12.8 CD 0.00	0.60	0.60

4.2.2 Groundwater Flow

Groundwater is represented as a diffuse source in the model. Past field reconnaissance of the borrow-pits and quarries that are much deeper than the stream bed found that no water was present. Groundwater is modeled as an inflow (positive value) and outflow (negative value) in the model. The groundwater varies between calibration and validation events, as shown in Table 4.2.

Table 4.2 QUAL2K groundwater inflows and outflows.

	Location upstream (RM)	Location downstream (RM)	8/4/2005 In/outflow (cfs/RM)	9/9/2009 In/outflow (cfs/RM)
West Branch Lac qui Parle River	tLqP-29.0 WB-1.30	tLqP-29.0 WB-1.10	-10.80	-4.76
Lac qui Parle River	**29.00**	27.90	0.00	0.78
Lac qui Parle River	27.90	24.30	-0.80	-0.52
Lac qui Parle River	24.30	22.00	0.00	-0.28
Lac qui Parle River	22.00	16.60	-0.80	-0.39
Lac qui Parle River	16.60	14.06	0.10	0.40
Lac qui Parle River	12.80	12.20	0.10	1.44
Lac qui Parle River	12.20	7.50	-0.80	-1.11
Lac qui Parle River	7.50	5.70	0.10	0.05
County Ditch 27	tLqP-23.4 CD 10.63	tLqP-23.4 CD 0.40	-1.00	-0.74
County Ditch 4	tLqP-12.8 CD 15.00	tLqP-12.8 CD 0.00	-0.50	-0.59

During the September 9-10, 2009 event, a groundwater seep was observed at the USGS site off CR31 near a section of river bank that had recently failed slumping sediment toward the river. We took this observation as an indication of substantial groundwater flow in this section.

4.2.3 Flow Calibration

Figures 4.1 and 4.2 show the monitored discharge compared to model predicted discharge (blue dashed line) for the August 2, 2005 event as well as the September 9-10, 2009 event after the diffuse source flow and groundwater flow were incorporated into the model. The QUAL2K model results were calibrated to depth and velocity measurements on August 2, 2005 event as well as the September 9-10, 2009 event.

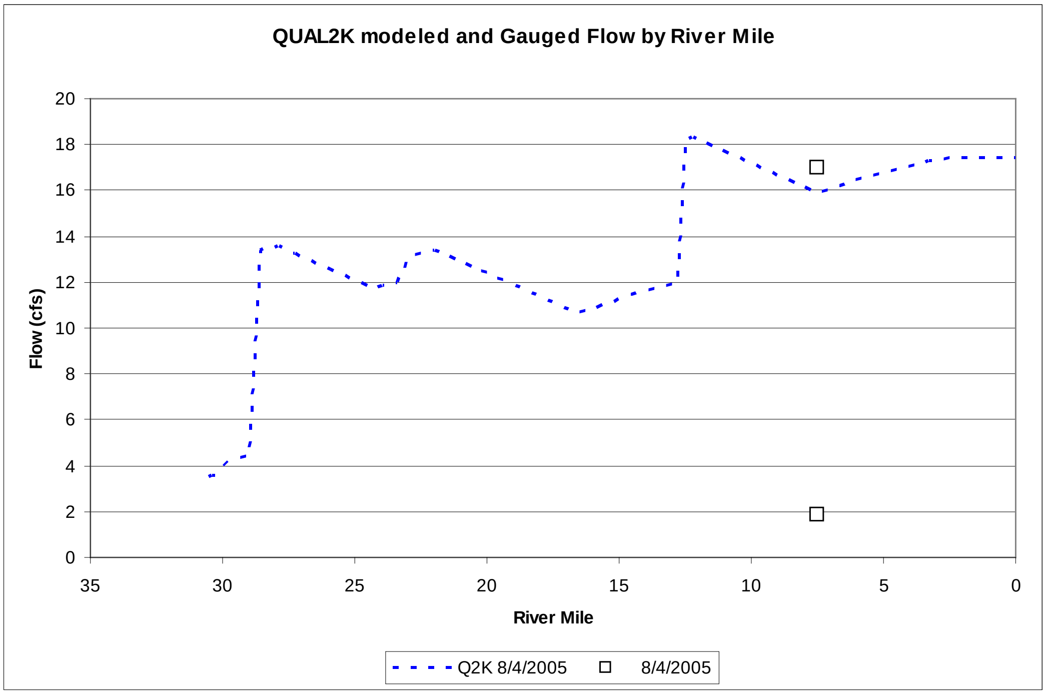


Figure 4.1: Final Lac qui Parle River flow calibration with diffuse inflows/abstractions. Note the USGS discharge was recorded to be 17cfs. Flow value 2cfs is theoretical based on ratio of USGS flow to gauged flow observed during 2009 gauging efforts (Section 3.2).

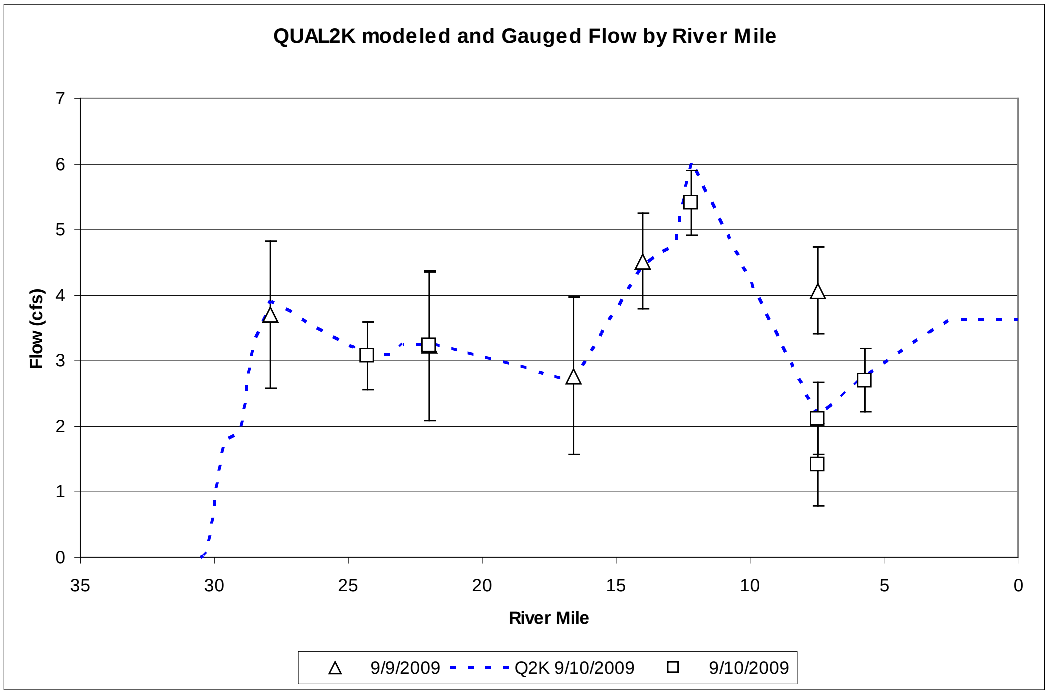


Figure 4.2: Final Lac qui Parle River flow validation with diffuse inflows/abstractions. Error bars on observed measurements represent estimated uncertainty of the Flow-Tracker field measurement. Note the USGS discharge recorded to be 21-24 cfs was not considered to be accurate. The flows shown at river mile 7.5 are the discharges gauged by Wenck.

4.3 Time of Travel Calibration

With total flow calibrated, rating curve coefficients and exponents were reviewed to determine if they needed adjustment to meet travel times calculated during the dye study portion of the synoptic survey. Observed travel times support the hydraulic rating curves (Figure 4.3). No major adjustments were made to the hydraulic parameters to calibrate to the time of travel data. Note that the hydraulic parameters assigned were a better fit to the September 9, 2009 data collected during the 2009 flow gauging efforts.

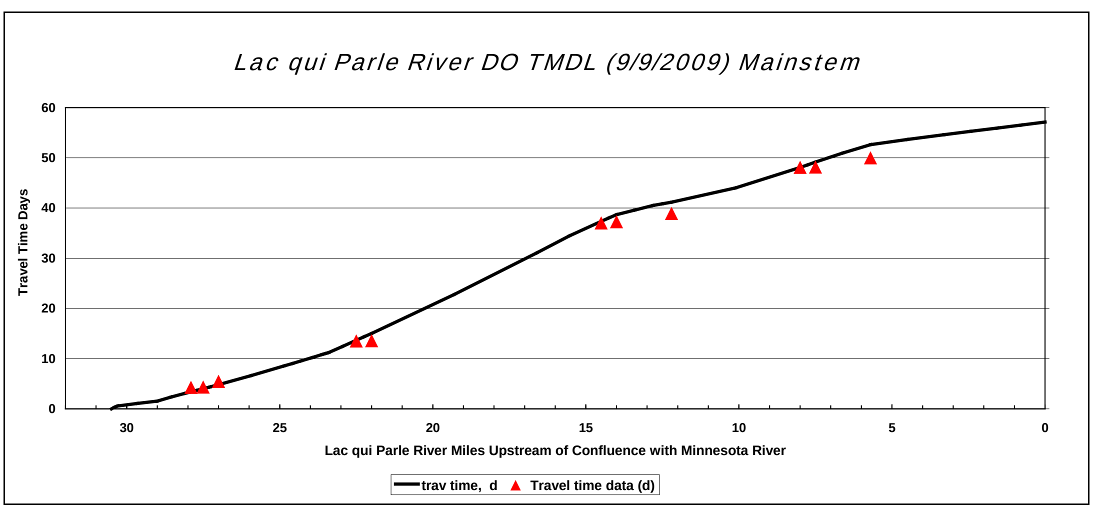


Figure 4.3: Lac qui Parle River time of travel calibration.

5.0 WATER QUALITY CALIBRATION

All water quality model inputs were derived from data collected during the August 4, 2005 survey. The QUAL2K model was set up to simulate temperature, pH, flow, velocity, depth, organic nitrogen (ON), ammonia nitrogen (NH_3-N), nitrate/nitrite nitrogen (NO_2/ NO_3-N), ultimate carbonaceous oxygen demand (UCBOD), DO, sediment oxygen demand (SOD), total phosphorus (TP), chlorophyll-*a*. All model changes to global and reach specific kinetic rates to calibrate water quality are discussed in this section. The model's water quality was calibrated using the August 4, 2005 conditions and validated using the September 9-10, 2009 conditions. This is the opposite of the sequence typically used in calibrating/validating the hydrologic aspects of the model because of the lack of longitudinal hydrologic data available for the 2005 event. It is preferred that detailed longitudinal hydraulic data and detailed water quality data are from the same event selected as the calibration event. The water quality data and QUAL2K model files will be provided in Appendix E of the TMDL report. The QUAL2K model file (Appendix E_LowDO\01_Q2K_Calibration\ 20050804_LqP_015.xls) house the modeled water quality model inputs.

5.1 Boundary Conditions

5.1.1 Tributary Headwaters

The tributary headwater conditions were defined using monitoring data for the calibration event. Diurnal DO and pH were applied to the boundary conditions.

5.1.1.1 Diurnal Oxygen

Diurnal DO was applied to the boundary conditions using the continuous DO data monitored between August 7-9, 2007 by the MPCA. This data shows that there is a pronounced diurnal variation in DO in portions of the Lac qui Parle River both immediately upstream of and within the listed reach. The diurnal DO was shifted up or down to reflect the August 4, 2005 DO grab samples taking into account the time of day the DO sample was collected.

5.1.1.2 Diurnal pH

Diurnal pH was applied to the boundary conditions using the continuous pH data was monitored between August 7-9, 2007 by the MPCA. The diurnal pH was shifted up or down to reflect the August 4, 2005 pH grab samples taking into account the time of day the pH sample was collected.

5.2 Groundwater

When groundwater is an outflow, the water is removed at the model-predicted in-stream concentrations. When the groundwater is an inflow, the water quality was defined as shown in Table 5.1. Table 5.1 is based on the MPCA report "Baseline Water Quality of Minnesota's

Principal Aquifers: Southwest Region" dated June 1998. The quaternary water table aquifer data for Lac qui Parle County, as well as the mean of the Southwest region (Table A.11 in that report) was used to define groundwater inflows.

Table 5.1 QUAL2K groundwater inflow water quality.

Water Quality Parameter [units]	Modeled Value for inflows
Temperature [C]	10.1
Specific Conductivity [μmhos]	943
Inorganic Suspended Solids [mgD/L]	75.5
Dissolved Oxygen [mg/L]	0.29
Ultimate CBOD [mgO_2/L]	0.02
Organic Nitrogen [μgN/L]	0.01
Ammonia Nitrogen [μgN/L]	0.2
Nitrate Nitrogen [μgN/L]	200
Organic Phosphorus [μgP/L]	43
Inorganic Phosphorus [μgP/L]	20
Phytoplankton [μg/L]	0
Detritus [mgD/L]	0
Alkalinity [$mgCaCO_3$/L]	343
pH [Standard Units]	6.94

5.3 Point Sources

The following sections describe the NPDES permitted treatment facilities of interest in terms of permitted water quality parameters modeled using QUAL2K. Treatment facilities requiring NPDES/SDS permits are considered in compliance with the provisions of this TMDL.

5.3.1 Dawson Wastewater Treatment Facility (WWTF)

Dawson WWTF discharges to Judicial Ditch 4 (tLqP-29.0 tWB-1.3 JD4-0.1), which is upstream of the listed reach. According to the NPDES/SDS permit MN0021881 issued September 4, 2007, Dawson WWTF has a permitted annual average flow of 0.278 MGD. Dissolved oxygen is permitted at 7 mg/L as a calendar monthly minimum. Five-day BOD is permitted at 5 mg/L calendar month average (UCBOD of 17.2 mg/L). Ammonia is permitted seasonally using calendar monthly averages for Dec-Mar (7.7 μg/L), Apr-May (8.6 μg/L), Jun-Sep (1.0 μg/L), Oct-Nov (2.4 μg/L). Total Phosphorus is not to exceed 817.2 kilograms TP per year (1797.84 TP pounds per year). Based on 365 days, that is equivalent to a daily average of 4.9 pounds TP per day. If the facility were to exceed the annual mass limit, the permit would be changed to a 1 mg/L annual average phosphorus limit. This would cause the facility to be upgraded to a Class A Facility. This facility's permit expires August 31, 2012.

5.3.2 Dawson Ag Processing (AGP) facility

Dawson AGP discharges to Judicial Ditch 4 (tLqP-29.0 tWB-1.3 JD4-1.3), which is upstream of the listed reach. According to the NPDES/SDS permit MN0040134 issued March 9, 2004, AGP has a permitted design flow of 1.548 MGD. Temperature is permitted at 100 degrees Fahrenheit (37.8 degrees Celsius). Five-day BOD is permitted at 7 mg/L (20 degrees Celsius) (UCBOD of 24.1 mg/L). This facility's permit expired July 31, 2008. At the time of this study the revised permit had not been issued.

5.3.3 Dawson Associated Milk Producers, Inc. (AMPI)

Dawson AMPI discharges to the listed reach (LqP-28.1). According to the NPDES/SDS permit MN0048968 issued November 12, 2002 and conversations with MPCA, Dawson AMPI facility discharges process wastewater and noncontact cooling water to stabilization ponds. The primary stabilization pond is 19-acres (northern most pond) and the secondary stabilization pond is 15-acres (southern most pond). The City of Dawson's composting site is located on the east side of the primary pond. The stabilization pond discharge is controlled by slide gate and is limited to 6-inches per day maximum discharge rate of 2.44 MGD. The acceptable period of discharge is seasonal (between April 1 through June 15 and September 15 through December 15). The stabilization ponds 5-day BOD is permitted at 25 mg/L calendar month average (UCBOD of 86.1 mg/L) and daily maximum of 50 mg/L (UCBOD of 172.1 mg/L). Total phosphorus is permitted as 1 mg/L annual average phosphorus limit. Discharge leaves the stabilization ponds and travels 5,760 feet (1.09 miles) to the outfall (SD001). The speed of water from discharge point is controlled by the sand filter (3.1 fps). This facility's permit expired September 30, 2007. As of 2009, AMPI had requested permit changes. At the time of this study the revised permit had not been issued.

5.3.4 Madison WWTF

Madison WWTF discharges to County Ditch 27 (tLqP-23.4 CD27-15.0), which is upstream of the listed reach. According to the NPDES/SDS permit MNG550028 issued May 15, 2007, Madison WWTF has a permitted average wet weather design flow of 0.48 MGD. Five-day BOD is permitted at 15 mg/L calendar month average (UCBOD of 51.6 mg/L). This facility's permit expired April 30, 2010. A Phosphorus Management Plan (PMP) is to be submitted to the MPCA 180 days prior to permit expiration. At the time of this study the revised permit had not been issued.

5.3.5 Madison WTP

Madison WTP discharges to County Ditch 27 (tLqP-23.4 CD27-15.0), which is upstream of the listed reach. According to the NPDES/SDS permit MN0061077 issued May 12, 2008, Madison WTP has a permitted average design flow of 0.070 MGD. Total phosphorus is reported in the DMRs as calendar year to date. This facility's permit expires April 30, 2013.

5.4 Rates, Kinetics and Coefficients

5.4.1 Reaeration Formula

Reaeration in QUAL2K may be prescribed by the user or calculated using one of eight hydraulic-based reaeration formulas built into the model. The O'Connor-Dobbins reaeration model was selected for Lac qui Parle River because it is the most appropriate to calculate reaeration given the streams velocities and depths. The O'Connor-Dobbins reaeration model formula is shown below:

$$K_{ah}(20) = 3.93(U^{0.5}/H^{1.5})$$

Where:
K_a = reaeration rate coefficient at 20°C (base e, day $^{-1}$)
U = mean water velocity (m/s)
H = mean water depth (m)

Flow velocity and water depth are the variables used to calculate reaeration in each reach. These variables were measured in the field at each monitoring station during flow gauging and represented in the model using hydraulic rating curves.

The calibration and validation model predicted reaeration for Lac qui Parle River is between 4.5 and 0.5, within published ranges for similar streams.

5.4.2 General Kinetic Rate Adjustments

Kinetic rates were adjusted from model default values in order to meet longitudinal changes in observed water quality data. The kinetic rates in Table 5.2 were adjusted from the default values within the range of published values. These parameters were not changed between the calibration and validation events.

Table 5.2 QUAL2K kinetic rates adjusted from model default values.

Kinetic rate	Calibrated	Default	Published Range
$CBOD_u$ oxidation rate (day^{-1})	0.02	0.1	0.02-3.4
Reaeration Model Reaeration, K_a (day^{-1})	O'Connor-Dobbins K_a = 0.5 - 4.5	User specified	Most appropriate for stream velocities 0.5 to 1.5 feet per second K_a = 0.0-100
Organic-N Hydrolysis (day^{-1}) *The release of ammonia due to decay of organic nitrogen*	0.07	0.2	0.02-0.4
Organic-N Settling (m/d)	0.02	0.1	0.001-0.1 [a]
Ammonium Nitrification (day^{-1})	2.4	1	0.10-1.00 0.5 – 9.0 (Koltz, 1982) 3.1 – 6.2 (Wezernak et al., 1968)
Nitrate Denitrification (day^{-1})	1	0	0.20-2.0

Kinetic rate	Calibrated	Default	Published Range
Organic-P Hydrolysis (day^{-1}) *The release of phosphate due to decay of organic phosphorus*	0.8	0.2	0.01-0.7
Organic-P Settling (m/d)	0.1	0.1	0.001-0.1 [a]
Inorganic-P Settling (m/d)	0.25	2	Variable [a]
Phytoplankton Light Model	Smith	Half Saturation	---
Phytoplankton Settling (m/d)	0.5	0.5	0.5-6.0
Bottom Algae Max Growth Rate (day^{-1}) [b]	500	50	0-500
Bottom Algae Respiration Rate (day^{-1}) [b]	0.05	0.1	0-0.5
Bottom Algae Death Rate (day^{-1}) [b]	0.06	0.1	0-0.5
Bottom External nitrogen half sat constant (mg N/L) [b]	15	300	0-300
Bottom External phosphorus half sat constant (mg P/L) [b]	10	100	0-100
Bottom Algae Light Model	Smith	Half Saturation	---
Subsistence quota for nitrogen (mg N /mg A) [b]	2.8	0.72	0.0072-7.2
Subsistence quota for phosphorus (mg P /mg A) [b]	0.4	0.1	0.001-1
Maximum uptake rate for nitrogen (mg N /mg A /day) [b]	2.8	72	1-500
Maximum uptake rate for phosphorus (mg P /mg A /day) [b]	0.4	5	1-500
Detritus (POM) Settling Velocity (m/d) [b]	1	0.1	Variable [a]

Note: [a] influenced by a material's size, shape, and density and the speed of water
[b] Published rates from a QUAL2K model of a periphyton dominated river (Turner et al., 2009)

5.4.3 Periphyton

MPCA staff had identified periphyton as a possible cause of diurnal oxygen fluctuations. The stoichiometry of algae was adjusted from default values (100gD : 40gC : 7200mgN : 1000mgP : 1000mgChlA) to the Chapra and Pelletier (2003) published values (100gD : 40gC : 8500mgN : 1400mgP : 1000mgChlA), since we lack Lac qui Parle River specific values. Bottom algae rates

(Table 5.5) were adjusted to match the rates from a published paper that directly addresses modeling a periphyton dominated river using QUAL2K (Turner et al., 2009). These parameters did not change between the calibration and validation events.

5.4.4 Bottom Algae Coverage

Bottom algae coverage, as monitored by MPCA on August 4, 2005, was applied to the QUAL2K reaches as documented in Table 5.3. The bottom algae coverage was assumed to be the same for both calibration and validation events.

Table 5.3 Bottom Algae coverage.

QUAL2K Reach	Bottom Algae Coverage
7 - 10	30%
1, 3, 13, 20 & 26	25%
5 & 6	20%
4, 11 - 12	10%
21 – 28	7%
2, 14 - 19	0%

During the September 2009 data collection period, few photos were taken or notes taken to characterize the bottom algae. Figure 5.1 shows attached filamentous algae observed near river mile 5.7 (model reach 24).

Figure 5.1 Photo taken LqP-5.7 September 10, 2009 of attached filamentous algae.

The presence of filamentous algae in the stream indicates high levels of nutrients, according to EPA's" Nutrient Criteria Technical Guidance Manual: Rivers and Streams."

5.5 Diffuse Sources

Additional model adjustments were made to $CBOD_5$, chlorophyll-*a* and the forms of nitrogen and phosphorus once global and reach specific kinetic rates were adjusted. The model performed well in predicting loads and concentrations of the primary water quality parameters that affect

DO (Figures 5.4 through 5.7). The diffuse loading of the calibration event (August 4, 2005) is modeled as the same diffuse loading of the validation event (September 9-10, 2009.)

5.5.1 Carbonaceous Oxygen Demand (CBOD)

The old EPA model (QUAL2E) version had one type of CBOD with one decay rate. The modernized version (QUAL2K) now includes two forms of CBOD to represent organic carbon; a slowly oxidizing form (slow CBOD) and a rapidly oxidizing form (fast CBOD). This allows the model to decay CBOD at two decay rates, if deemed necessary. This model enhancement is great for waste streams with slow and fast oxidizing carbon sources. Ultimate CBOD (UCBOD) was defined for all tributary boundary conditions and permitted point sources. In order to calibrate to the in stream concentrations of UCBOD diffuse source loading of detritus was incorporated.

5.5.1.1 Detritus

The modernized version (QUAL2K) now includes detritus particulate organic matter (POM). The detritus was used to represent the September 9-10, 2009 event field observations of detached "clumps" or "mats" floating on the water's surface comprised likely of algae, leaves and plant material (as shown in Figure 5.2).

Figure 5.2 Photo taken LqP-27.9 September 9, 2009.

Detritus settling (1 m/day; Table 1, Turner et al., 2009) and dissolution (0.5/day; Table 1, Turner et al., 2009) rates were selected to create model predicted SOD and represent the longitudinal transport and breakdown of detritus as a source of UCBOD. This QUAL2K model assumes that detritus is 100% UCBOD. Detritus was incorporated as a diffuse source load used to calibrate to longitudinal UCBOD data. Table 5.4 summarizes the calibration and validation event detritus added as a diffuse source to produce the calibration shown in Figures 5.3 and 5.4.

Table 5.4 Diffuse source detritus loading

Diffuse (loads) [lbs/day]	**Detritus [pounds/day]**
tLqP-29.0 WB-1.50 to LqP-29.0 (tributary to listed reach)	92
LqP 29.0 (**Start of Listed Reach**) to LqP 23.4 (conf CD27)	990
LqP 23.4 (conf CD27) to LqP 12.8 (conf CD4)	2,444
LqP 12.8 (conf CD4) to LqP 3.30 (**end of listed reach**, inflow of tributary Ten Mile Creek)	2,629
County Ditch 27 (tributary to listed reach)	660
County Ditch 4 (tributary to listed reach)	1,719

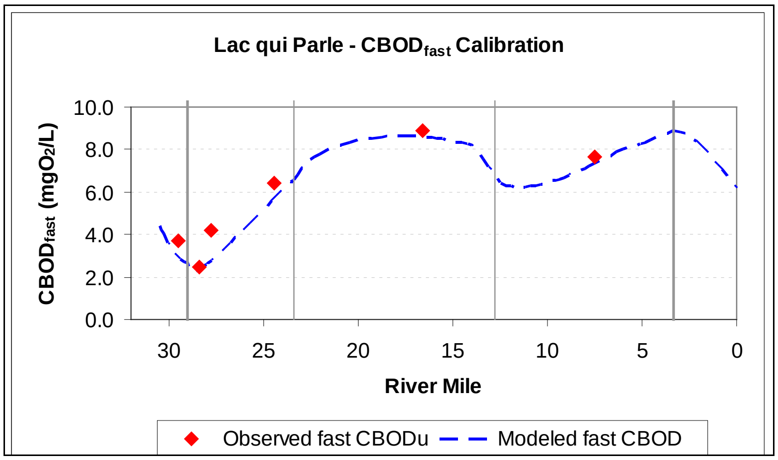


Figure 5.3 Final concentration calibration plot of $CBOD_{ultimate}$

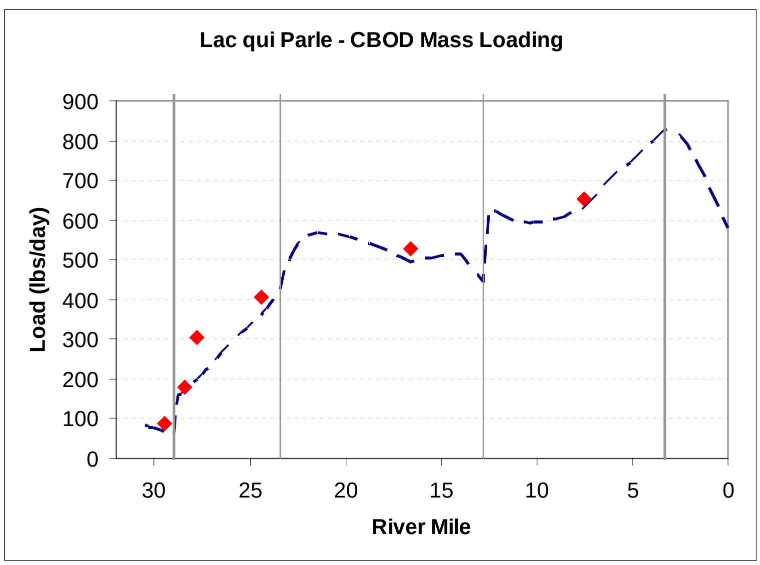


Figure 5.4 Final mass load calibration plot of $CBOD_{ultimate}$

River Mile 29.0 = start of listed reach
River Mile 23.4 = inflow of tributaries County Ditch 27
River Mile 12.8 = inflow of tributaries County Ditch 4
River Mile 3.3 = end of listed reach, inflow of tributary Ten Mile Creek

5.5.2 Nitrogen Series

The nitrogen series is organic nitrogen (ON), ammonia nitrogen (NH_3-N), and nitrate/nitrite nitrogen (NO_2/ NO_3-N). Table 5.5 summarizes the calibration and validation event organic nitrogen and nitrate added as a diffuse source to produce the calibration shown in Figure 5.5.

Table 5.5 Diffuse source organic nitrogen and nitrate loading

Diffuse (loads) [lbs/day]	Organic N [pounds/day]	Ammonia N [pounds/day]	Nitrate N [pounds/day]
tLqP-29.0 WB-1.50 to LqP-29.0 (tributary to listed reach)	8	0	0
LqP 29.0 (**Start of Listed Reach**) to LqP 23.4 (conf CD27)	22	0	2
LqP 23.4 (conf CD27) to LqP 12.8 (conf CD4)	7	0	3
LqP 12.8 (conf CD4) to LqP 3.30 (**end of listed reach**, inflow of tributary Ten Mile Creek)	6	0	3
County Ditch 27 (tributary to listed reach)	43	0	18
County Ditch 4 (tributary to listed reach)	145	131	-

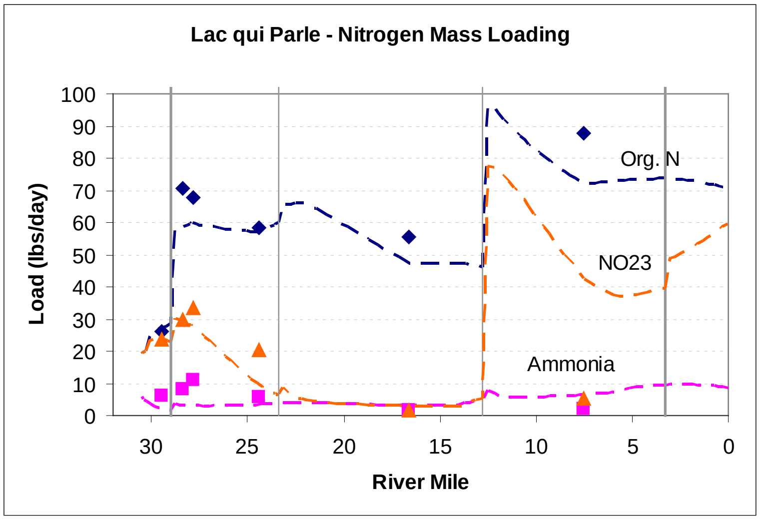


Figure 5.5 Final calibration mass load plot of nitrogen parameters.
River Mile 29.0 = start of listed reach
River Mile 23.4 = inflow of tributaries County Ditch 27
River Mile 12.8 = inflow of tributaries County Ditch 4
River Mile 3.3 = end of listed reach, inflow of tributary Ten Mile Creek

5.5.3 Phosphorus Series

The phosphorus series is total phosphorus (TP) in both organic and inorganic forms. This inorganic form is assumed to be dissolved phosphorus in the form of ortho-phosphorus (SRP). SRP is readily available for uptake by chlorophyll-*a*. Organic phosphorus was estimated by subtracting ortho-phosphorus (SRP) from total phosphorus. Table 5.6 summarizes the calibration and validation event organic phosphorus, inorganic phosphorus (SRP) and phytoplankton (chlorophyll-*a*) added as a diffuse source. Table 5.7 summarizes the SRP flux that was added to various reaches. The combination of these additions produce the calibration shown in Figures 5.6 and 5.7.

Table 5.6 Diffuse source organic phosphorus, inorganic phosphorus, and phytoplankton loading

Diffuse (loads) [lbs/day]	**Organic P [pounds/day]**	**Inorganic P [pounds/day]**	**Phyto plankton [pounds/day]**
tLqP-29.0 WB-1.50 to LqP-29.0 (tributary to listed reach)	0	0	-
LqP 29.0 (**Start of Listed Reach**) to LqP 23.4 (conf CD27)	0	0	-
LqP 23.4 (conf CD27) to LqP 12.8 (conf CD4)	1	0	2
LqP 12.8 (conf CD4) to LqP 3.30 (**end of listed reach**, inflow of tributary Ten Mile Creek)	1	0	4
County Ditch 27 (tributary to listed reach)	1	56	0
County Ditch 4 (tributary to listed reach)	2	41	-

Table 5.7 SRP flux.

Reaches	**SRP mg P /m^2/day**
5-8	80
1, 3, 4, 9-12	49
14-19	40
21-25	30
2, 13, 20, 26-28	0.0

.

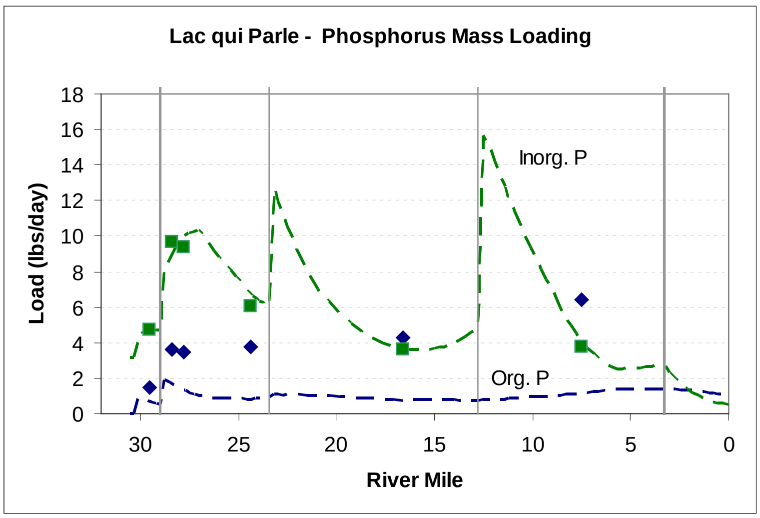


Figure 5.6 Final calibration mass load plot of phosphorus parameters.
River Mile 29.0 = start of listed reach
River Mile 23.4 = inflow of tributaries County Ditch 27
River Mile 12.8 = inflow of tributaries County Ditch 4
River Mile 3.3 = end of listed reach, inflow of tributary Ten Mile Creek

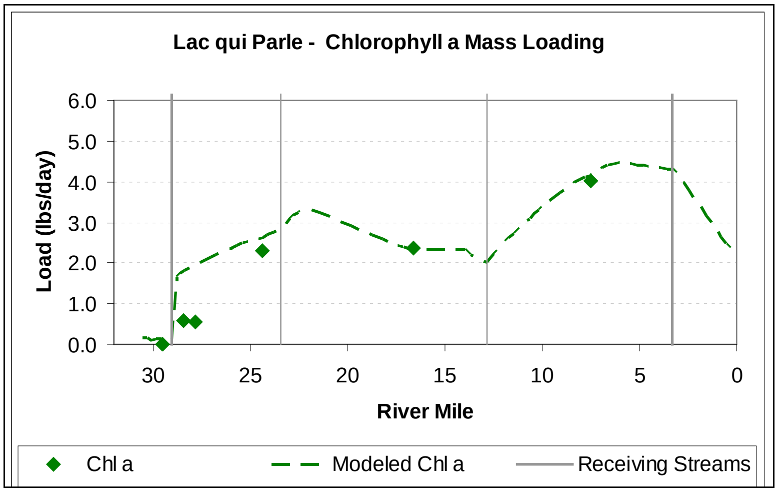


Figure 5.7 Final calibration mass load plot of chlorophyll *a*.

River Mile 29.0 = start of listed reach
River Mile 23.4 = inflow of tributaries County Ditch 27
River Mile 12.8 = inflow of tributaries County Ditch 4
River Mile 3.3 = end of listed reach, inflow of tributary Ten Mile Creek

5.6 Sediment Oxygen Demand

QUAL2K has the ability to simulate sediment–water interactions involving DO and nutrients. Sediment oxygen demand (SOD) is calculated in QUAL2K based on the delivery and breakdown of particulate organic matter from the water column. DO concentrations should be close to calibration once diurnal variability is calibrated and reasonable assumptions have been made in allocating nutrient loads and adjusting kinetic rates. MPCA staff has determined that in portions of the Lac qui Parle system, especially the portions below Dawson, such interactions may play an important role. The August 4, 2005 (calibration event) needed prescribed SOD added to the model to predict the DO. Table 5.8 shows the prescribed SOD added to the specified reaches to achieve calibration of the model. Table 5.9 presents reference ranges for SOD based on Thomanm, et. al. (1987). The model assumes bottom coverage SOD was 100% for all reaches. This may be related to the pre-event rainfall watershed washoff feeding the stream additional detritus from upstream sources that elevated the SOD in the West Branch Lac qui Parle.

Table 5.8 SOD prescribed to each reach that is added to model-predicted SOD under steady state conditions for the calibration event.

Prescribed SOD ($g\ O_2/m^2/day$)	**Reaches**
0	2,4,14-28
1	6-12
4	5
5	1,3
15	13

Notes: Elevated SOD had to be added to Reach 13 (CD27) and Reaches 1, 3 and 5 (West Branch LQP from the Dawson Dam to LqP River mile 28.1 which is just upstream of the AMPI point source discharge location)

Table 5.9 Summary of published SOD

Prescribed SOD ($g\ O_2/m^2/day$)	**Description**
3	Thomann suggests typical value of SOD near an outfall with poor secondary treatment
1.5	Thomann suggests typical value of SOD near an outfall with secondary treatment
0.4	Thomann suggests typical value of SOD near an outfall with Advanced treatment

5.7 Dissolved Oxygen

Figure 5.8 shows the final calibration results for model-predicted and observed DO concentrations. Field grabs of DO were taken in the early morning on August 4, 2005. The model performs well in predicting average daily DO concentrations (in plot as black dashed line) and the diurnal pattern (daily minimum and maximum, shown in plots as blue dashed lines) at the monitoring stations.

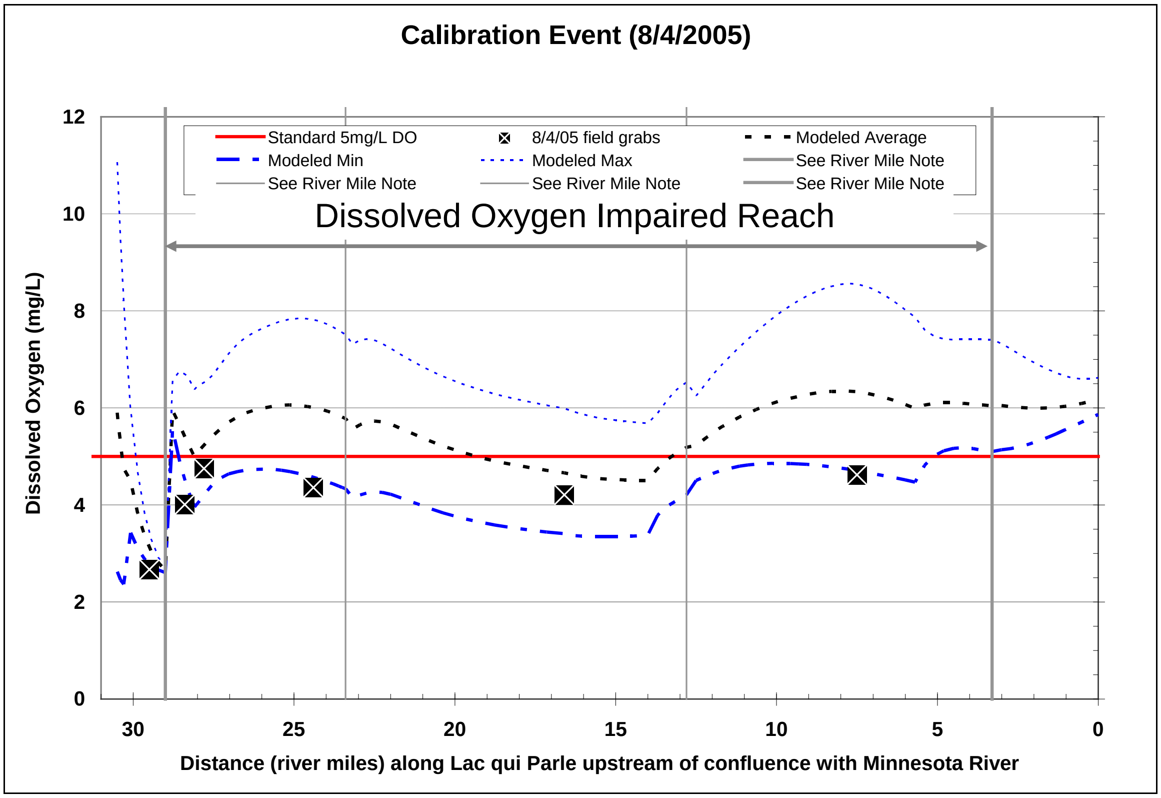


Figure 5.8. Lac qui Parle River calibration dissolved oxygen longitudinal profile (20050804_LqP_015.xls).

River Mile 29.0 = start of listed reach
River Mile 23.4 = inflow of tributaries County Ditch 27
River Mile 12.8 = inflow of tributaries County Ditch 4
River Mile 3.3 = end of listed reach, inflow of tributary Ten Mile Creek

6.0 WATER QUALITY VALIDATION

The calibrated tributary boundary conditions were modified using the limited set of monitoring data for the validation event. The water quality data and QUAL2K model files will be provided in Appendix E of the TMDL report. The QUAL2K model file (Appendix E_LowDO\02_Q2K_Validation\ 20090909_LqP_015.xls) house the modeled water quality model inputs.

6.1 Flow

There is considerably more hydraulic data for the validation event, than the calibration event. The diffuse source flows were not changed (Section 4.2.1), while the groundwater flows were modified (Section 4.2.2). Point source inflows were adjusted using daily monitoring reports (DMR) data to reflect the validation event conditions. Figure 4.2 in Section 4.2.2 shows the model predicted flow rates compared to monitoring data. There is a higher confidence in the validation event hydraulics than the calibration event given, the increased number of flow gauging sites on the listed reach.

6.2 Water Quality

The calibrated tributary boundary conditions were modified using September 9-10, 2009 monitoring data. The diurnal DO curves were adjusted to reflect the field grabs collected for the validation event. The diurnal pH for the validation event was assumed the same as the calibration event. Groundwater water quality for the validation event was assumed the same as the calibration event (Section 5.2). Point source water quality was adjusted using daily monitoring reports (DMR) data to reflect the validation event conditions. No changes were made to the calibration reaeration rates (Table 5.2 in Section 5.4.2), periphyton (Section 5.4.3), bottom algae coverage (Section 5.4.4), and diffuse source loading (Section 5.5).

6.3 SOD Modifications

Validation event SOD is model-predicted only. The model uses settling rates of organic materials to create model-predicted SOD. The calibration event's prescribed SOD was removed because the period preceding the validation event didn't indicate occurrence of a runoff event response that could have supplied the river bottom with material contributing to SOD in-excess of the material delivered by defining of the boundary condition. The removal of prescribed SOD also can be interpreted to represent successful implementation of soil conservation improvements in the watershed and improvements as direct result of Dawson WWTF upgrades and low permit discharge limits.

6.4 Dissolved Oxygen

Figure 6.1 shows the validation results for model-predicted and observed DO concentrations. DO statistics from Table 3.4 are plotted longitudinally. The minimum and maximum values shown as a range of DO, the average shown as a black box. No DO samples were collected on the listed reach before 9am. Not all sites were visited multiple times during the sampling period. The model predicted average daily DO concentrations (in plot as black dashed line) and the diurnal pattern (daily minimum and maximum, shown in plots as blue dashed lines). Note that the model predicts very little daily fluctuation in DO and DO below the standard at most locations on the listed reach. The following section discusses other sensitivity considerations that explain what is likely different between the calibration and validation events.

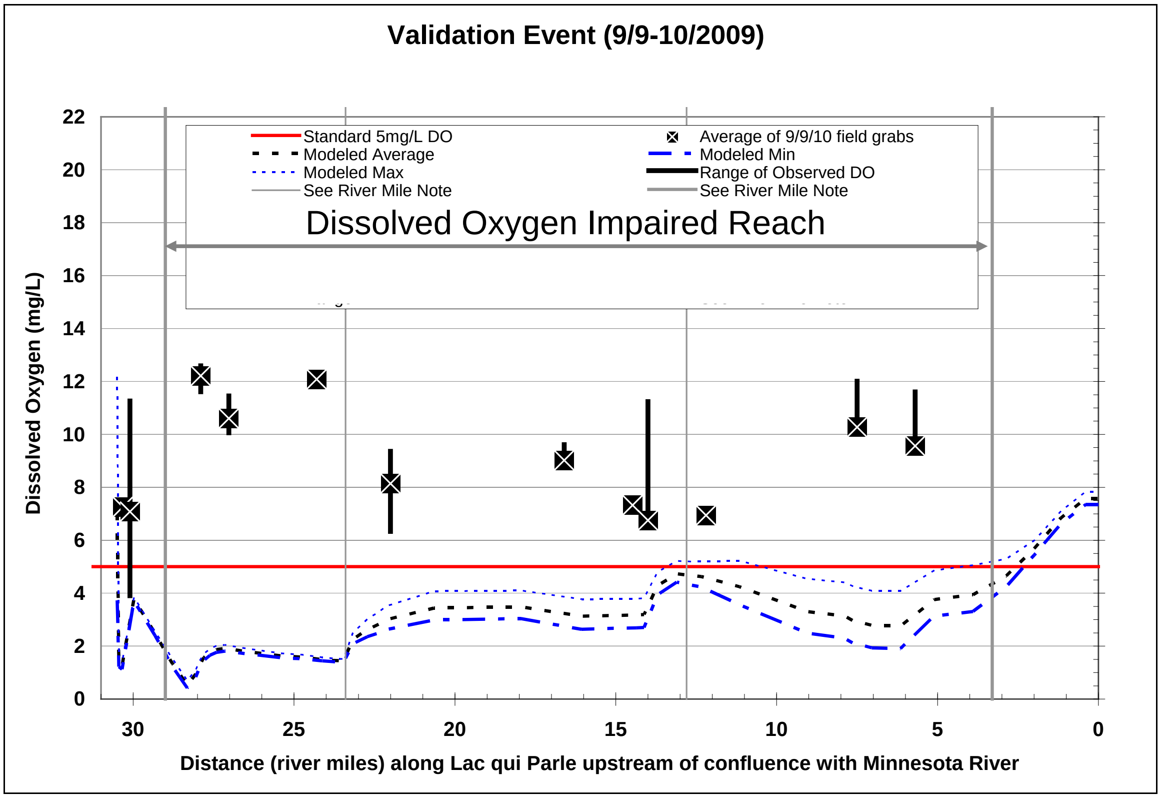


Figure 6.1 Lac qui Parle River validation event dissolved oxygen longitudinal profile (20090909_LqP_015.xls).

River Mile 29.0 = start of listed reach
River Mile 23.4 = inflow of tributaries County Ditch 27
River Mile 12.8 = inflow of tributaries County Ditch 4
River Mile 3.3 = end of listed reach, inflow of tributary Ten Mile Creek

6.5 Other Sensitivity Considerations

The model is predicting lower than observed DO for the validation event, even after the removal of prescribed SOD. As stated before, the diffuse loading of the calibration event (August 4, 2005) may be an over estimate of the diffuse loading for the validation event (September 9-10, 2009,) thus explaining (partially) why the model predicted DO is lower than monitored. The DO data was generally taken after the occurrence of the night-time respiration induced minimum. Even so, the model predicted minimums are close to the early morning monitored values. It is likely that the bottom algae coverage of the August 4, 2005 event is not representative of the validation data collection period. The split between flows considered to be groundwater and diffuse source could influence the validation results. It is likely that the productivity of the September 9-10, 2009 event were greater than that monitored by the MPCA during the 8/7-

9/2007 data collection period. These factors, as well as the lack of water quality data to define the boundary conditions, could explain the model predicting DO lower than that monitored.

Figure 6.2 was created increasing boundary condition (South Branch and West Branch) phytoplankton increased to 500 μg A/L, bottom algae coverage increased to 100%, SRP flux for river miles 29.0 to 27.0 (reaches 5-8) reduced to 49 mg P /m^2/day and increased mass loading of phytoplankton. These changes increase the model predicted range of DO.

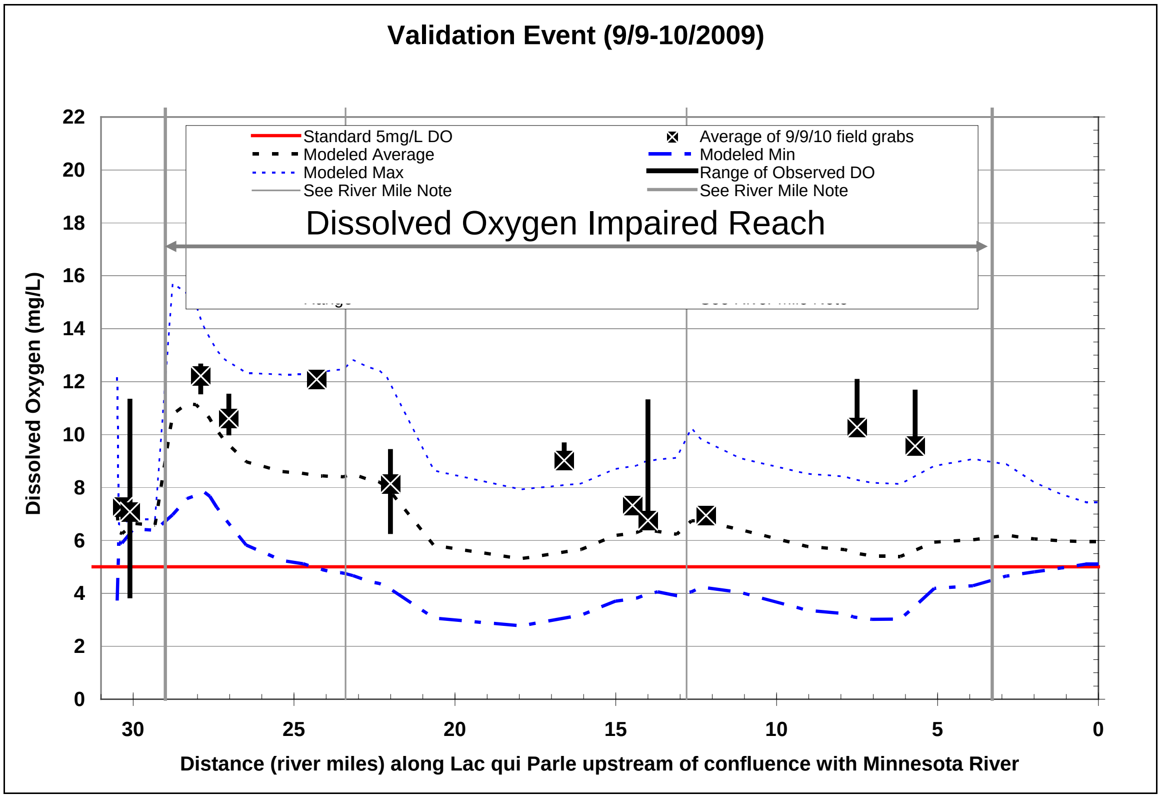


Figure 6.2 Lac qui Parle River validation event dissolved oxygen longitudinal profile (20090909_LqP_019.xls).

River Mile 29.0 = start of listed reach
River Mile 23.4 = inflow of tributaries County Ditch 27
River Mile 12.8 = inflow of tributaries County Ditch 4
River Mile 3.3 = end of listed reach, inflow of tributary Ten Mile Creek

The QUAL2K model file (Appendix E_LowDO\02_Q2K_Validation\ 20090909_LqP_019.xls) house the modeled water quality model inputs.

7.0 SENSITIVITY ANALYSIS

To evaluate the sensitivity of model predicted DO to changes in model variables, kinetic rates and reach specific rates were removed or adjusted by within the published ranges. Table 7.1 summarizes the QUAL2K default value, calibrated value, published range of value, and sensitivity run values adjusted.

Table 7.1 QUAL2K Parameters adjusted during the sensitivity analysis.

Kinetic rate	Sensitivity Run A (High)	Sensitivity Run B (Low)	Calibrated Value	QUAL2K Default Value	Published Range
$CBOD_u$ oxidation rate (day^{-1}) - Represented in model as Fast CBOD	3.4	---	0.02	0.1	0.02-3.4
Reaeration Model Reaeration, K_a (day^{-1})	Add Reach Prescribed Reaeration = 9.0	---	O'Connor-Dobbins K_a = 0.5 - 4.5	User specified	K_a = 0.0-100
Organic-N Hydrolysis (day^{-1}) *The release of ammonia due to decay of organic nitrogen*	0.4	0.02	0.07	0.2	0.02-0.4
Organic-N Settling (m/d)	0.1	0.001	0.02	0.1	0.001-0.1
Ammonium Nitrification (day^{-1})	1	0.01	2.4	1	0.10-1.00
Nitrate Denitrification (day^{-1})	2	0.2	1	0	0.20-2.0
Organic-P Hydrolysis (day^{-1}) *The release of phosphate due to decay of organic phosphorus*	0.7	0.01	0.8	0.2	0.01-0.7
Organic-P Settling (m/d)	---	0.001	0.1	0.1	0.001-0.1 [a]
Inorganic-P Settling (m/d)	---	---	0.25	2	Variable [a]
Phytoplankton Light Model	---	---	Smith	Half Saturation	---
Phytoplankton Settling (m/d)	6	---	0.5	0.5	0.5-6.0
Bottom Algae Light Model	---	---	Smith	Half Saturation	---
Detritus (POM) Settling Velocity (m/d) [b]	6	0.1	1	0.1	Variable [a]

Note: [a] influenced by a material's size, shape, and density and the speed of water
[b] Published rates from a QUAL2K model of a periphyton dominated river (Turner et al., 2009)

The following parameters were also adjusted during the sensitivity analysis:

- Remove diffuse organic nitrogen loading from model
- Remove diffuse detritus loading from model
- Remove diffuse inorganic phosphorus flux loading from model
- Remove diffuse phytoplankton loading from model
- Remove prescribed SOD from model reaches

Table 7.2 summarizes the percent change these changes have on the average model-predicted DO concentration for the entire modeled stretch of Lac qui Parle River.

Table 7.2 QUAL2K parameter sensitivity.

Kinetic rate Modification	**Sensitivity Run A (High)**	**Sensitivity Run B (Low)**	**Default**
$CBOD_u$ oxidation rate (day^{-1}) Represented in model as Fast CBOD	-8.9%		-1.3%
Reaeration Model Reaeration, K_a (day^{-1})	36.0%		
Organic-N Hydrolysis (day^{-1}) *The release of ammonia due to decay of organic nitrogen*	1.1%	-2.0%	1.6%
Organic-N Settling (m/d)	0.9%	-0.4%	0.9%
Ammonium Nitrification (day^{-1})	1.1%	3.4%	1.1%
Nitrate Denitrification (day^{-1})	-0.7%	0.5%	0.5%
Organic-P Hydrolysis (day^{-1}) *The release of phosphate due to decay of organic phosphorus*	0.0%	-1.1%	-0.4%
Organic-P Settling (m/d)		0.2%	
Inorganic-P Settling (m/d)			-9.0%
Phytoplankton Light Model			-7.8%
Phytoplankton Settling (m/d)	-17.2%		
Bottom Algae Light Model			0.0%
Detritus (POM) Settling Velocity (m/d)	0.0%	2.0%	2.0%

Modification	**Action**
Remove diffuse organic nitrogen loading from model (diffuse source)	-0.9%
Remove diffuse detritus loading from model (diffuse source)	36.9%
Remove diffuse inorganic phosphorus flux loading from model (Reach)	-12.1%
Remove diffuse phytoplankton loading from model (diffuse source)	-0.4%
Remove prescribed SOD from model reaches (Reach)	10.8%

Results show DO throughout the system is most sensitive to additional reaeration and reductions in diffuse source detritus loading. Removal of prescribed SOD also increases DO.

Photosynthesis by algae and other green plants during the day gives off oxygen to the water which increases DO concentrations. If you reduce the mass of items photosynthesizing in the model, this lowers the DO. As expected, reductions in diffuse source inorganic phosphorus loading, increased settling of phytoplankton and increased phytoplankton settling negatively impact DO. The inorganic form of phosphorus is assumed to be dissolved phosphorus in the form of ortho-phosphorus (SRP). SRP is readily available for uptake by chlorophyll-*a*. By reducing the "food" of algae, the growth is hindered, thus decreasing amount of productivity.

Water column CBOD oxidation also appear sensitive, though to a lesser degree.

- Model DO is highly sensitive to the adjustments made to enhance sediment geochemical processes (prescribed SOD and prescribed inorganic-P flux). These adjustments were required in order to calibrate to observed DO and inorganic-P measurements.
- Model DO also appears sensitive to the reaeration model selected by the user. However, this model (O'Connor Dobbins) is a widely accepted method to calculate reaeration and was justified in this report.
- Model DO is less sensitive to the kinetic rates that define the breakdown of organic matter and nutrient transformations throughout the water column.
- These results imply that the DO dynamics of the calibrated model is most sensitive to the prescribed sediment parameter adjustments required for calibration and less sensitive to the water column kinetic rate settings.
- While not explicitly modeled in the sensitivity analysis, the model DO is sensitive to the water quality of the upstream boundary conditions (West Branch and South Branch Lac qui Parle River).

The sensitivity analysis results are included in Appendix E of the final TMDL report (Appendix E_LowDO\03_Q2K_Sensitivity\).

8.0 EXISTING CRITICAL CONDITIONS

The calibrated model was modified to reflect existing condition hydraulic changes after the removal of the Dawson Dam, to reflect 2010 existing critical conditions. The Dawson dam is located 1.6 river miles above the confluence of the West Branch and South Branch Lac qui Parle River. In December 2009, the impoundment was removed and replaced with a series of rock weirs. The new structure was expected to have positive reaeration effects on the river. The calibrated model was modified to incorporate representation of the Dawson Dam improvements. The new existing condition model is the starting point for the TMDL because:

- The model reflects the Dawson dam replacement,
- The model represents summer low flow conditions and conditions following a runoff related high flow event (two critical conditions when low DO are most expected),
- The model assumes the upstream boundary conditions (South Branch Lac qui Parle River and West Branch Lac qui Parle River) have low DO as monitored on August 4, 2005, and
- The model represents point sources discharging at permitted limits.

Figure 8.1 shows the existing critical condition results for model-predicted DO concentrations. The model predicted average daily DO concentrations (plotted as black dashed line) and the diurnal pattern (daily minimum and maximum, shown plotted as blue dashed lines). The existing critical condition model shows the impaired reach not meeting the 5.0 mg/L DO standard. The TMDL will be based on what needs to be changed to meet the 5.0 mg/L DO standard in the impaired reach.

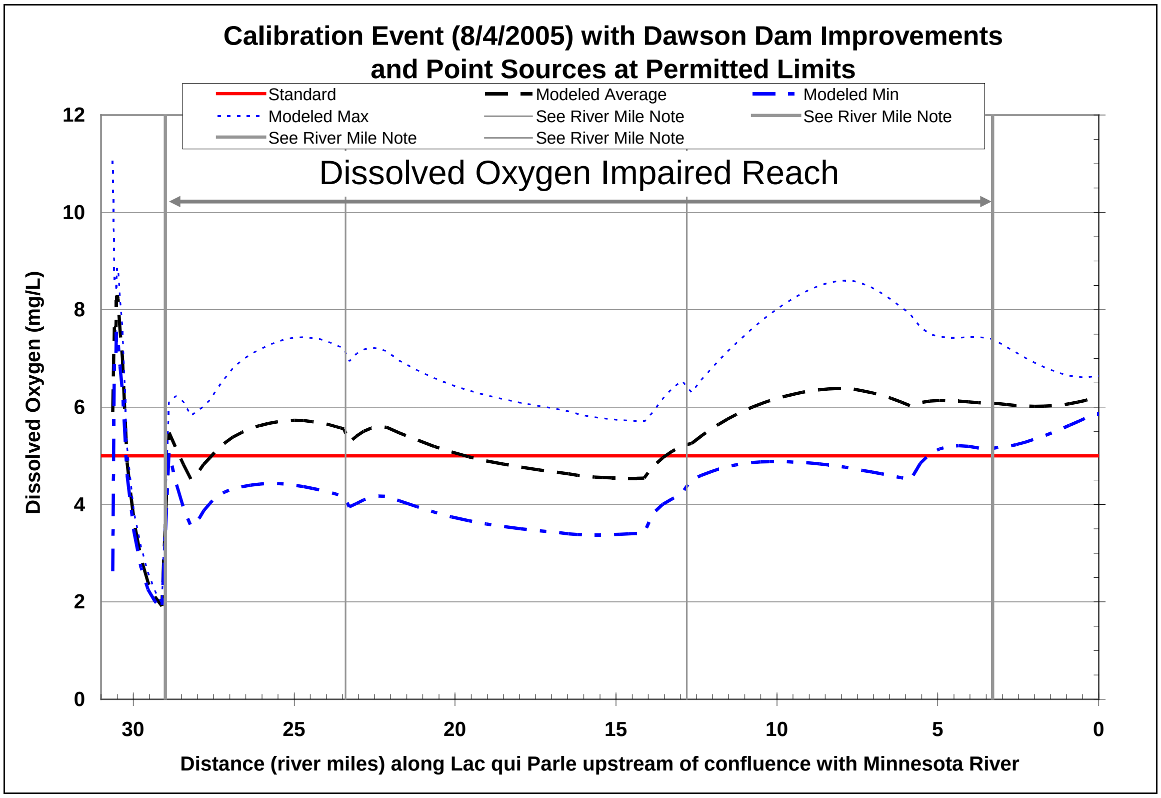


Figure 8.1 Lac qui Parle River existing critical conditions event dissolved oxygen longitudinal profile (2010LqPEC_001.xls).

River Mile 29.0 = start of listed reach
River Mile 23.4 = inflow of tributaries County Ditch 27
River Mile 12.8 = inflow of tributaries County Ditch 4
River Mile 3.3 = end of listed reach, inflow of tributary Ten Mile Creek

The water quality data and QUAL2K model files will be provided in Appendix E of the TMDL report. The QUAL2K model file (Appendix E_LowDO\04_Q2K_ExistingConditions\ 2010LqPEC_001.xls) house the modeled water quality model inputs.

8.1 Identifying the Appropriate TMDL Parameters

The modeling and monitoring efforts have not established a clear cause–and–effect relationship between sources and the dissolved oxygen impairment. Two prominent parameters were selected to change to meet the 5.0 mg/L DO standard in the impaired reach. They are:

- Reductions in SOD, as a directly related cause of low DO, and
- Reductions in diffuse source detritus/nutrients, as an indirectly related cause of periphyton/algae.

The TMDL model assumes that all point sources are discharging at permitted discharge limits in the existing critical condition model. The load reductions of SOD and diffuse source detritus/nutrients were made to meet the DO requirements throughout the impaired reach.

Figure 8.2 shows the model-predicted DO concentrations with the TMDL reductions. The model predicted average daily DO concentrations (plotted as black dashed line) and the diurnal pattern (daily minimum and maximum, shown plotted as blue dashed lines).

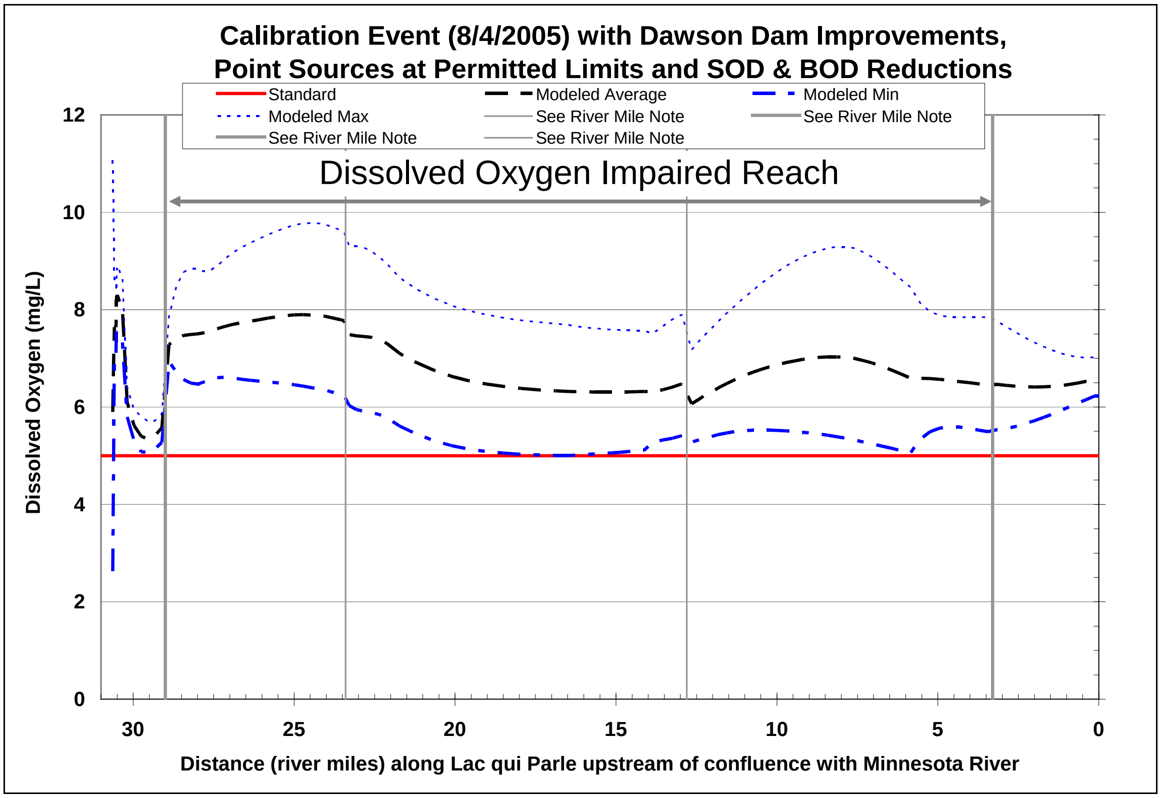


Figure 8.2 Lac qui Parle River TMDL endpoint event dissolved oxygen longitudinal profile (20050804_LqP_015TMDL.xls).

River Mile 29.0 = start of listed reach
River Mile 23.4 = inflow of tributaries County Ditch 27
River Mile 12.8 = inflow of tributaries County Ditch 4
River Mile 3.3 = end of listed reach, inflow of tributary Ten Mile Creek

The water quality data and QUAL2K model files will be provided in Appendix E of the TMDL report. The QUAL2K model file (Appendix E_LowDO\05_Q2K_TMDL\ 20050804_LqP_015TMDL.xls) house the modeled water quality model inputs.

The TMDL loads will be based on reductions of SOD and detritus required to meet the DO standard under existing critical conditions.

8.2 Oxygen Deficit Terms

Dissolved oxygen is consumed both in the water column and at the sediment interface. This consumption is expressed in terms of the mass of oxygen-demanding substances available per day.

Carbonaceous biological oxygen demand (CBOD) represents the oxygen equivalent (amount of oxygen that micro-organisms require to breakdown and convert organic carbon to CO_2) of the carbonaceous organic matter in a sample.

A second source is nitrogenous biological oxygen demand (NBOD). A wide variety of micro-organisms rapidly transform organic nitrogen (ON) to ammonia nitrogen (NH_3-N). Bacteria then transform NH_3-N to nitrate through an oxygen consuming process called nitrification. For this TMDL, NBOD was calculated by multiplying the sum of organic and ammonia nitrogen by 4.33. The factor 4.33 is the stoichiometric ratio (mass basis) of oxygen demand to nitrogen that is used in the QUAL2K modeling and TMDL calculations.

Finally, sediment oxygen demand (SOD) is the aerobic decay of organic materials in stream bed sediments and in peat soils in wetlands. SOD rates are defined in units of oxygen used per surface area per day (g-O_2/m^2/day). While the tributary areas and WLAs in the watershed may be sources of SOD for this TMDL, SOD loads were only determined for explicitly modeled stream reaches.

8.3 Upstream Boundary Conditions & Point Sources

The listed reach has the following boundary conditions:

- West Branch Lac qui Parle River,
- South Branch Lac qui Parle River,
- County Ditch 27 and
- County Ditch 4.

The August 4, 2005 data collected just upstream of the confluence with the listed reach was used to calculate the boundary condition CBOD and NBOD loads for the existing critical conditions as well as TMDL. Table 8.1 summaries the oxygen demand terms of CBOD, NBOD and SOD for the boundary conditions of the listed reach.

Table 8.1 Boundary Conditions: Critical Period (Jun 16 – Sept 14)[1] Loads and TMDL

Boundary Condition: Tributary to Listed Reach	**Oxygen Demand (lbs/day) from:**						**Total Oxygen Demand (lbs/day)** [2]	
	CBOD [3]		**NBOD**[4]		**SOD**[5]			
	Existing Critical	TMDL	Existing Critical	TMDL	Existing Critical	TMDL	Existing Critical	TMDL
West Branch Lac qui Parle River (1.50 river miles)	551.6	459.5	233.5	233.5	728.6	237.4	1,513.6	930.4
South Branch Lac qui Parle River	105.0	105.0	131.2	131.2	--	--	236.1	236.1
County Ditch 27	963.3	963.3	250.6	250.6	--	--	1,214.0	1,214.0
County Ditch 4	154.0	154.0	199.4	199.4	--	--	353.5	353.5

The TMDL scenario represents the some of the necessary CBOD and SOD reductions to the upstream boundary condition for West Branch Lac qui Parle River. This analysis did not include explicitly modeling of the West Branch Lac qui Parle River.

The following NPDES permitted treatment facilities of interest are a component of the upstream of the boundary conditions loads:

- Dawson WWTF (MN0021881)
- AGP (MN0040134)
- Madison WWTP (MNG550028)
- Madison WTP (MN0061077)

Dawson AMPI (MN0048968) is the only NPDES permitted treatment facilities of interest directly discharging to the listed reach. Based on the permit issued at the time of this study, the facility does not discharge during the critical conditions. Additional load allocation reductions would be required to allow AMPI to discharge during the critical period (June 16 through September 14). Table 8.2 summaries the oxygen demand terms of CBOD and NBOD for the NPDES permitted treatment facilities of interest. We acknowledge that these point sources likely have SODs. For the purposes of this TMDL, SOD loads were only determined for explicitly modeled reaches.

[1] For this TMDL, the critical period is summer low flow conditions based on the 2010 existing critical condition changes made to the August 4, 2005 calibration event.
[2] The total oxygen demand is the sum of CBOD, NBOD and SOD.
[3] CBOD loads are ultimate CBOD and include detritus (assumed to be 100% ultimate CBOD).
[4] For this TMDL, NBOD was calculated by multiplying the sum of organic and ammonia nitrogen by 4.33. The factor 4.33 is the stoichiometric ratio (mass basis) of oxygen demand to nitrogen that is used in the QUAL-TX modeling and TMDL calculations.
[5] We acknowledge that these point sources likely have SODs. For the purposes of this TMDL, SOD loads were only determined for explicitly modeled reaches.

Table 8.2 NPDES permitted treatment facilities of interest Loads for Critical Period (Jun 16 – Sept 14) and TMDL.

				Oxygen Demand (lbs/day) from:			
	Equivalent Permit Limits			CBOD		NBOD[6]	
Permittee	Flow (MGD)	5-day CBOD (mg/L)	Ultimate CBOD (mg/L)	2010 Existing Critical Conditions	TMDL Endpoint	2010 Existing Critical Conditions	TMDL Endpoint
Dawson WWTF (MN0021881)	0.471	8.31	17.21	67.61	67.61	0.02	0.02
Dawson AGP (MN0040134)	1.533	11.64	24.10	308.07	308.07	91.34	91.34
Dawson AMPI [7] (MN0048968)	0.0	---	---	---	---	---	---
Madison WWTF (MNG550028)	0.48	24.94	51.63	206.70	206.70	0.87	0.87
Madison WTP (MN0061077)	0.10	2.49	5.16	4.31	4.31	3.61	3.61

Three additional NPDES permitted treatment facilities are located in the LQPYBWD upstream of the DO impaired reach. These are Marietta WWTP (MNG580160, AUID 07020003-516), Canby WWTP (MN001236-SD2, AUID 07020003-508) and Hendricks WWTP (MN0021121, AUID 07020003-505). This analysis did not include explicitly modeling of the West Branch Lac qui Parle River.

8.4 Diffuse Sources

The diffuse sources of oxygen demanding terms of the TMDL (CBOD, NBOD and SOD) were presented in Section 5.5 (detritus, groundwater and sediment flux). Table 8.3 documents the diffuse sources of oxygen demand terms of CBOD, NBOD and SOD for the diffuse sources by listed reach subparts (in between boundary conditions). Diffuse source CBOD and SOD reductions are needed on all sections of the listed reach.

[6] NBOD loads are based on a combination of modeling assumptions, available water quality data, and the permits issued at the time of this analysis. None of the permittees listed in Table 8.2 have permit limits for organic nitrogen (ON), and only Dawson WWTF has a seasonally variable permit limit for ammonia nitrogen (NH_3-N).

[7] Based on the permit issued to AMPI at the time of this analysis, AMPI does not discharge during the critical period. Additionally, in-stream water quality data paired with discharge data was not available during a period where AMPI was discharging.

Table 8.3 Diffuse Source Loads for Critical Period (Jun 16 – Sept 14) and TMDL.

Boundary Condition: Tributary to Listed Reach	**Oxygen Demand (lbs/day) from:**						**Total Oxygen Demand (lbs/day)**	
	CBOD		**NBOD**		**SOD**			
	Existing Critical	TMDL	Existing Critical	TMDL	Existing Critical	TMDL	Existing Critical	TMDL
Diffuse Detritus								
LqP 29.0 (**Start of Listed Reach**) to LqP 23.4 (conf CD27)	989.6	602.30	93.1	93.1	---	---	1082.7	695.4
LqP 23.4 (conf CD27) to LqP 12.8 (conf CD4)	2444.0	1140.50	28.2	28.2	---	---	2472.2	1168.7
LqP 12.8 (conf CD4) to LqP 3.30 (**end of listed reach**, inflow of tributary Ten Mile Creek)	2628.5	1898.30	25.3	25.3	---	---	2653.8	1923.6
Diffuse Groundwater								
LqP 29.0 (**Start of Listed Reach**) to LqP 23.4 (conf CD27)	---	---	---	---	---	---	---	---
LqP 23.4 (conf CD27) to LqP 12.8 (conf CD4)	0.0274	0.0274	0.0013	0.0013	---	---	0.0287	0.0287
LqP 12.8 (conf CD4) to LqP 3.30 (**end of listed reach**, inflow of tributary Ten Mile Creek)	0.0259	0.0259	0.0011	0.0011	---	---	0.0270	0.0270
Sediment Oxygen Demand								
LqP 29.0 (**Start of Listed Reach**) to LqP 23.4 (conf CD27)	---	---	---	---	1995.17	1292.19	1995.17	1292.19
LqP 23.4 (conf CD27) to LqP 12.8 (conf CD4)	---	---	---	---	4762.71	3940.34	4762.71	3940.34
LqP 12.8 (conf CD4) to LqP 3.30 (**end of listed reach**, inflow of tributary Ten Mile Creek)	---	---	---	---	2930.66	2543.97	2930.66	2543.97

Sediment flux is the SOD load (shown in Table 8.3) is calculated by integrating the SOD rate across the streambed area of each reach. Specifically, each SOD target reach rate, represented in g-O_2/m^2/day, was multiplied by the wetted area of the reach to calculate the SOD TMDL in pounds/O_2/day for the entire reach. Table 8.4 documents the areas used for each modeled reach in the Lac qui Parle River load calculations.

Table 8.4 Reach Streambed Areas for Critical Period (Jun 16 – Sept 14) and TMDL.

Reach	Reach Length (km)	Average SOD Reach Rate Existing Critical	Average SOD Reach Rate TMDL	Wetted Width (m)		Wetted Surface Area (m^2)	
				Existing Critical	TMDL	Existing Critical	TMDL
1	0.32	3.15	0.32	17.83	17.83	5,706	5,706
2	**JD4**						
3	2.09	8.40	2.85	17.83	17.83	37,267	37,267
4	**SB LqP**						
5*	1.45	6.82	2.42	17.83	17.83	25,855	25,855
6*	0.32	4.17	2.88	17.83	17.83	5,706	5,706
7*	0.60	4.28	2.95	17.83	17.83	10,699	10,699
8*	0.80	4.48	3.10	17.83	17.83	14,265	14,265
9*	3.50	5.07	3.62	17.83	17.83	62,409	62,409
10*	0.89	5.51	4.03	17.83	17.83	15,870	15,870
11*	1.11	5.63	4.16	23.62	23.62	26,220	26,220
12*	0.34	5.69	4.23	23.62	23.62	8,031	8,031
13	**CD27**						
14*	1.46	4.82	4.34	23.62	23.62	34,488	34,488
15*	0.79	4.91	4.27	27.43	27.43	21,671	21,671
16*	8.69	4.76	3.97	27.43	27.43	238,384	238,384
17*	3.42	4.53	3.67	27.43	27.43	93,817	93,817
18*	0.77	4.43	3.56	28.65	28.65	22,061	22,061
19*	1.93	4.22	3.24	28.65	28.65	55,296	55,296
20	**CD4**						
21*	0.97	3.99	3.31	28.65	28.65	27,791	27,791
22*	6.73	4.60	3.96	19.51	19.51	131,282	131,282
23*	0.83	5.13	4.53	21.79	21.79	18,088	18,088
24*	2.90	5.21	4.61	17.07	17.07	49,500	49,500
25*	3.86	5.27	4.64	13.11	13.11	50,589	50,589
26	**10-mile Creek**						
27	2.81	4.80	4.11	13.11	13.11	36,828	36,828
28	2.50	3.72	3.05	13.11	13.11	32,765	32,765

* denotes listed reach.

In order to discuss TMDL percent reductions, we need to understand what the CBOD, NBOD and SOD loads are under existing (baseline) conditions. The existing critical event daily loads in pounds are summarized below (Table 8.5). The final tables are presented in pounds rather than kilograms so that values can be readily compared to existing approved dissolved oxygen TMDLs.

The 2010 existing critical conditions load is the sum of the wasteload and load, with no margin of safety. The existing load is based on existing critical conditions model (reflecting the Dawson dam replacement) and point sources discharging at permitted limits (Figure 8.1).

Table 8.5 Loads in pounds per day for Critical Period (Jun 16 – Sept 14).

	2010 Existing CBOD *(pounds O_2 per day)*	2010 Existing NBOD *(pounds O_2 per day)*	2010 Existing SOD *(pounds O_2 per day)*	2010 Existing *Total Oxygen Demand (pounds O_2 per day)*
Existing Load = Σ WL + Σ L + MOS	**7,836.0**	**961.3**	**10,417.1**	**19,214.4**
Σ WL				
NPDES Permitted Treatment Facilities	--	--	--	--
Feedlots Requiring NPDES Permits	--	--	--	--
Noncompliant Septic Systems	--	--	--	--
Construction Stormwater	--	--	--	--
Industrial Stormwater	--	--	--	--
Σ L				
Sources of Sediment Flux	--	--	9,688.5	9,688.5
Diffuse Sources	6,062.2	146.6	--	6,208.8
Boundary Condition: West Branch Lac qui Parle River (1.50 river miles)	551.5	233.4	728.6	1,513.6
Boundary Condition: South Branch Lac qui Parle River	105.0	131.2	--	236.1
Boundary Condition: County Ditch 27	963.3	250.6	--	1,214.0
Boundary Condition: County Ditch 4	154.0	199.4	--	353.5
MOS	--	--	--	--

The Total Maximum Daily Load (TMDL) is the sum of the wasteload allocations, load allocations and the margin of safety. The TMDL is based on existing critical conditions model (reflecting the Dawson dam replacement) and point sources discharging at permitted limits with reductions in SOD and detritus to meet the 5.0 mg/L DO standard (Figure 8.2). Detritus loading was modeled as a diffuse source tributary to the listed reach. Detritus was removed starting 1.5 miles upstream of the impaired reach on West Branch Lac qui Parle River continuing downstream the entire impaired reach of the Lac qui Parle River. Reductions in detritus directly result in model predicted SOD reductions. Prescribed SOD was removed from model reaches starting 1.5 miles upstream of the impaired reach on West Branch Lac qui Parle River, along Lac qui Parle River 5.6 miles to the confluence with County Ditch 27, and along County Ditch 27. Table 8.6 shows the TMDL allocations for Lac qui Parle River.

Table 8.6 Loads in pounds per day for TMDL.

	TMDL CBOD (*pounds O_2 per day*)	TMDL NBOD (*pounds O_2 per day*)	TMDL SOD (*pounds O_2 per day*)	TMDL Total Oxygen Demand (*pounds O_2 per day*)
TMDL Allocation = Σ WLA + Σ LA + MOS	**5,322.9**	**961.3**	**8,013.9**	**14,298.1**
Σ WLA				
NPDES Permitted Treatment Facilities	--	--	--	--
Feedlots Requiring NPDES Permits	--	--	--	--
Noncompliant Septic Systems	--	--	--	--
Construction Stormwater	--	--	--	--
Industrial Stormwater	--	--	--	--
Σ LA				
Sources of Sediment Flux	--	--	6,998.9	6,998.9
Diffuse Sources	3,277.0	146.6	--	3,409.9
Boundary Condition: West Branch Lac qui Parle River (1.50 river miles)	459.4	233.4	237.4	930.3
Boundary Condition: South Branch Lac qui Parle River	105.0	131.2	--	236.1
Boundary Condition: County Ditch 27	963.3	250.6	--	1,214.0
Boundary Condition: County Ditch 4	154.0	199.4	--	353.5
MOS	364.1	--[8]	777.7	1,156.4

8.5 Percent Reductions

Table 8.7 shows the total percentage reductions in loads for Lac qui Parle River to achieve the TMDL.

[8] Margins of safety are only applicable to oxygen deficit terms that require a TMDL reduction to achieve the dissolved oxygen standard. For this TMDL, only reductions in CBOD and SOD are required.

Table 8.7 Total Percentage Reduction in Oxygen Demand.

	TMDL CBOD (*pounds O_2 per day*)	TMDL NBOD (*pounds O_2 per day*)	TMDL SOD (*pounds O_2 per day*)	TMDL Total Oxygen Demand (*pounds O_2 per day*)
TMDL Allocation = Σ WLA + Σ LA + MOS	32%	--	23%	26%
Σ WLA				
NPDES Permitted Treatment Facilities	--	--	--	--
Feedlots Requiring NPDES Permits	--	--	--	--
Noncompliant Septic Systems	--	--	--	--
Construction Stormwater	--	--	--	--
Industrial Stormwater	--	--	--	--
Σ LA				
Sources of Sediment Flux	---	---	28%	28%
Diffuse Sources	46%	--	---	45%
Boundary Condition: West Branch Lac qui Parle River (1.50 river miles)	17%	---	67%	39%
Boundary Condition: South Branch Lac qui Parle River	---	---	---	-
Boundary Condition: County Ditch 27	---	---	---	-
Boundary Condition: County Ditch 4	---	---	---	-

This TMDL requires CBOD load reductions of 46 percent to diffuse sources for the listed reach (Lac qui Parle River) and 17 percent for the 1.5 miles upstream of the impaired reach on West Branch Lac qui Parle River.

This TMDL does not require NBOD load reductions for the listed reach (Lac qui Parle River).

This TMDL requires SOD load reductions of 28 percent for the listed reach (Lac qui Parle River) and 67 percent for the 1.5 miles upstream of the impaired reach on West Branch Lac qui Parle River. SOD load reductions can be achieved by reducing sources of particulate organic matter, as well as reducing wetted perimeter as part of a channel form scenario.

8.6 Seasonal and Annual Variation

Seasonal variation is accounted for by establishing the TMDL for the critical low flow condition. By selecting the most sensitive conditions for the stream, dissolved oxygen concentrations in all seasons will be protected.

8.7 Critical Condition

The critical condition for this TMDL is the summer low flow season. During summer low flow, stream temperatures are at their maximum resulting in minimal holding capacity for stream dissolved oxygen. Stream velocities are typically low, reducing reaeration of the stream. As a result, summer low flow represents the most sensitive conditions for stream dissolved oxygen.

8.8 Reserve Capacity

The population of Lac qui Parle County was estimated to be 7,756 people in 2004 (Table 8.7). This represents a four percent decrease from the year 2000, and a 13.1 percent decrease from 1990 (U.S. Census Bureau, 2006).

Table 8.7 Population in 1990, 2000, and 2004 (U.S. Census Bureau, 2006).

Location	Number of People in 1990	Number of People in 2000	Number of People in 2004	Percentage Change in Population 2000 - 2004
Lac qui Parle County	8,924	8,067	7,756	-3.86
Town of Dawson	1,626	1,539	1,480	-3.83

The population in the town of Dawson was approximately 1,480 people in the year 2004. From 2000 to 2004, the town of Dawson experienced a 3.8 percent decrease in population, and a nearly 9 percent decrease from 1990 (U.S. Census Bureau, 2006). If this trend continues, populations in these areas are expected to continually decrease.

No new NPDES point sources are anticipated in this watershed. There are no Wasteloads identified in this TMDL, and therefore no portion of the Wasteload Allocation is being held in reserve. With negative population trends no portion of the Wasteload Allocation is being held in reserve.

9.0 REFERENCES

Baca, R.G. and R.C. Arnett. 1976. A Limnological Model for Eutrophic Lakes and Impoundments. Battell, Inc., Pacific Northwest Laboratories, Richland, Washington.

Bansal, M.K., 1975. Deoxygenation in Natural Systems. Water Resources Bulletin 11: 491-504.

Bowie, G.L., C.W. Chen, and D.H. Dykstra. 1980. Lake Ontario Ecological Modeling, Phase III. Tetra Tech, Inc., Lafayette, California. For National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan.

Bowie, G.L., et al., 1985. Rates, constants and kinetic formulations in surface water quality modeling (2^{nd} Edition.) USEPA

Chapra, S.C., Pelletier, G.J. and H. Tao. 2007. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 2.07: Documentation and Users Manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA.

Climatology Working Group www.climate.umn.edu State Climatology Office – DNR Waters, Extension Climatology Office – MES, Academic Climatology – University of Minnesota.

Fillos, J., and W. R. Swanson. 1975. "The release rate of nutrients from river and lake sediments." Journal (Water Pollution Control Federation), Vol. 47, No. 5 (May, 1975), pp. 1032-1042.

Hubbard, E.F., et al. 1982. “Measurement of Time of Travel and Dispersion in Streams by Dye Tracing,” Techniques of Water-Resources Investigations, Book 3, Chapter A9. U.S. Geological Survey, Washington, D.C.: Government Printing Office.

Leopold, L.B. and Maddock, T. 1953. “The hydraulic geometry of stream channels and some physiographic implications.” U.S. Geol. Survey, Professional Paper, 252, 56 pp.

McCollor and Heiskary. 1993. “Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota’s Seven Ecoregions.” Minnesota Pollution Control Agency Water Quality Division

Midje, H.C., et al. c. 1966. “Hydrology Guide for Minnesota.” U.S. Department of Agriculture Soil Conservation Service.

Minnesota Pollution Control Agency. 1998. Baseline Water Quality of Minnesota’s Principal Aquifers: Southwest Region. June 1998 <http://www.pca.state.mn.us/index.php/water/water-types-and-programs/groundwater/groundwater-monitoring-and-assessment/statewide-baseline-study.html>

Minnesota Pollution Control Agency. May 1999. State Baseline Study. Chemical Specific Fact Sheet: Phosphorus in Minnesota's Ground Water. (http://www.pca.state.mn.us/water/groundwater/gwmap/gw-baseline.html)

Minnesota Pollution Control Agency. August 1998. State Baseline Study. Chemical Specific Fact Sheet: Nitrates in Minnesota's Ground Water. (http://www.pca.state.mn.us/water/groundwater/gwmap/gw-baseline.html)

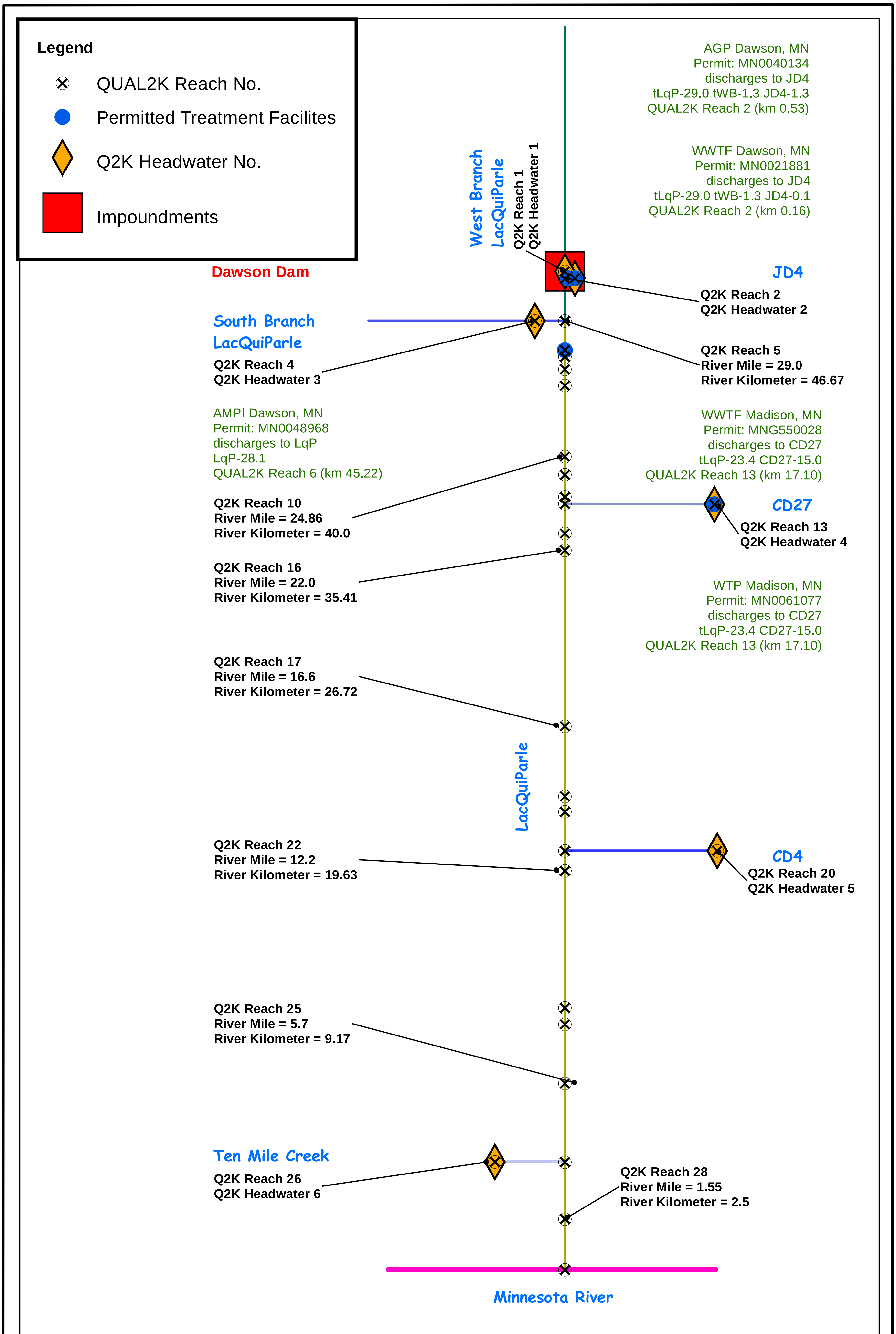
O'Connor, D.J., and Dobbins, W.E. 1958. Mechanism of reaeration in natural streams. Trans. ASCE, 123, 641-684.

Tchobanoglous, G. 1991. Wastewater Engineering: Treatment, Disposal and Reuse. McGraw-Hill, Inc., New York, New York.

Thomann, R. V., Mueller, J. A., 1987. "Principles of Surface Water Quality Modeling and Control." Harper Collins Publishers Inc.

Turner, Daniel F., Gregory J. Pelletier, and Brian Kasper "Dissolved Oxygen and pH Modeling of a Periphyton Dominated, Nutrient Enriched River." *Journal of Environmental Engineering,* Vol. 135, Issue 8, pp. 645-652, August 2009,

USEPA. 2009. River and Stream Water Quality Model (QUAL2K).
<<http://www.epa.gov/athens/wwqtsc/html/qual2k.html>>



Mxd: L:\2297\01\mxd\20090810_Schematic_PS_ML_Trib_JS.mxd

LAC QUI PARLE WATERSHED

QUAL2K Modeling Schematic

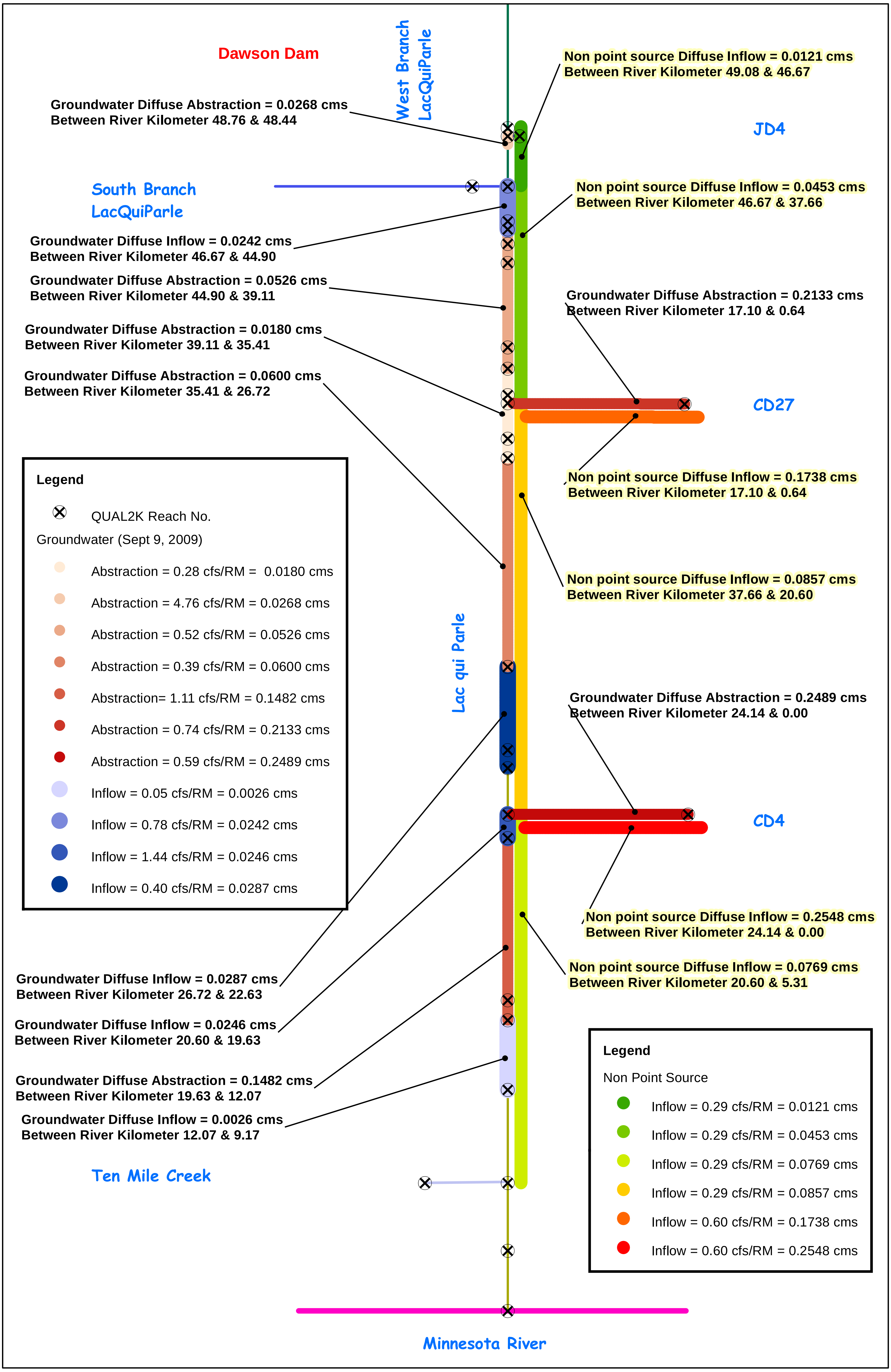
COPYRIGHT

Wenck

Wenck Associates, Inc. Environmental Engineers
1800 Pioneer Creek Center Maple Plain, MN 55359-0429

MAY 2011

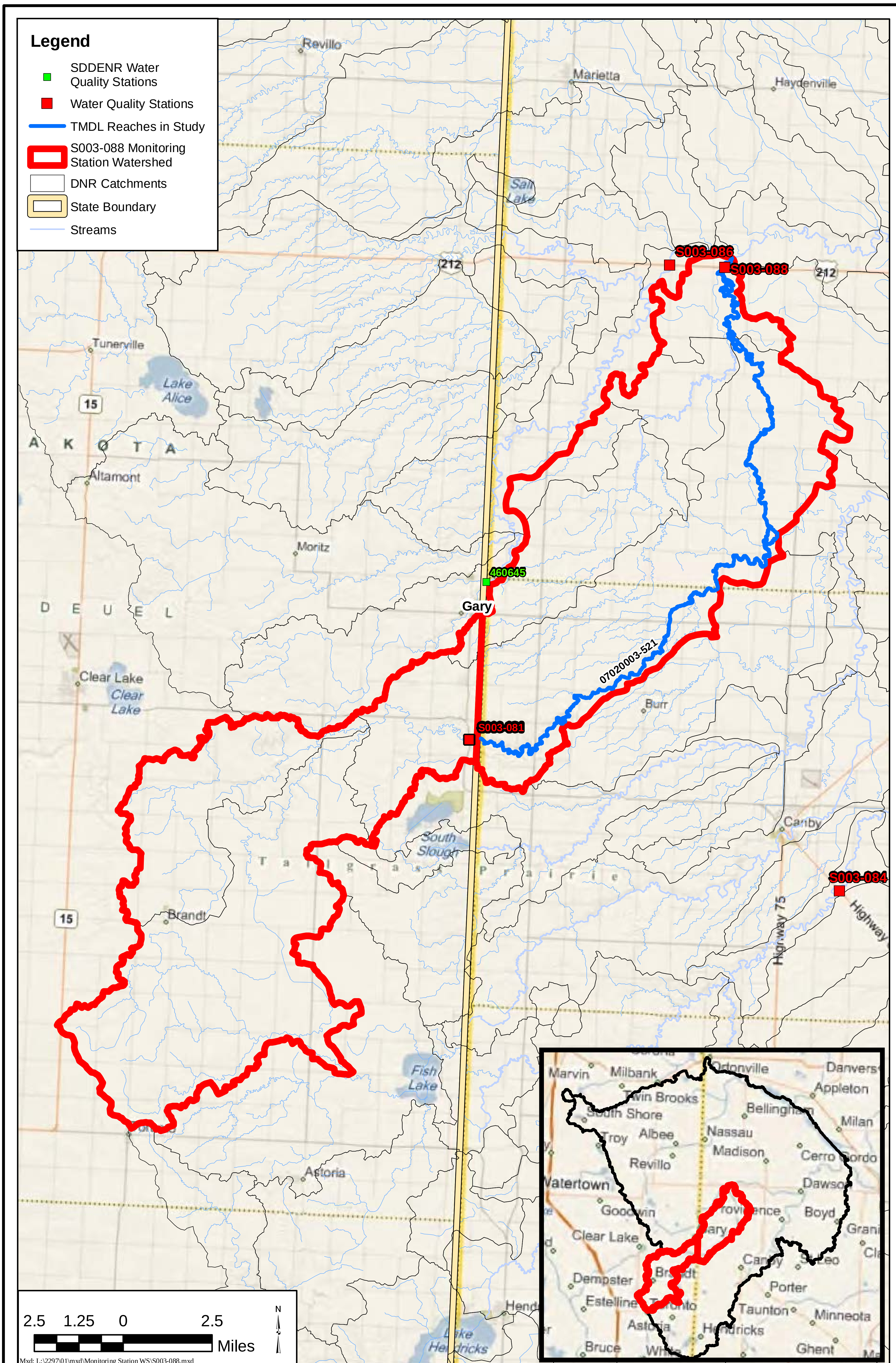
Figure 1



Mxd: L:\2297\01\mxd\20090810_Schematic_PS_ML_Trib_JS.mxd

LAC QUI PARLE WATERSHED	Wenck	MAY 2011
QUAL2K Modeling Schematic	Wenck Associates, Inc. 1800 Pioneer Creek Center Environmental Engineers Maple Plain, MN 55359-0429	Figure 2

Appendix B



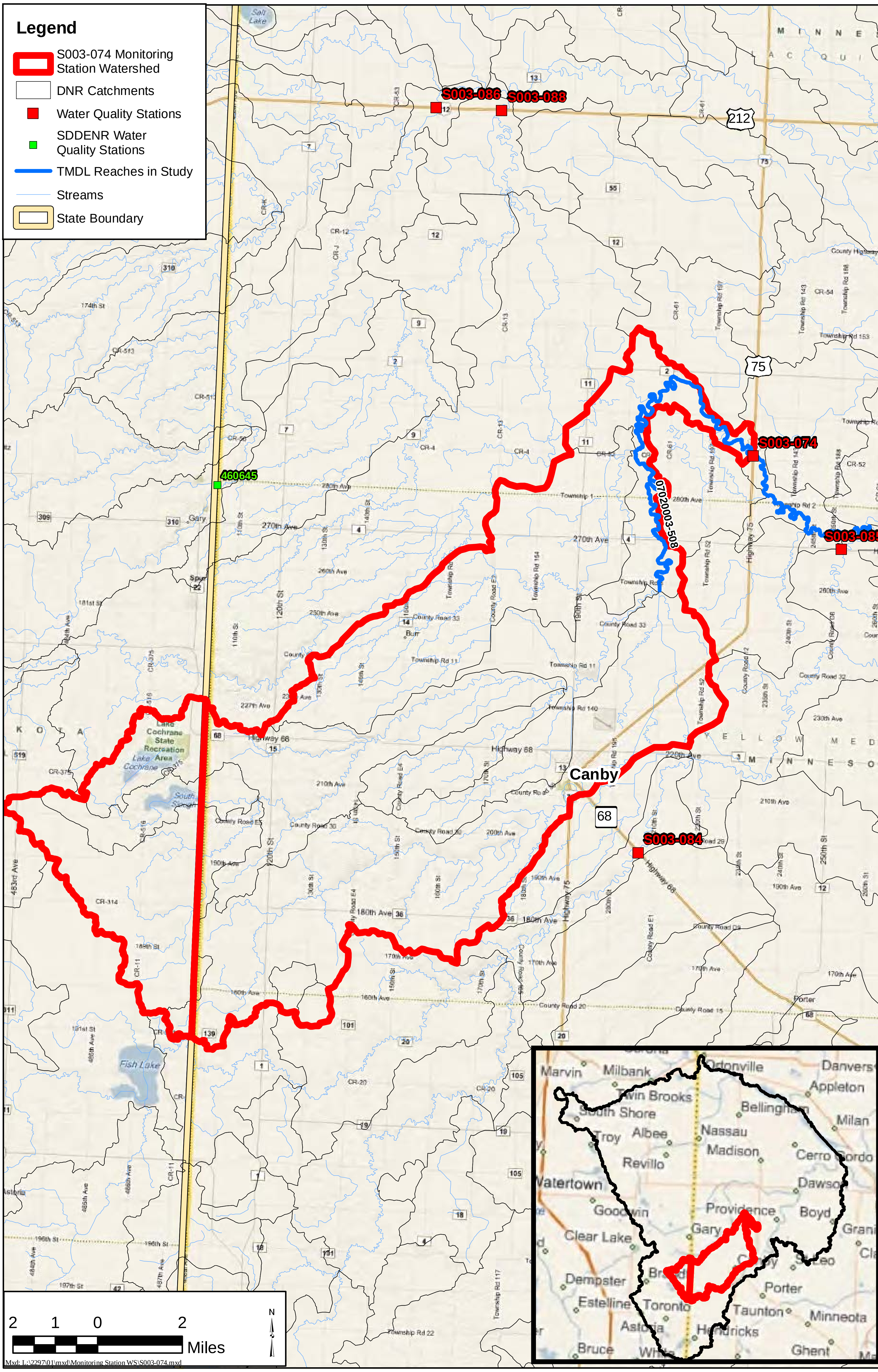
LQPYB CWP TMDL

Florida Creek-
SD/MN Border to West Branch Lac Qui Parle River

COPYRIGHT
Wenck
Wenck Associates, Inc. 1800 Pioneer Creek Center
Environmental Engineers Maple Plain, MN 55359-0429

SEP 2010

MAP B1

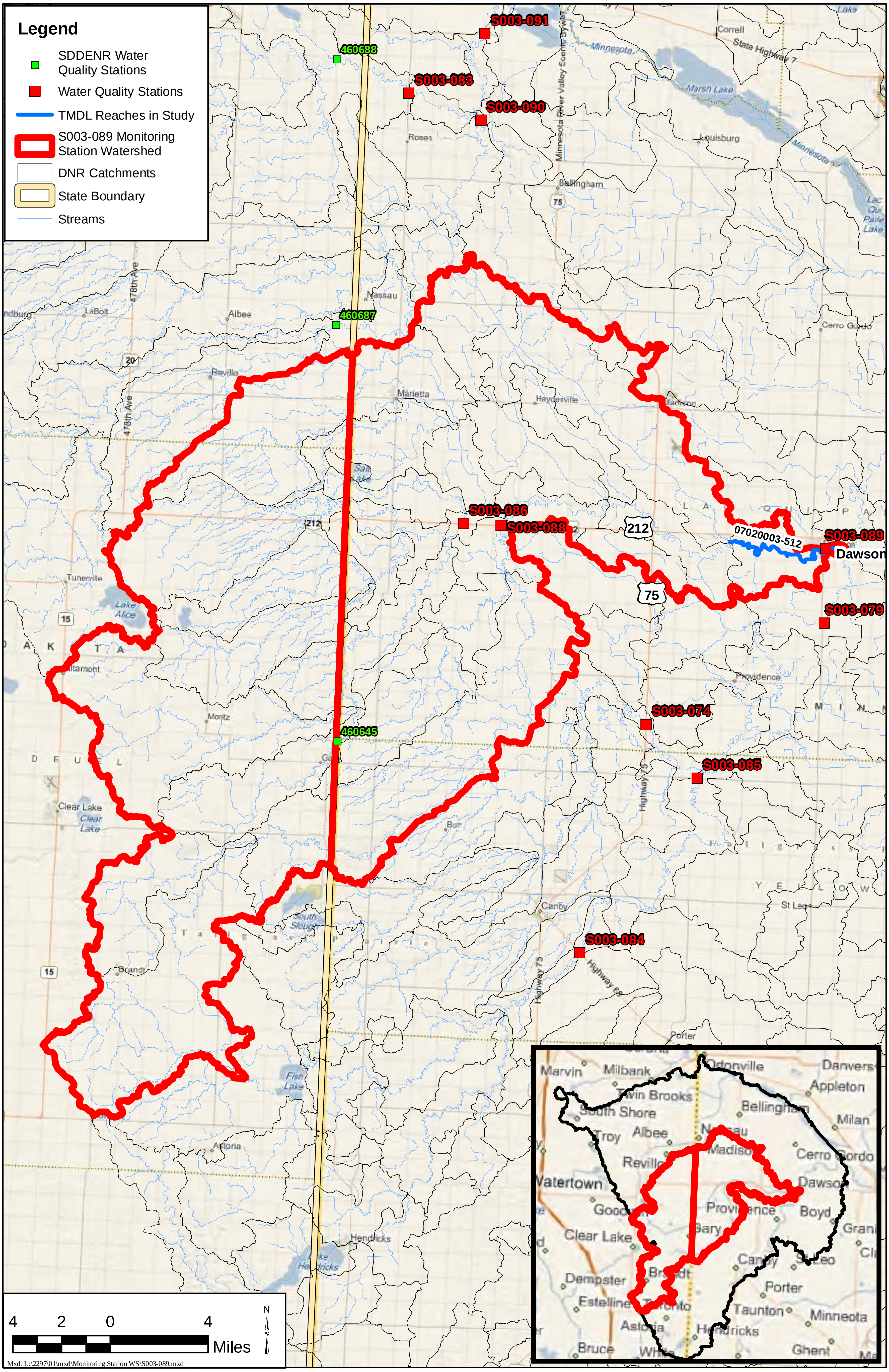


LQPYB CWP TMDL
Lazarus Creek-Canby Creek to Lac Qui Parle River

COPYRIGHT
Wenck
Wenck Associates, Inc. 1800 Pioneer Creek Center
Environmental Engineers Maple Plain, MN 55359-0429

SEP 2010

MAP B2



LQPYB CWP TMDL

West Branch Lac Qui Parle River-
Unnamed Ditch to Unnamed Creek

COPYRIGHT

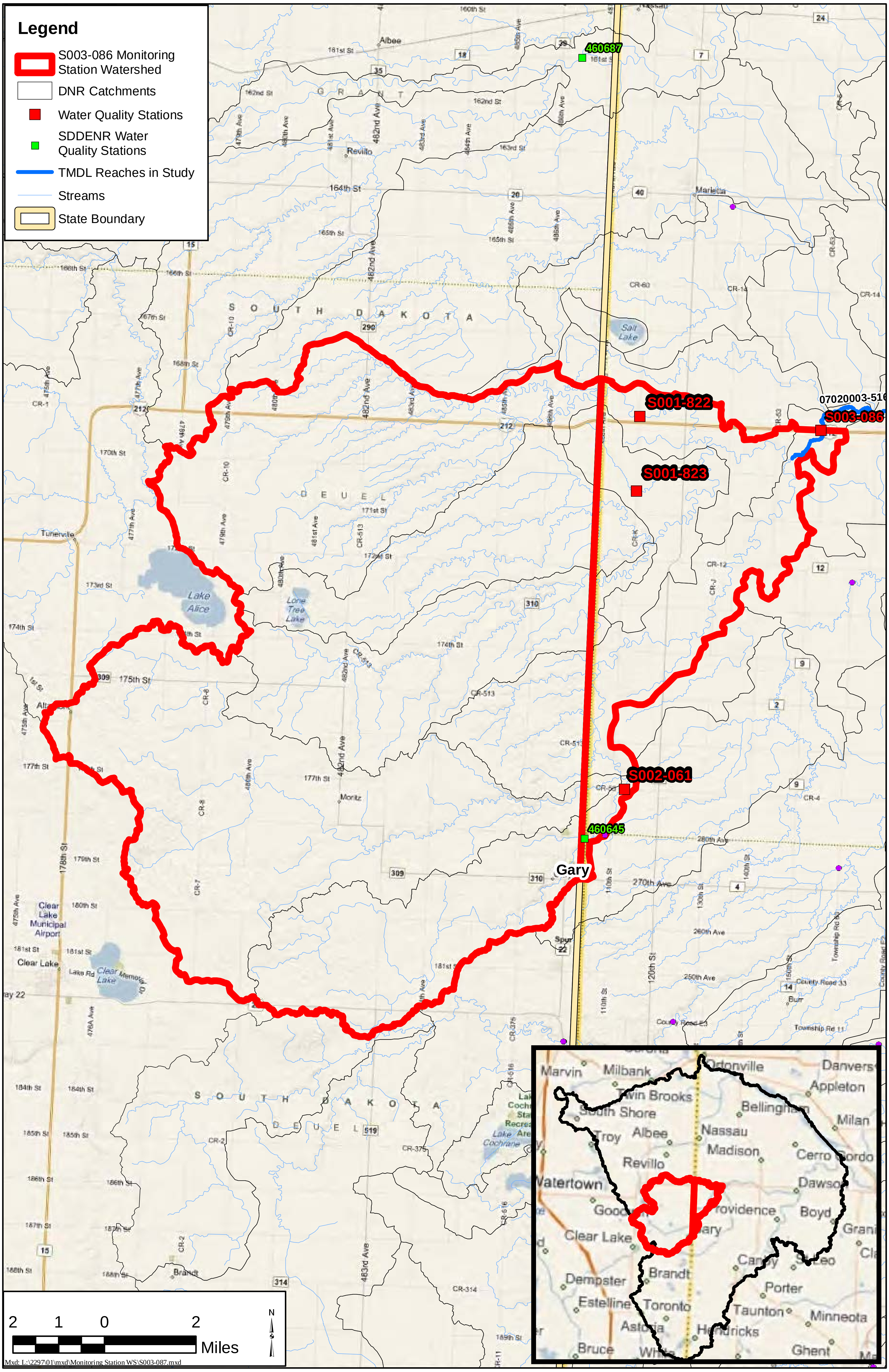
Wenck

Wenck Associates, Inc.
Environmental Engineers

1800 Pioneer Creek Center
Maple Plain, MN 55359-0429

SEP 2010

MAP B3



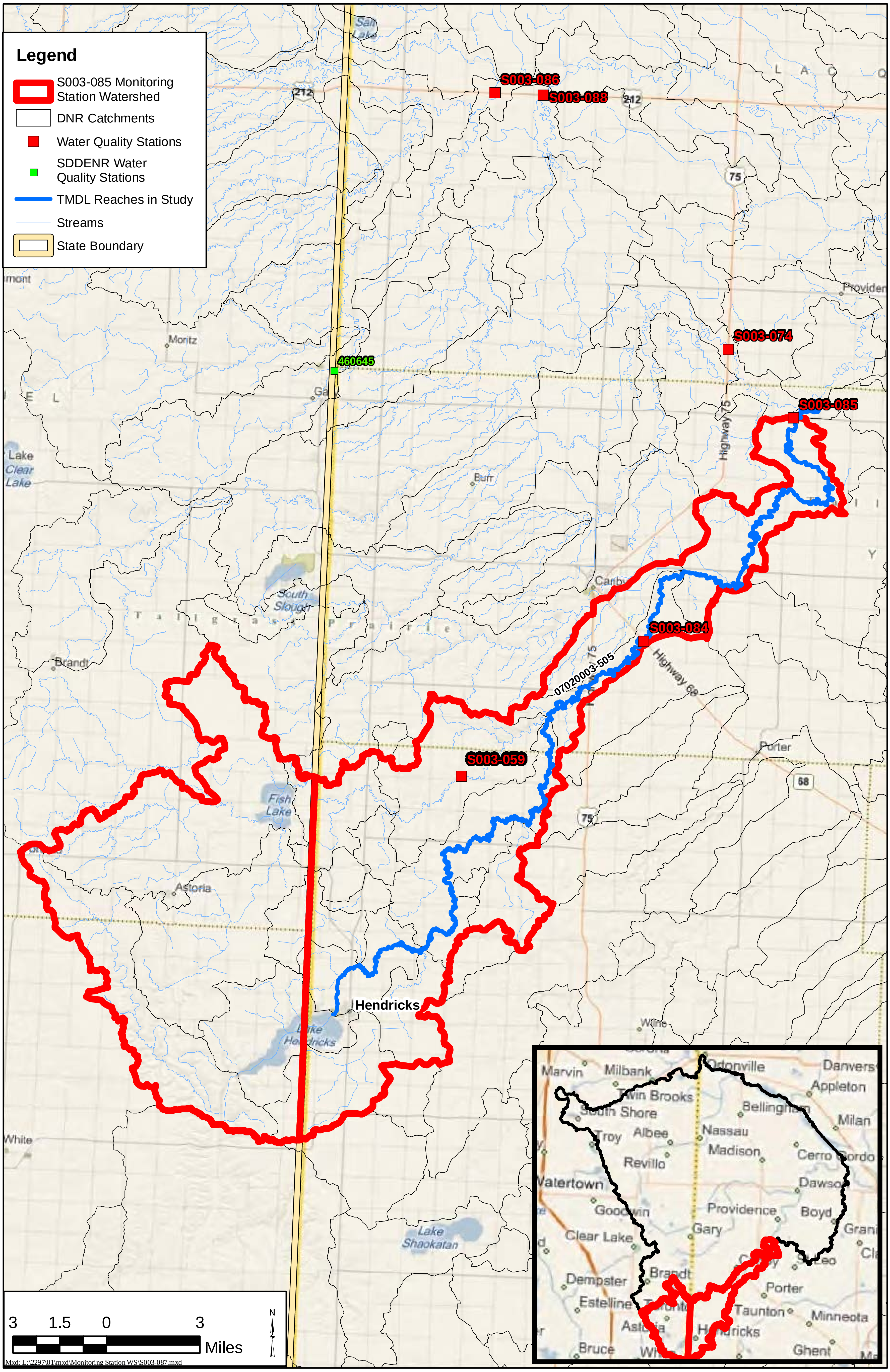
LQPYB CWP TMDL

West Branch Lac Qui Parle River-
Lost Creek to Florida Creek

COPYRIGHT
Wenck
Wenck Associates, Inc. 1800 Pioneer Creek Center
Environmental Engineers Maple Plain, MN 55359-0429

SEP 2010

MAP B4



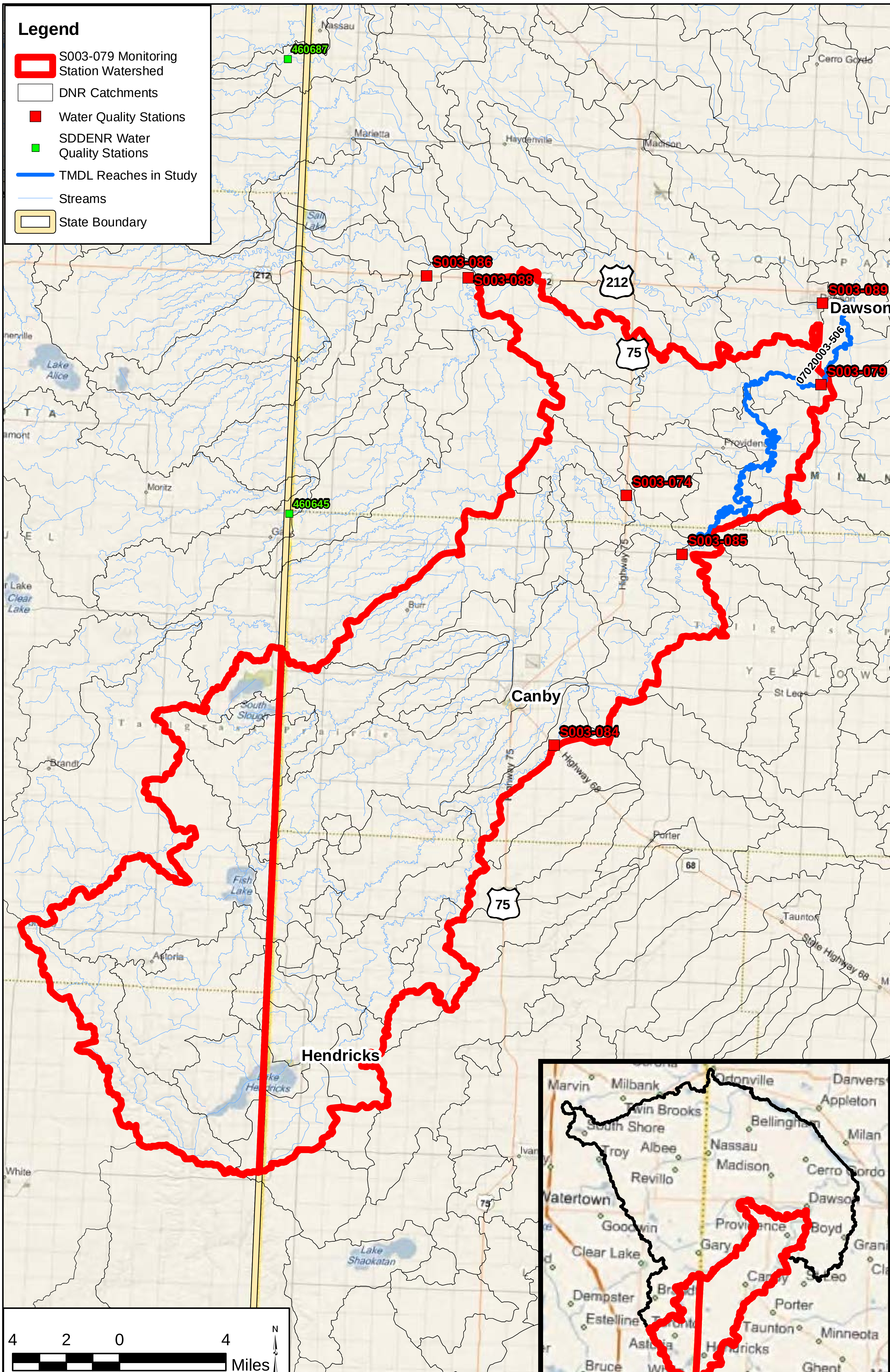
LQPYB CWP TMDL

Lac Qui Parle River-Headwaters to Lazarus Creek

COPYRIGHT
Wenck
Wenck Associates, Inc. 1800 Pioneer Creek Center
Environmental Engineers Maple Plain, MN 55359-0429

SEP 2010

MAP B5



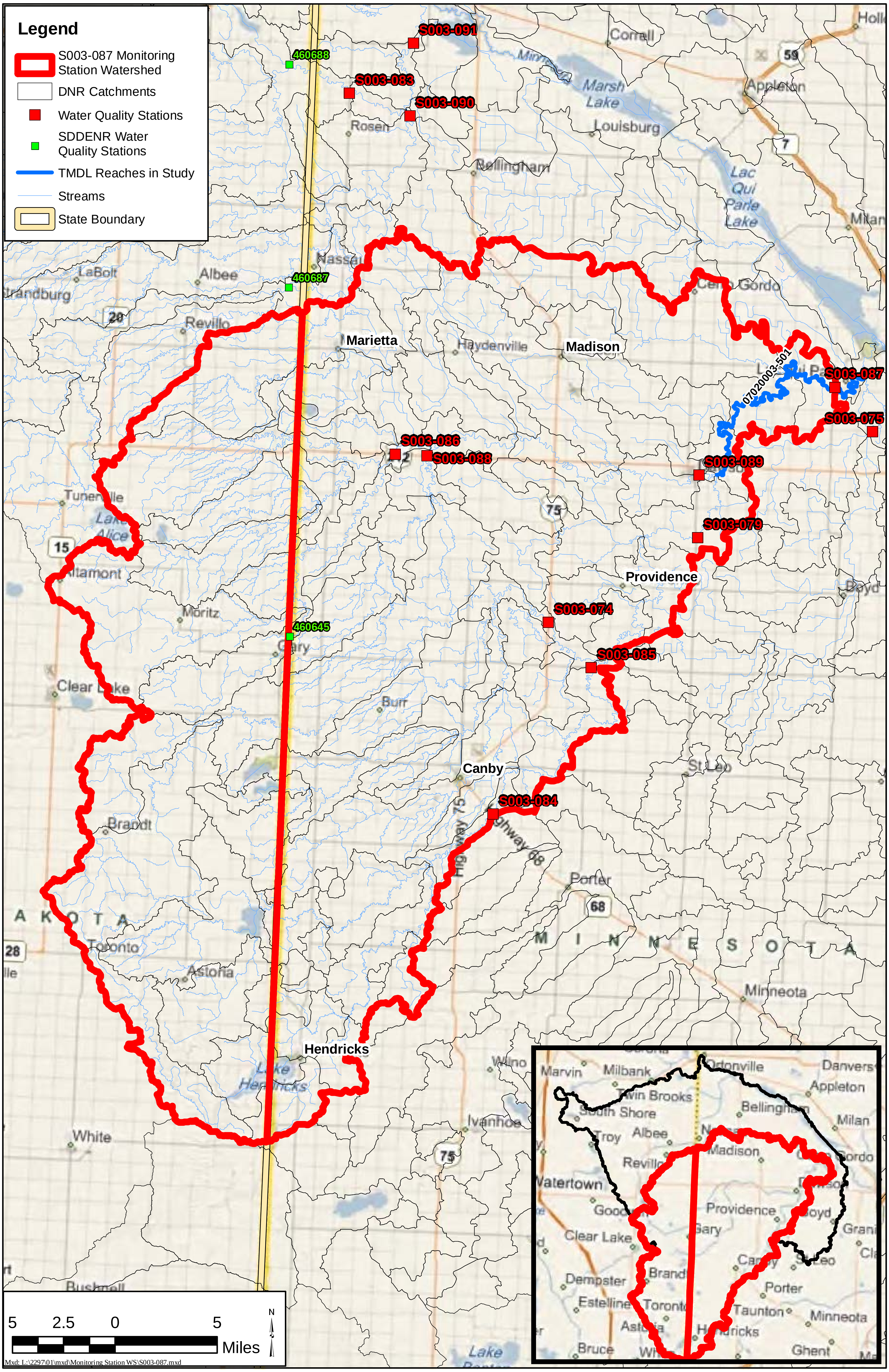
LQPYB CWP TMDL

Lac Qui Parle River-
Lazarus Creek to West Branch Lac Qui Parle River

COPYRIGHT
Wenck
Wenck Associates, Inc. Environmental Engineers
1800 Pioneer Creek Center Maple Plain, MN 55359-0429

SEP 2010

MAP B6



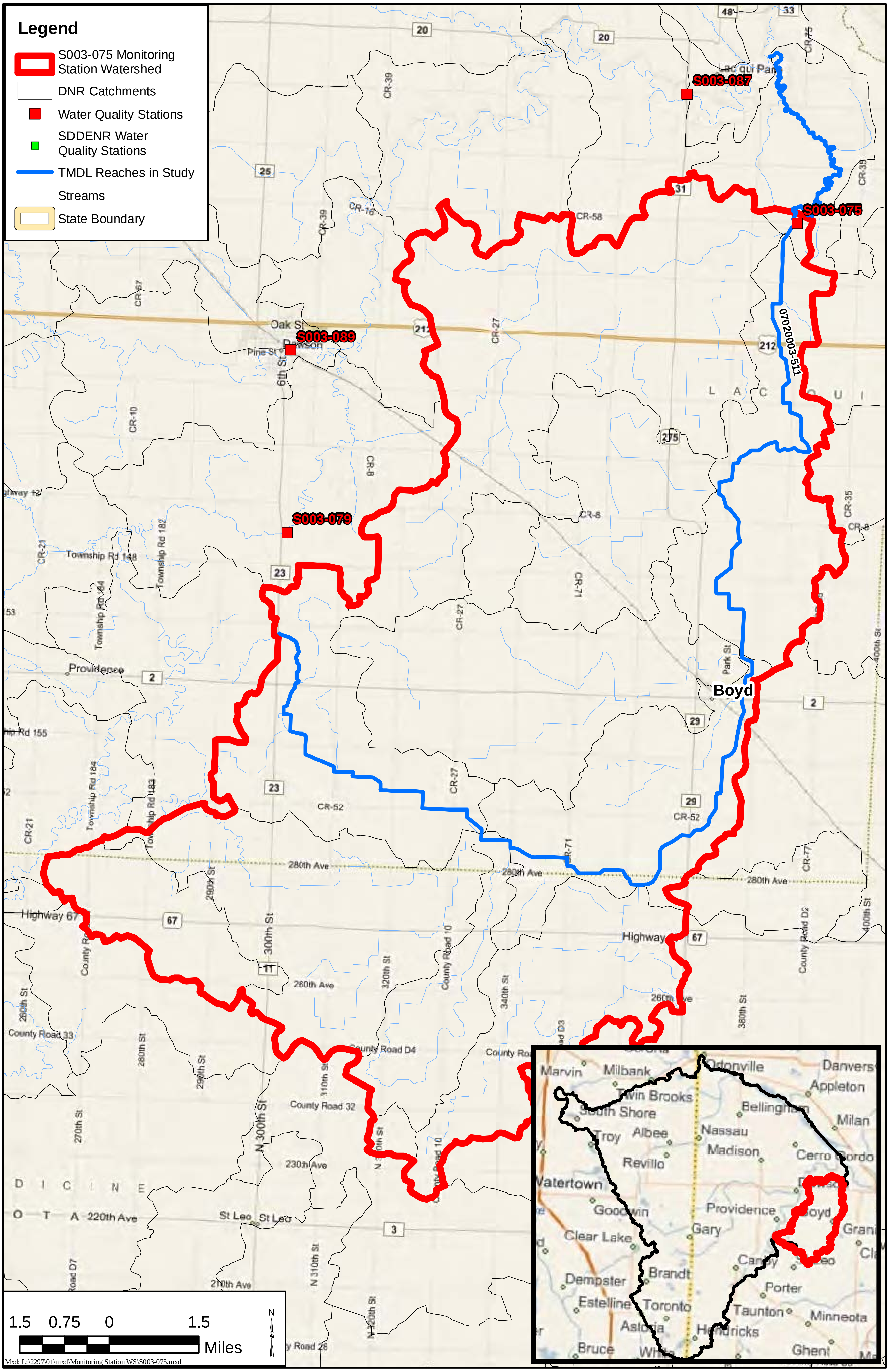
LQPYB CWP TMDL

Lac Qui Parle River-
West Branch Lac Qui Parle River to 10-Mile Creek

COPYRIGHT
Wenck
Wenck Associates, Inc. Environmental Engineers
1800 Pioneer Creek Center Maple Plain, MN 55359-0429

SEP 2010

MAP B7



LQPYB CWP TMDL

Ten-Mile Creek-Headwaters to Lac Qui Parle River

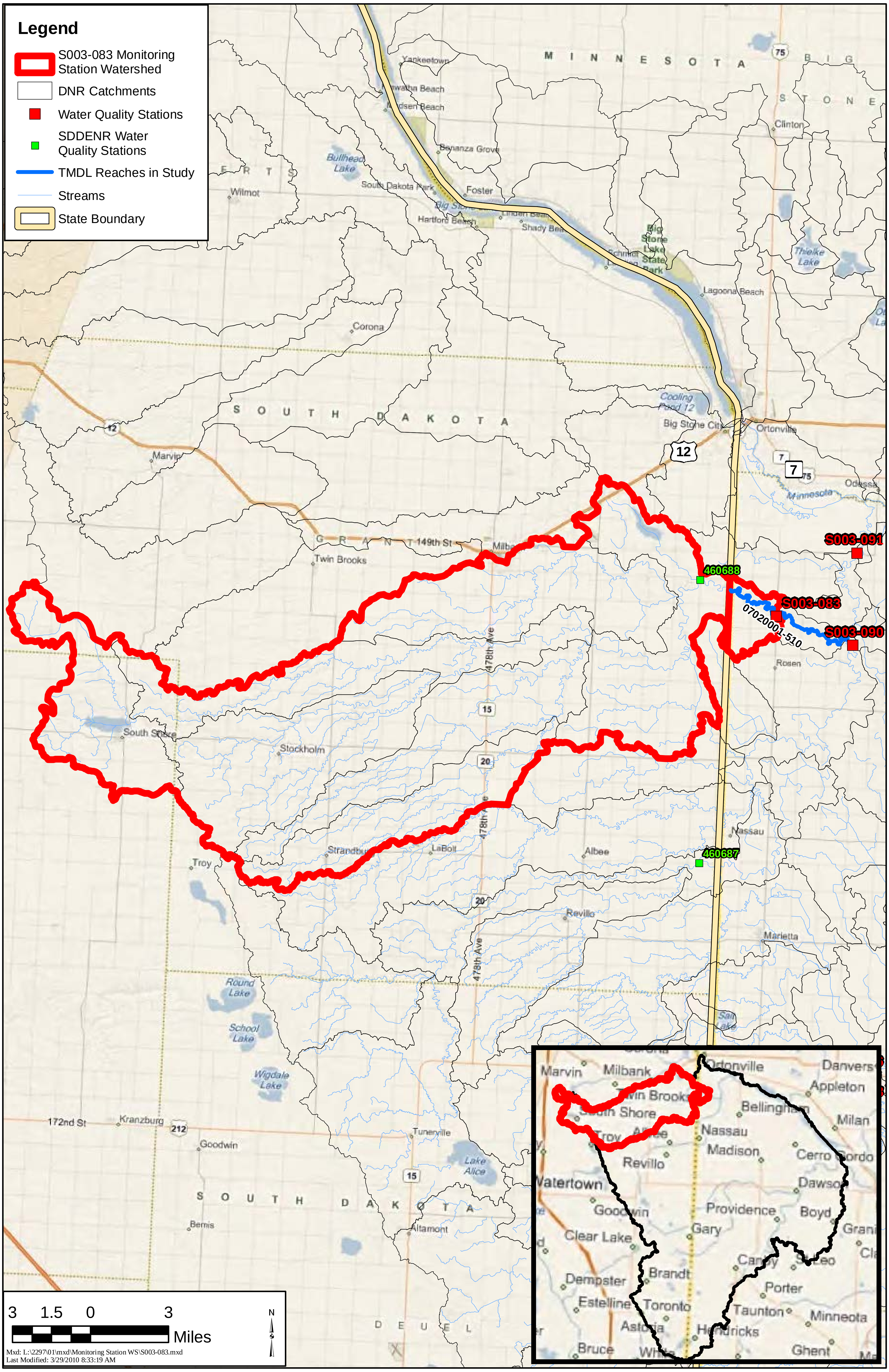
Wenck

Wenck Associates, Inc.
Environmental Engineers

1800 Pioneer Creek Center
Maple Plain, MN 55359-0429

SEP 2010

MAP B8



LQPYB CWP TMDL

North Fork Yellow Bank River-
SD/MN Border to Mainstem

COPYRIGHT

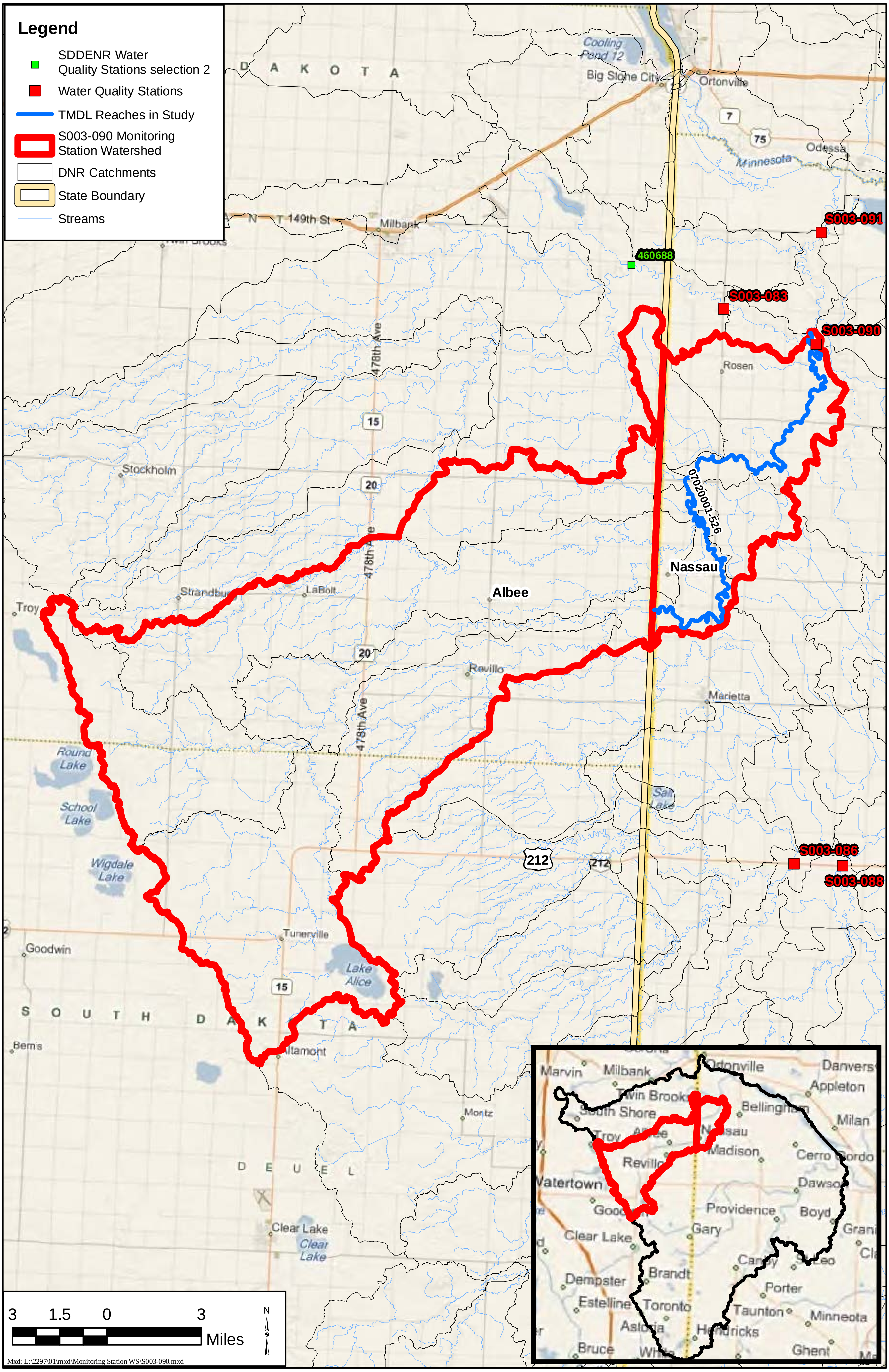
Wenck

Wenck Associates, Inc.
Environmental Engineers

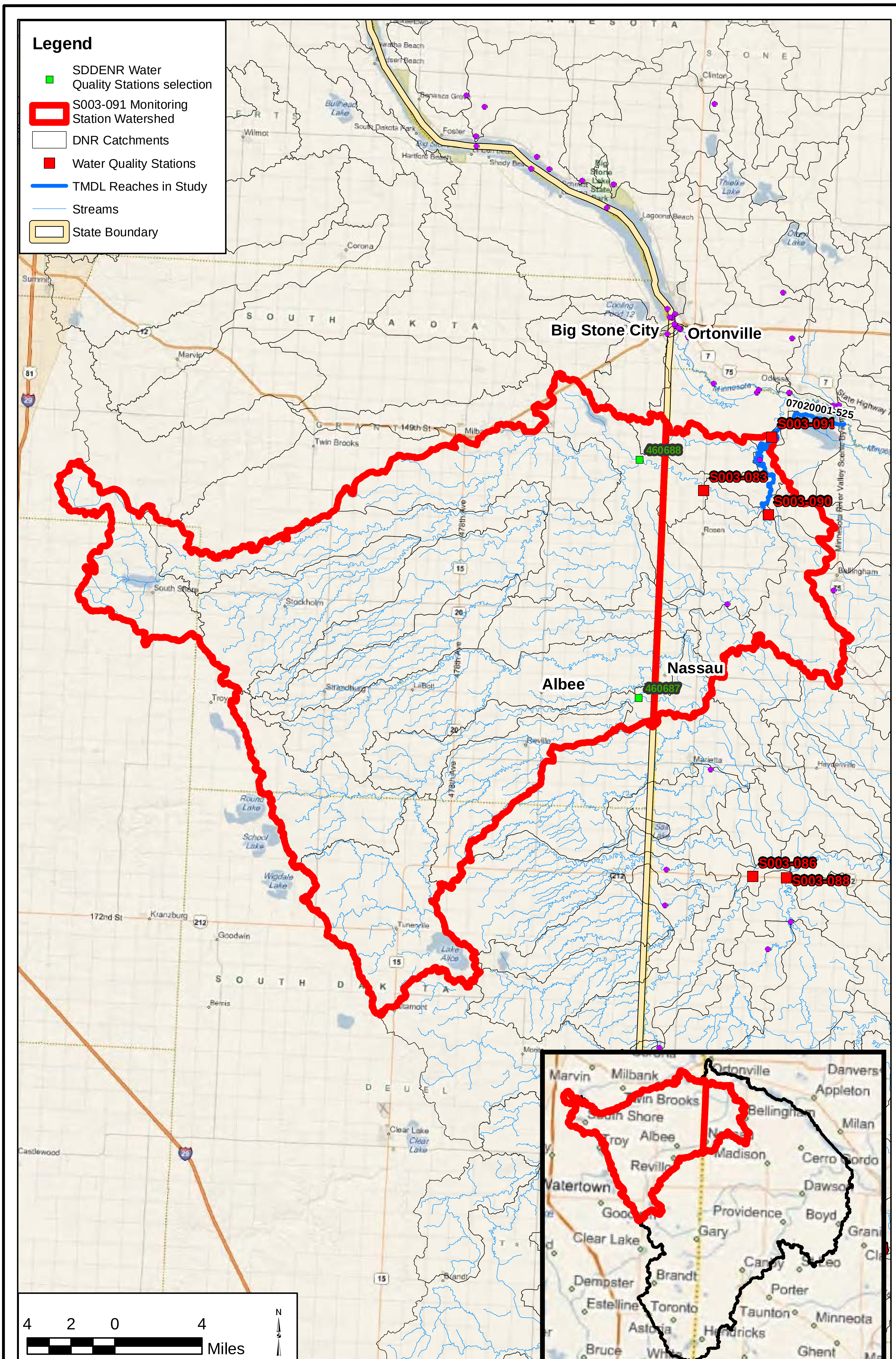
1800 Pioneer Creek Center
Maple Plain, MN 55359-0429

SEP 2010

MAP B9



LQPYB CWP TMDL	Wenck Associates, Inc. Environmental Engineers 1800 Pioneer Creek Center Maple Plain, MN 55359-0429	SEP 2010
South Fork Yellow Bank River- MN/SD Border to Mainstem		MAP B10



LQPYB CWP TMDL

Yellow Bank River-North Fork to Minnesota River

COPYRIGHT Wenck

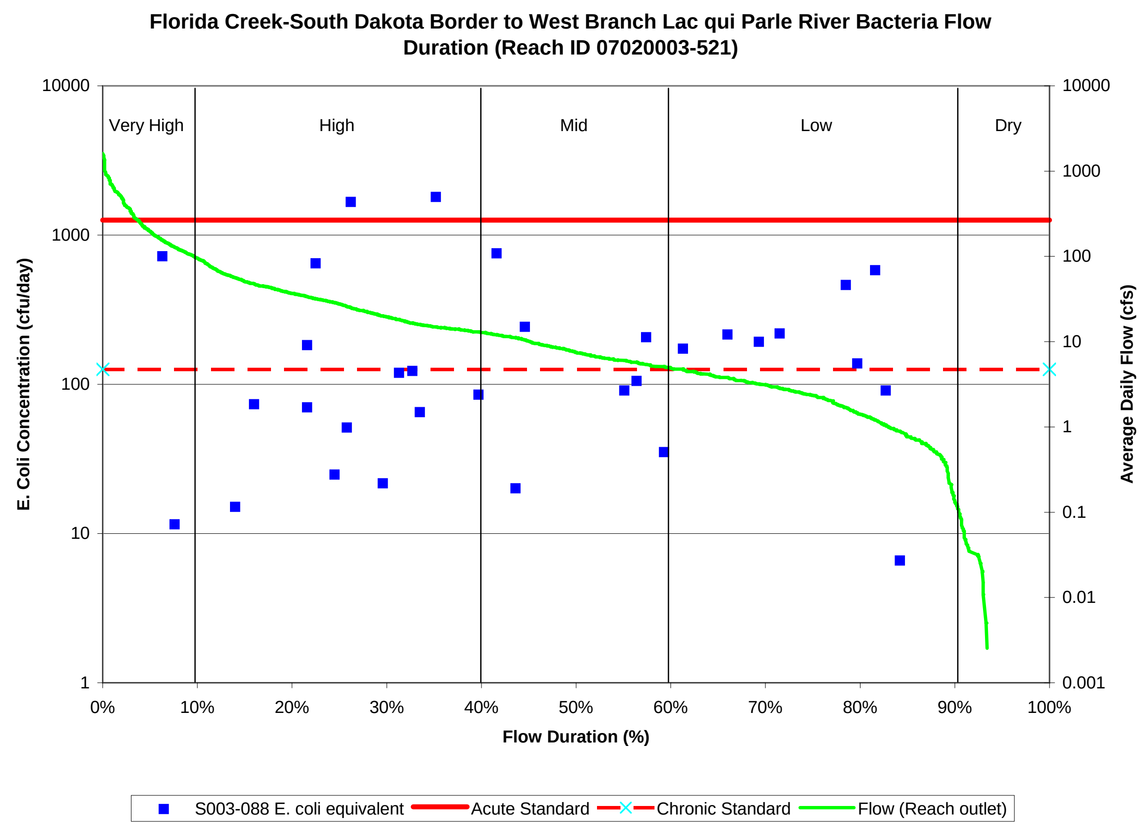
Wenck Associates, Inc.
Environmental Engineers

1800 Pioneer Creek Center
Maple Plain, MN 55359-0429

SEP 2010

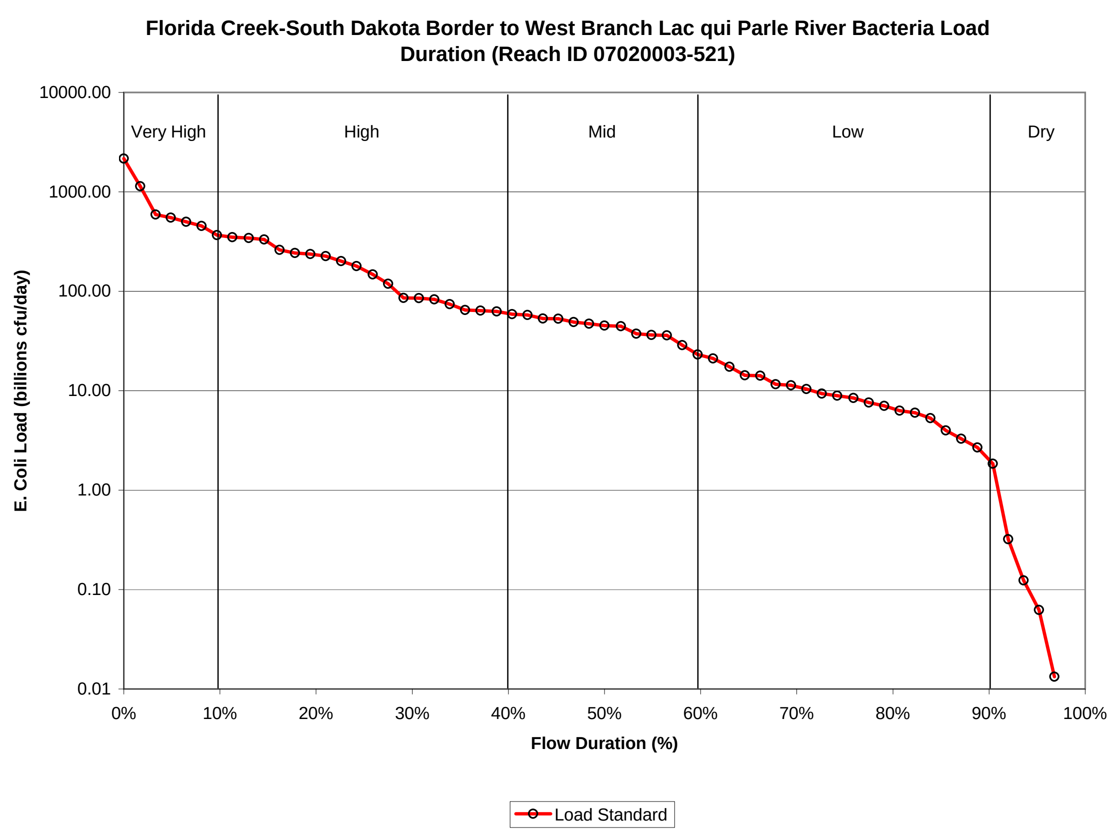
MAP B11

Appendix C



Note: Figure uses flow frequency developed for bottom of reach and bacteria concentrations from station(s) shown.

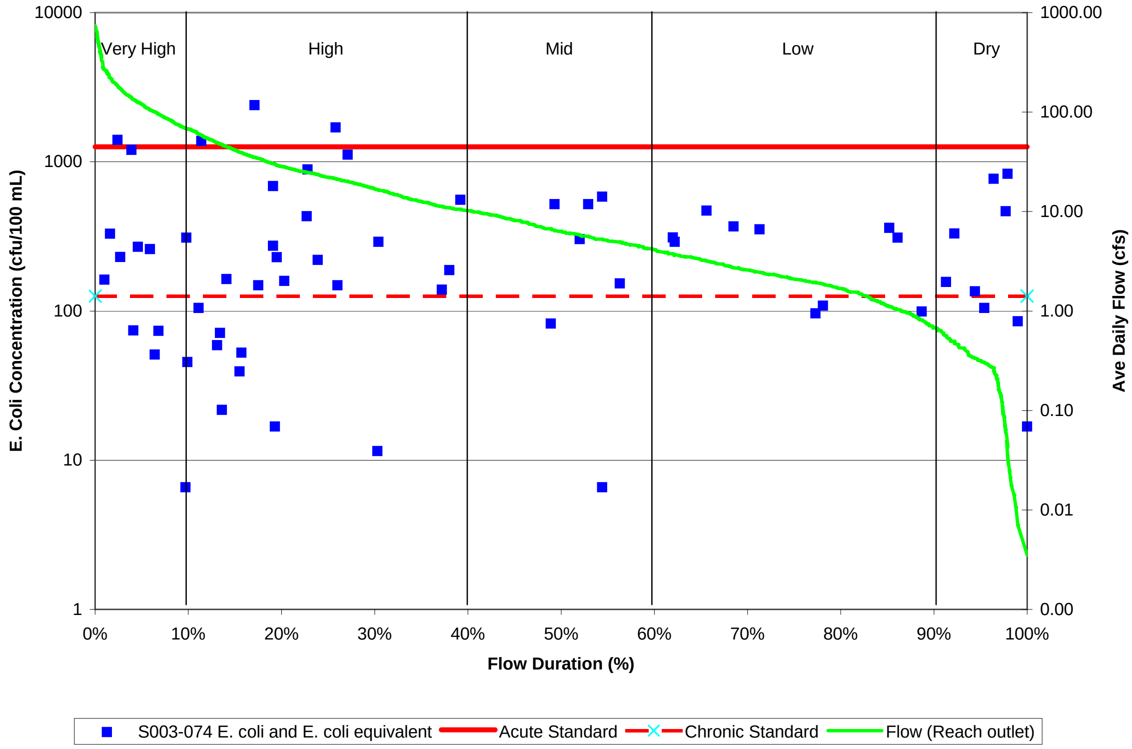
T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Florida Creek\Revised_09232010_521_Bacteria_FlowDurationFigure_Daily_Conc



Note: Figure uses flow frequency developed for entire reach and TSS concentrations from S003-088.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Florida Creek\07020003_521_Bacteria_allocationsFigure_Daily

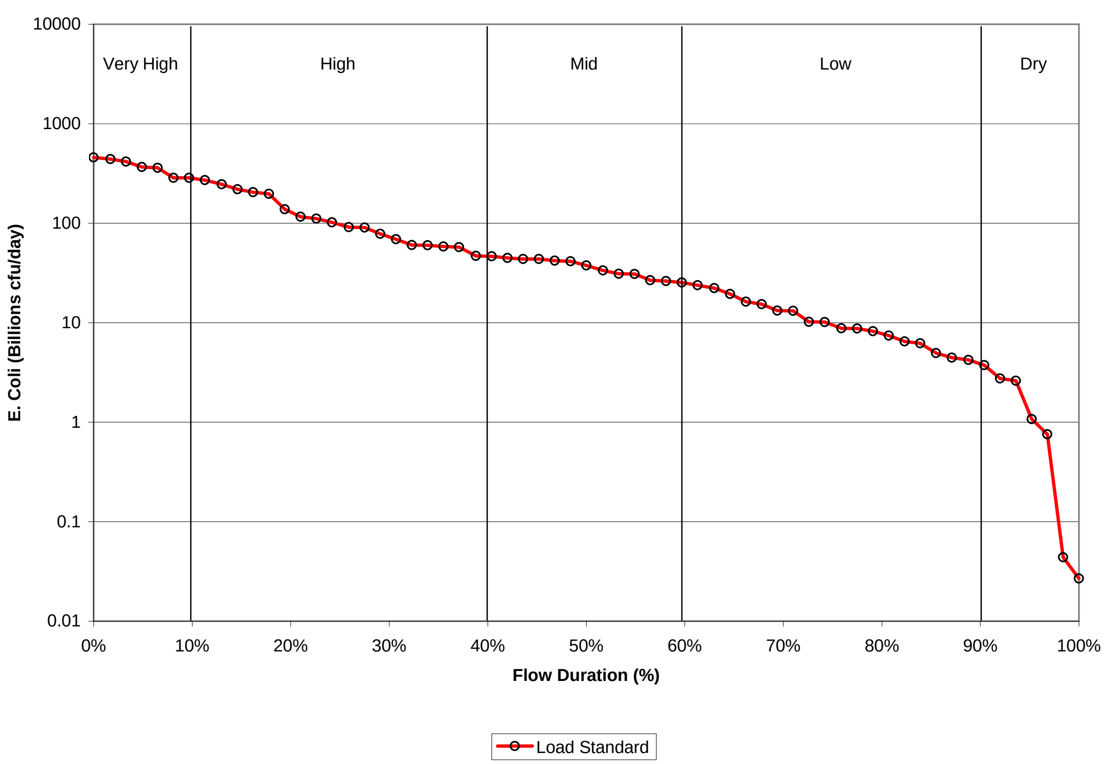
Lazarus Creek-Canby Creek to Lac qui Parle River Bacteria Flow Duration (Reach ID 07020003-508)



Note: Figure uses flow frequency developed for bottom of reach and bacteria concentrations from station(s) shown.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\lazarus Creek\Revised_09232010_508_Bacteria_FlowDurationFigure_FlowDuration

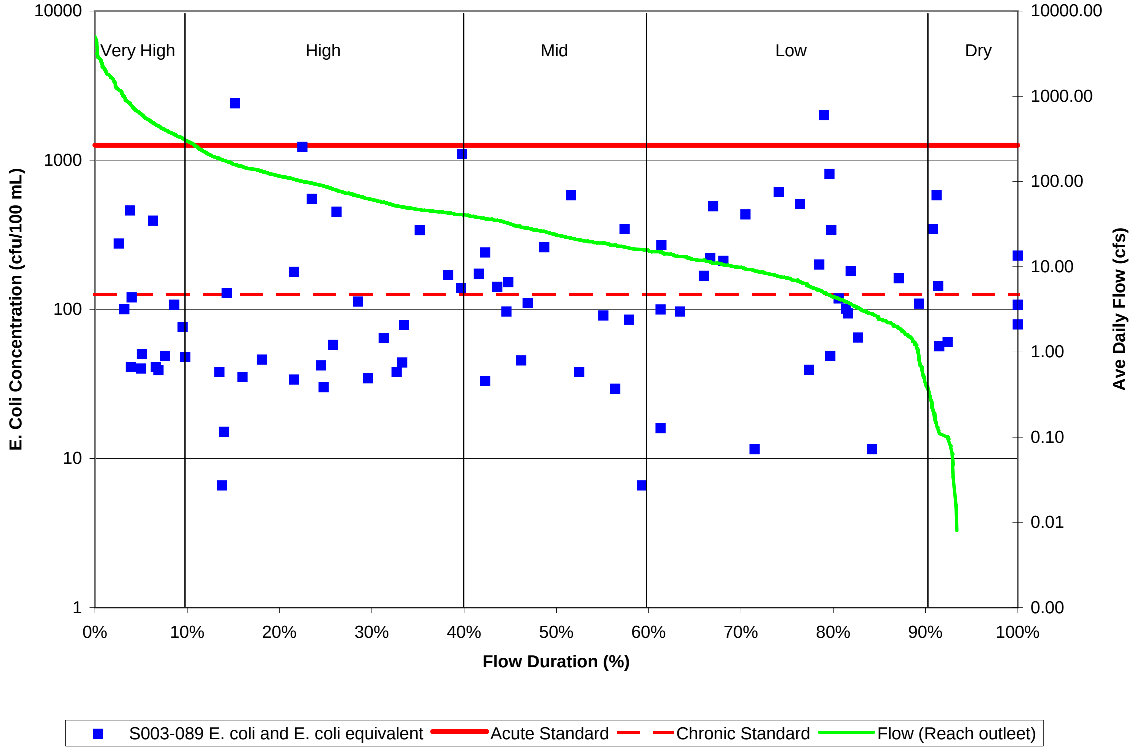
Lazarus Creek-Canby Creek to Lac qui Parle River Bacteria Load Duration (Reach ID 07020003-508)



Note: Figure uses flow frequency developed for entire reach and TSS concentrations from S003-074.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\lazarus Creek\Revised_09232010_508_Bacteria_allocationsFigure_S003-074

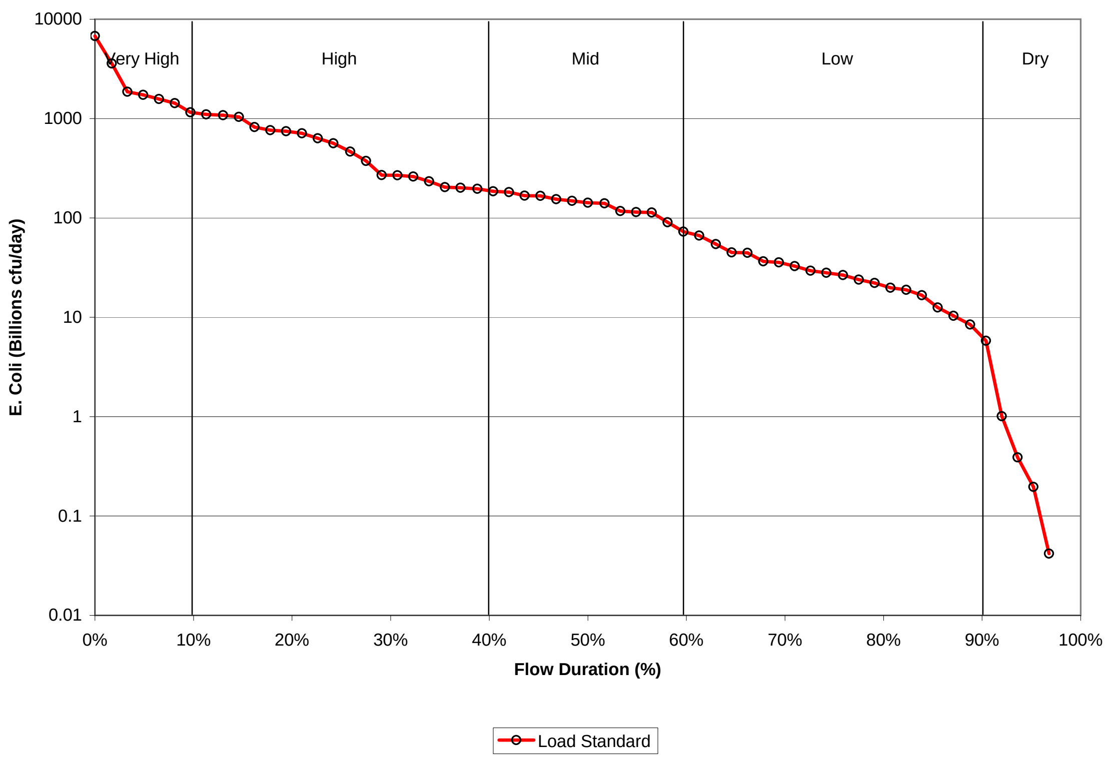
West Branch La qui Parle River-Unnamed Ditch to Unnamed Creek Bacteria Flow Duration (Reach ID 07020003-512)



Note: Figure uses flow duration developed for bottom of reach and bacteria concentrations from stations(s) as shown.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\W Br Laq Qui Parle\Revised_09232010_512_Bacteria_FlowDuration.xlsFigure_FlowDuration

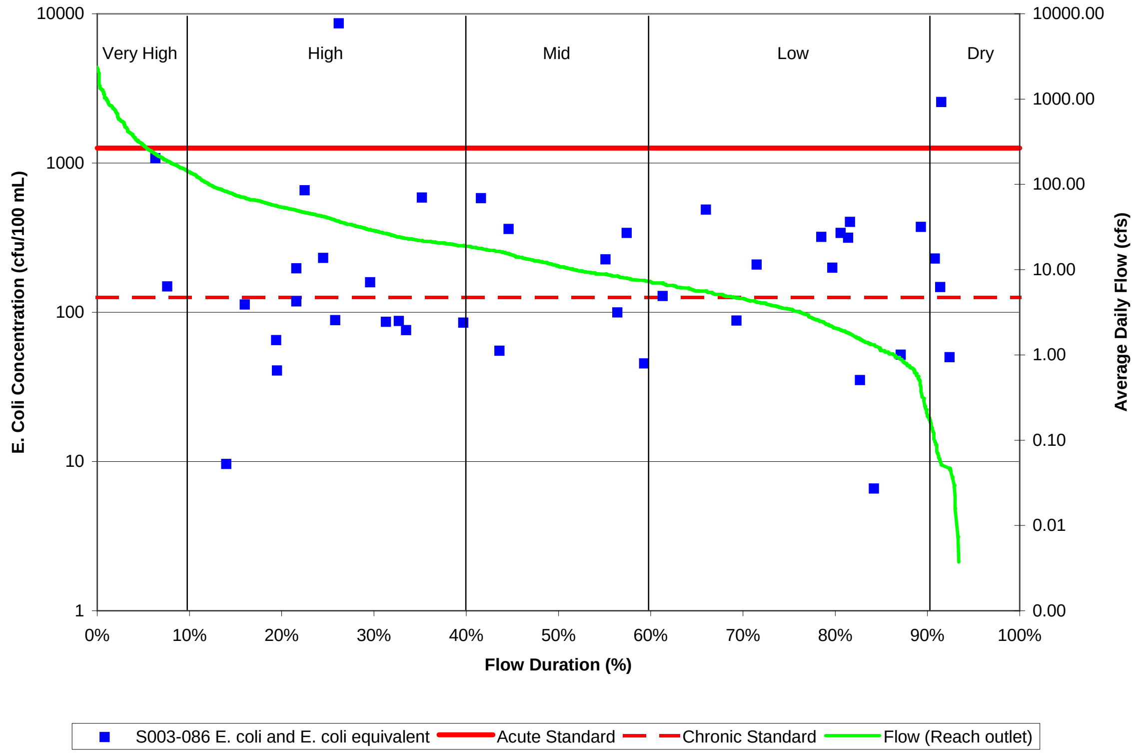
West Branch La qui Parle River-Unnamed Ditch to Unnamed Creek Bacteria Load Duration (Reach ID 07020003-512)



Note: Figure uses flow duration developed for entire reach and Bacteria concentrations from S003-089.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\W Br Laq Qui Parle\Revised_09232010_512_Bacteria_allocations.xlsFigure_S003-089

West Branch Lac qui Parle River-Lost Creek to Florida Creek Bacteria Flow Duration (Reach ID 07020003-516)



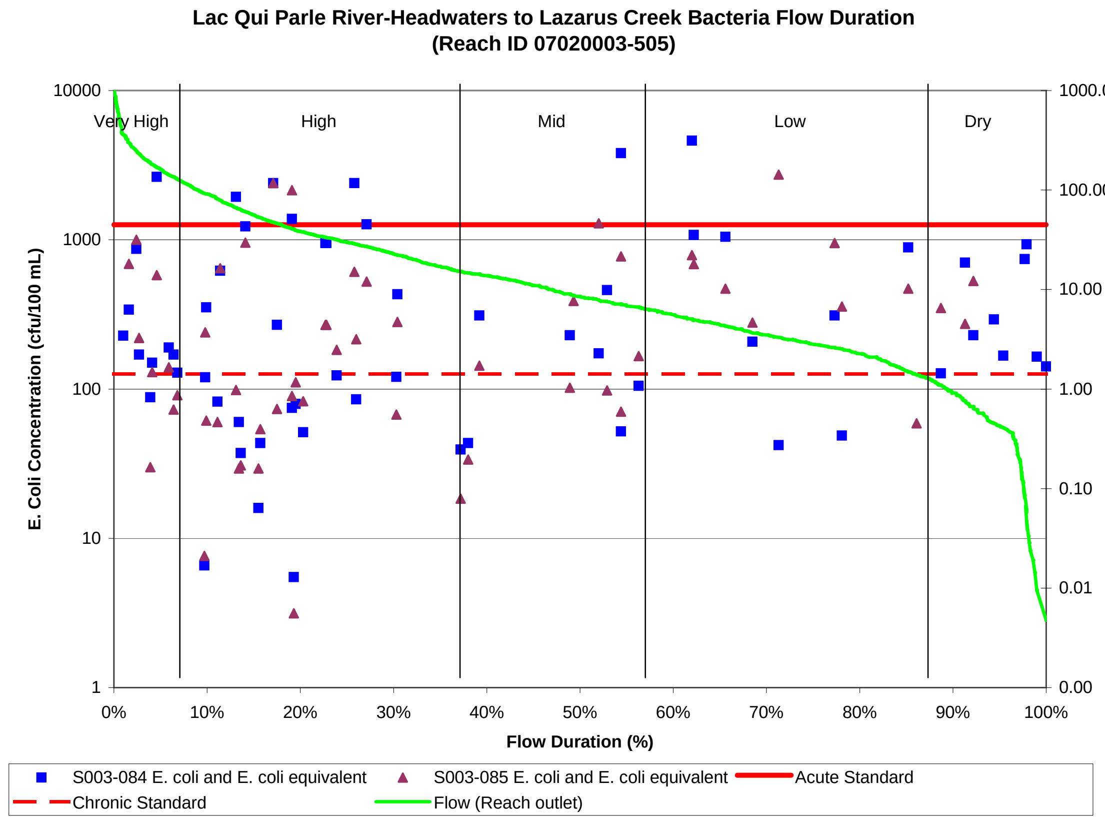
Note: Figure uses flow duration developed for bottom of reach and bacteria concentrations from station(s) shown

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\W Br Laq Qui Parle\Revised_09232010_516_Bacteria_FlowDuration.xlsFigure_S003-086

West Branch Lac qui Parle River-Lost Creek to Florida Creek Bacteria Load Duration (Reach ID 07020003-516)

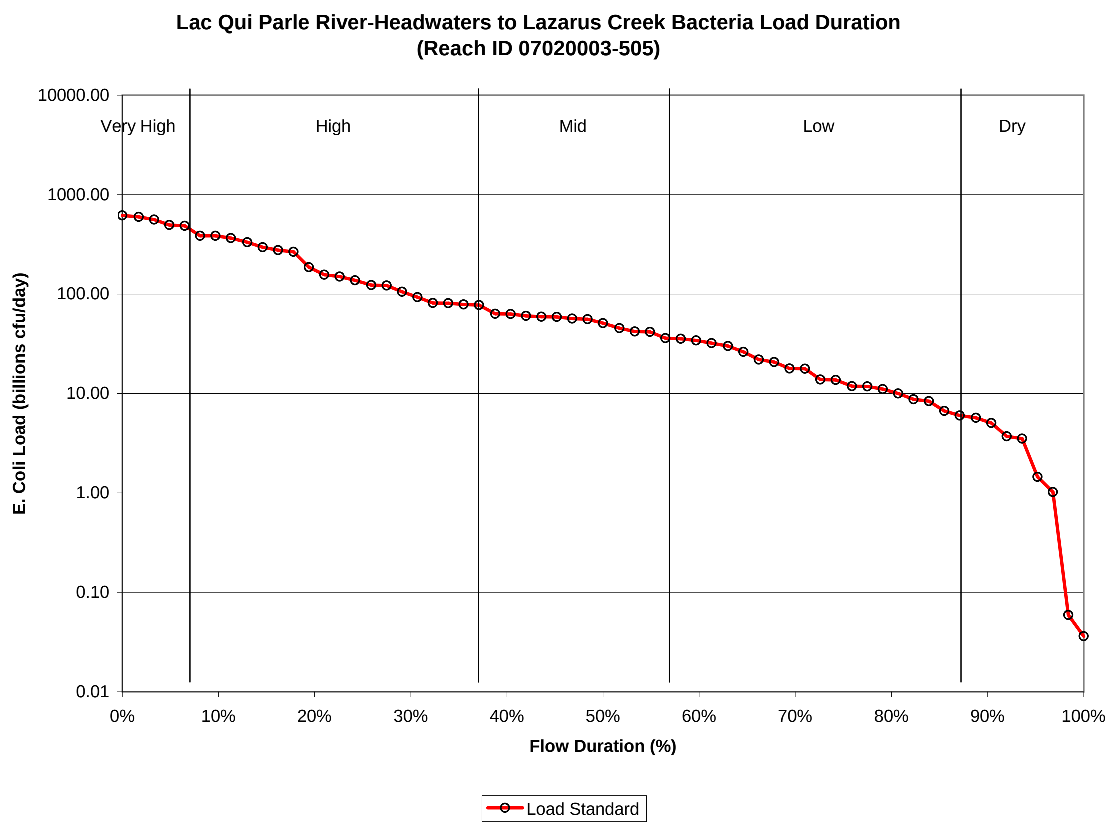
Note: Figure uses flow duration developed for entire reach and TSS concentrations from S003-086.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\W Br Laq Qui Parle\Revised_09232010_516_Bacteria_allocations.xlsFigure_S003-086



Note: Figure uses flow frequency developed for bottom of reach and bacteria concentrations from station(s) shown.

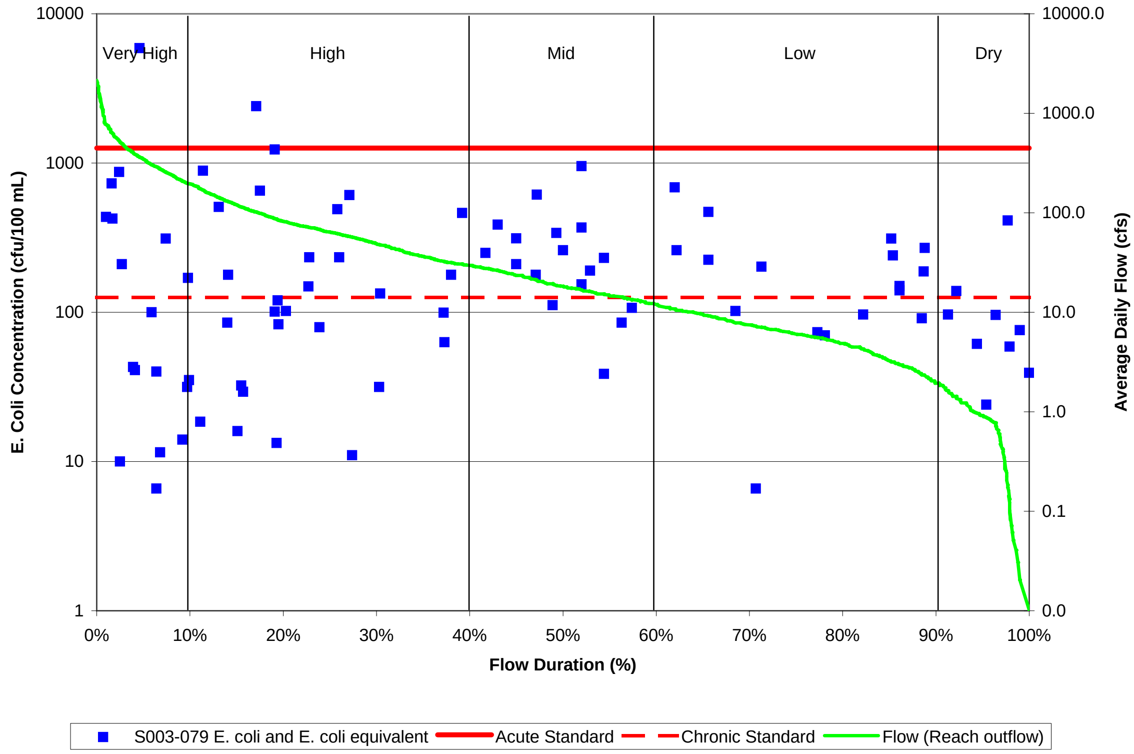
T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Lac Qui Parle\Revised_09232010_505_Bacteria_FlowDurationFigure_FlowDuration



Note: Figure uses flow frequency developed for entire reach and TSS concentrations from S003-084 and S003-085.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Lac Qui Parle\Revised_09232010_505_Bacteria_allocationsFigure_S003-084-085

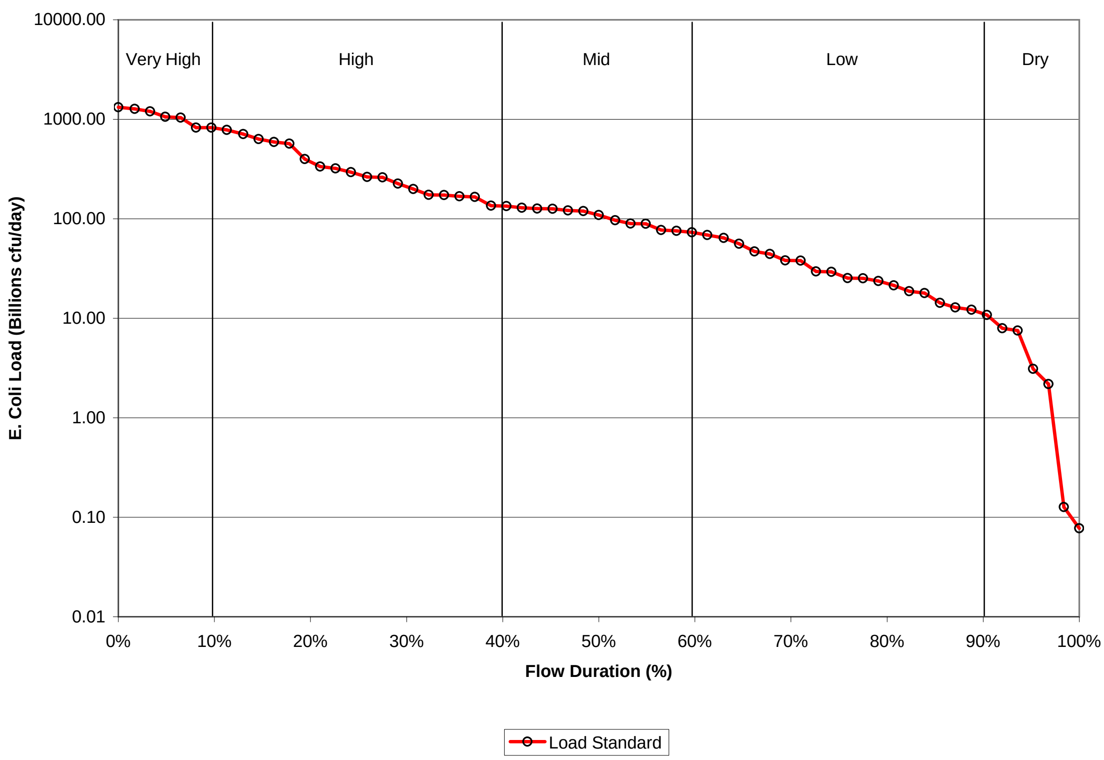
Lac Qui Parle River-Lazarus Creek to West Branch Lac qui Parle River Bacteria Load Duration (Reach ID 07020003-506)



Note: Figure uses flow frequency developed for bottom of reach and bacteria concentrations from stations(s) shown.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Lac Qui Parle\Revised_09232010_506_Bacteria_FlowDurationFigure_S003-079

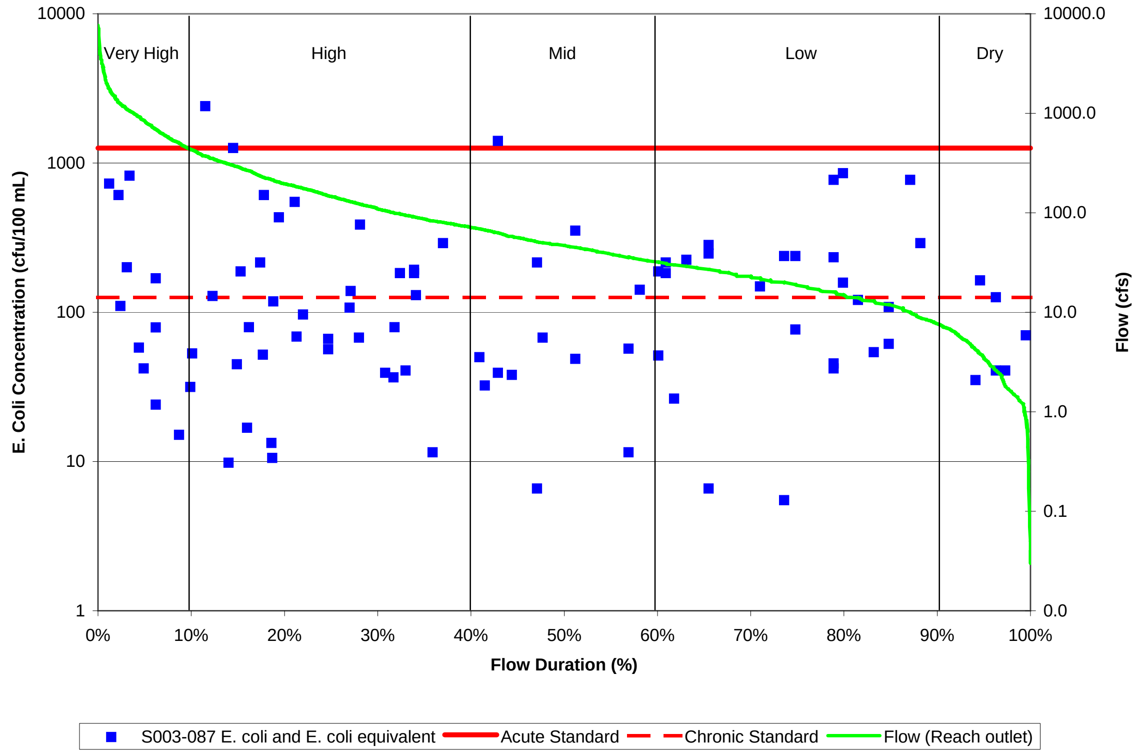
Lac Qui Parle River-Lazarus Creek to West Branch Lac qui Parle River Bacteria Load Duration (Reach ID 07020003-506)



Note: Figure uses flow frequency developed for entire reach and TSS concentrations from S003-079.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Lac Qui Parle\Revised_09232010_506_Bacteria_allocationsFigure_S003-079

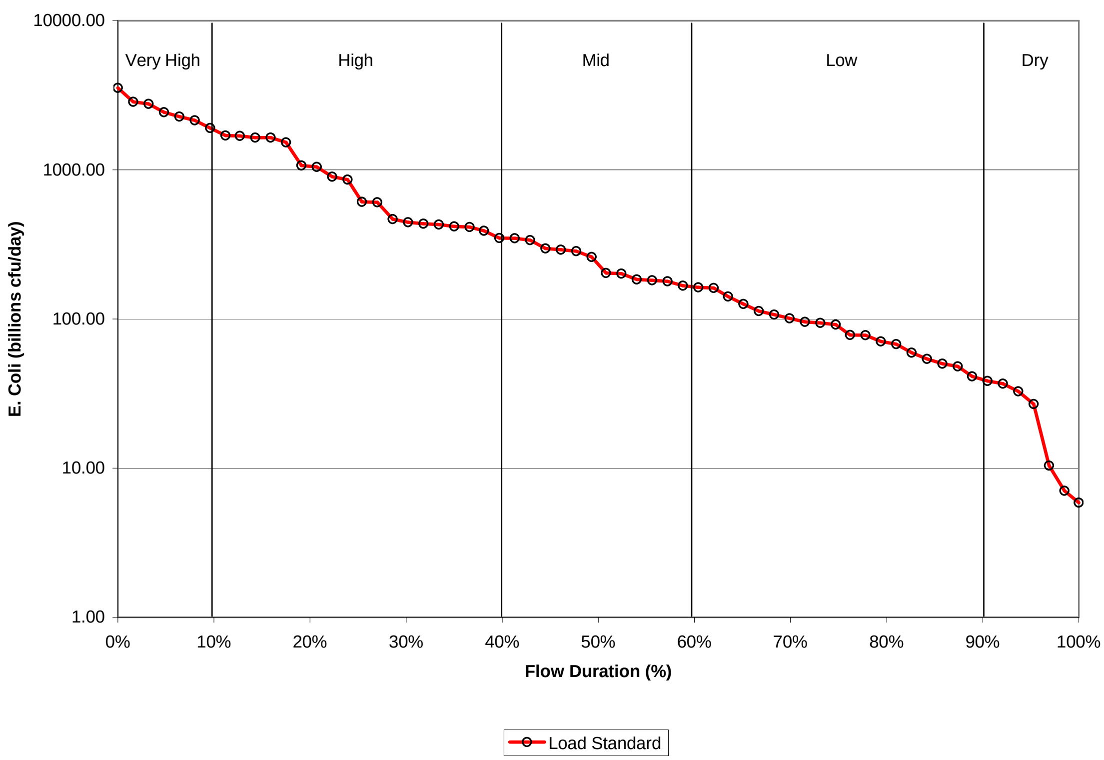
Lac Qui Parle River-West Branch Lac qui Parle River to Ten-Mile Creek Bacteria Flow Duration (Reach ID 07020003-501)



Note: Figure uses flow frequency developed for bottom of reach and bacteria concentrations from stations(s) shown

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Lac Qui Parle\Revised_09232010_501_Bacteria_FlowDurationLoad_Standard

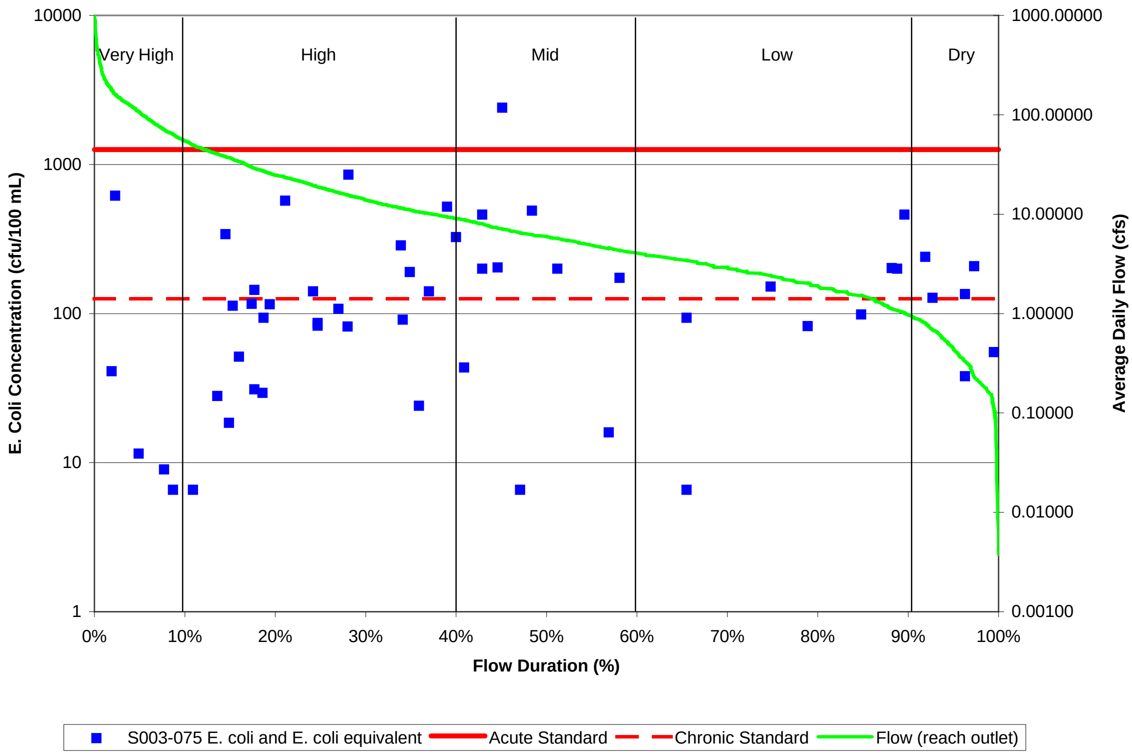
Lac Qui Parle River-West Branch Lac qui Parle River to Ten-Mile Creek Bacteria Load Duration (Reach ID 07020003-501)



Note: Figure uses flow frequency developed for entire reach and TSS concentrations from S003-087.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Lac Qui Parle\Revised_09232010_501_Bacteria_allocationsLoad_Standard

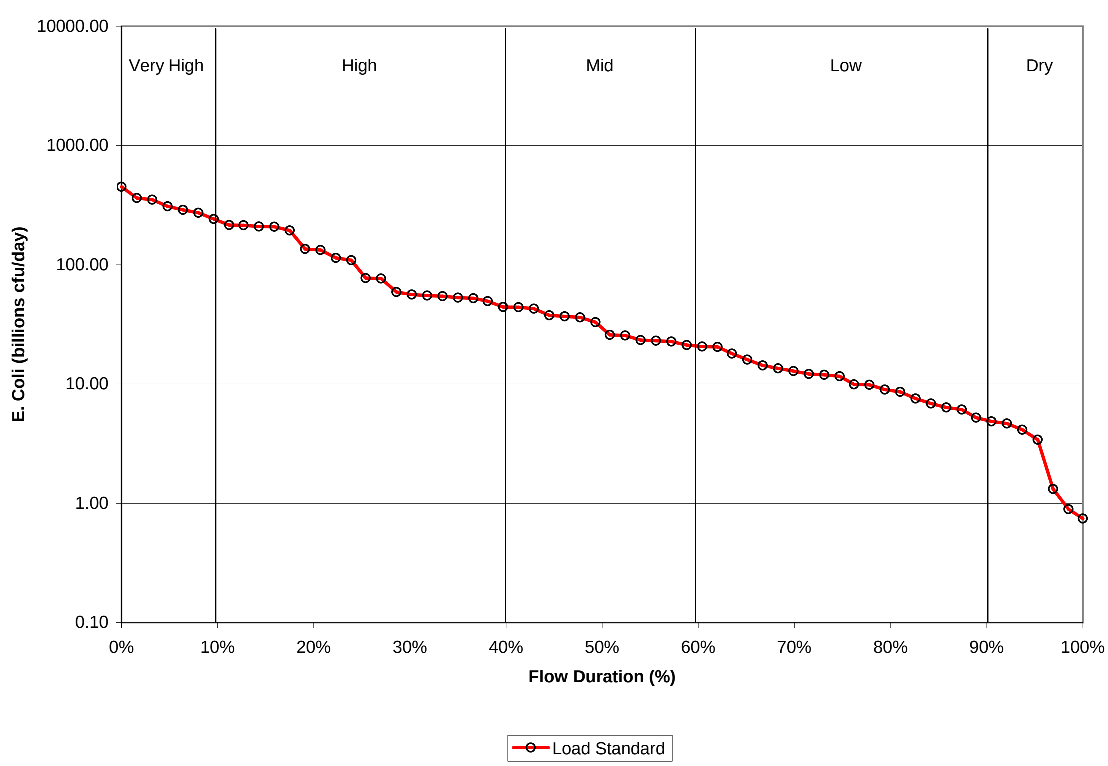
Ten-Mile Creek Bacteria Flow Duration (Reach ID 07020003-511)



Note: Figure uses flow frequency developed for bottom of reach and bacteria concentrations from stations(s) shown

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\10-Mile Creek\Revised_09232010_511_Bacteria_FlowDurationFigure_S003-075

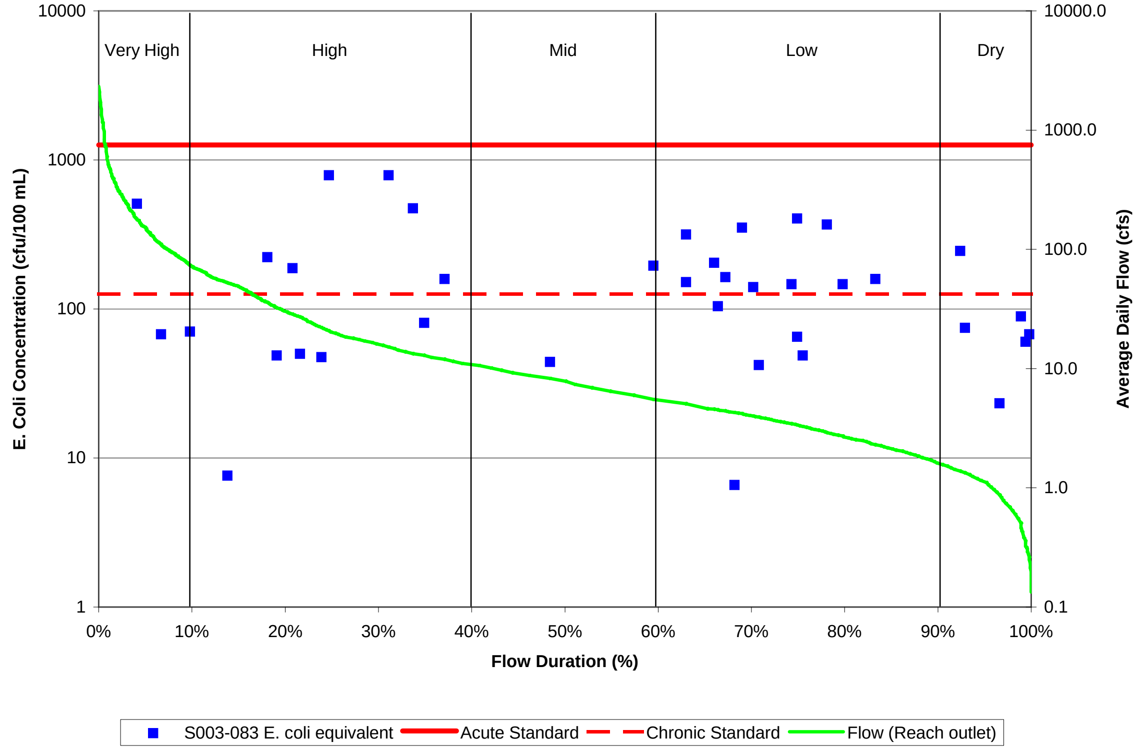
Ten-Mile Creek Bacteria Load Duration (Reach ID 07020003-511)



Note: Figure uses flow frequency developed for entire reach and TSS concentrations from S003-075.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\10-Mile Creek\Revised_09232010_511_Bacteria_allocationsFigure_S003-075

North Fork Yellow Bank River, South Dakota Boarder to Yellow Bank Main Stem Bacteria Flow Duration (Reach ID 07020001-510)



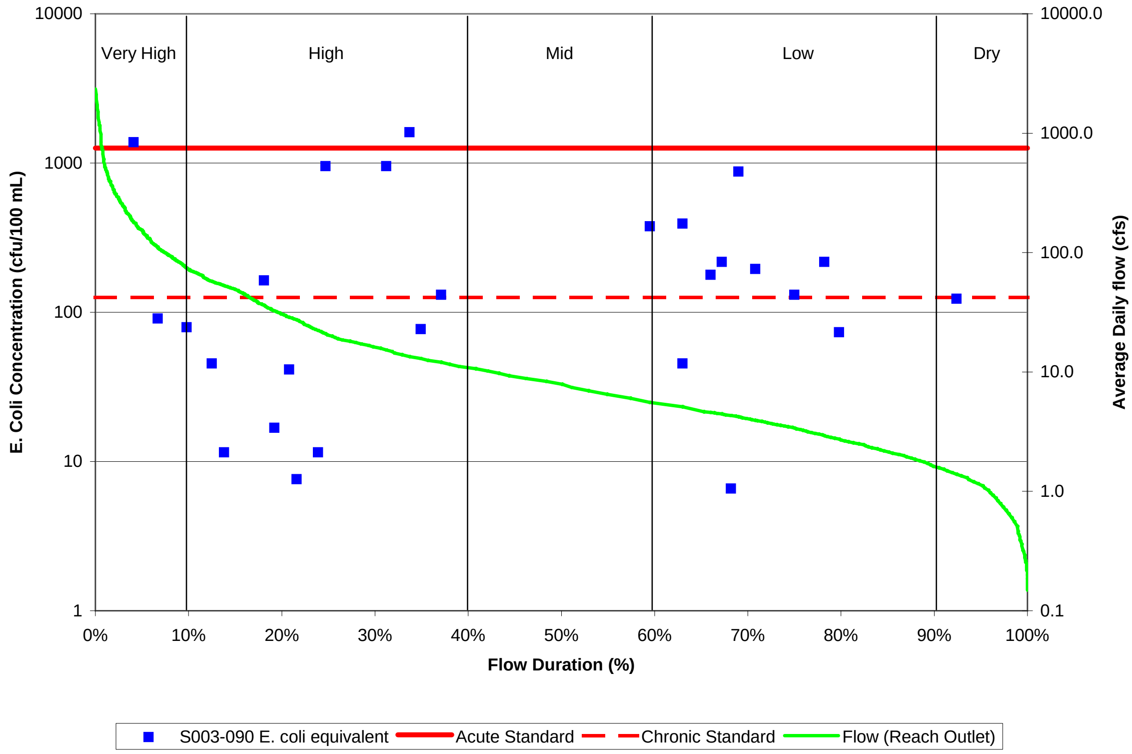
Note: Figure uses flow duration developed for bottom of reach and bacteria concentrations from station(s) as shown

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Yellow Bank\07020003_510_Bacteria_FlowDuration.xlsFigure_S003-083

North Fork Yellow Bank River, South Dakota Boarder to Yellow Bank Main Stem Bacteria Load Duration (Reach ID 07020001-510)

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Yellow Bank\07020001_510_Bacteria_allocations.xlsFigure_S003-083

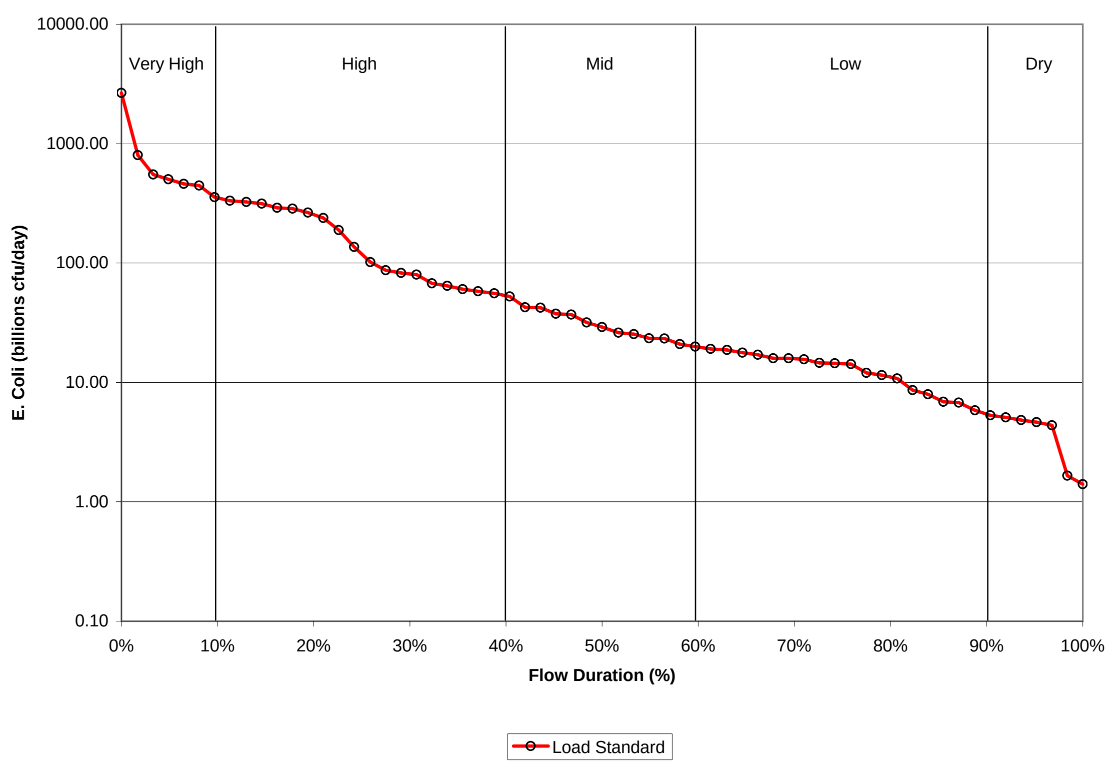
South Fork Yellow Bank River, South Dakota Boarder to Yellow Bank Main Stem Bacteria Flow Duration (Reach ID 07020001-526)



Note: Figure uses flow duration developed for bottom of reach and bacteria concentrations from station(s) as shown

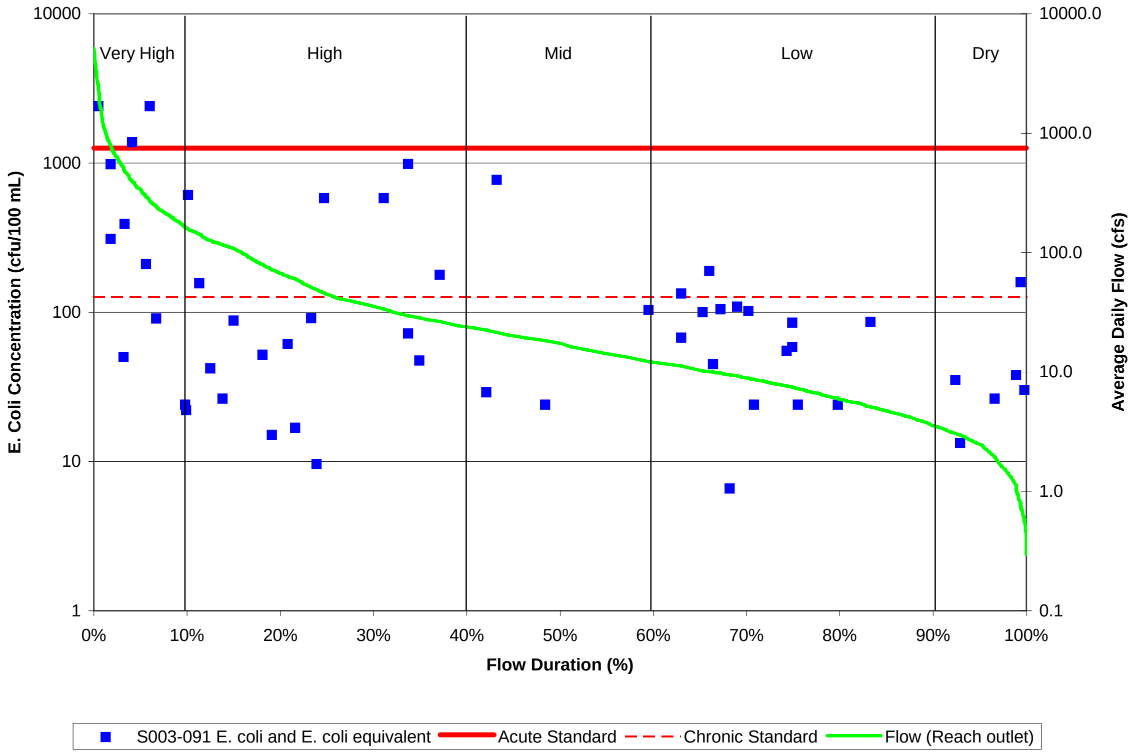
T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Yellow Bank\07020003_526_Bacteria_FlowDuration.xlsFigure_S003-090

South Fork Yellow Bank River, South Dakota Boarder to Yellow Bank Main Stem Bacteria Load Duration (Reach ID 07020001-526)



T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Yellow Bank\07020001_526_Bacteria_allocations.xlsFigure_S003-090

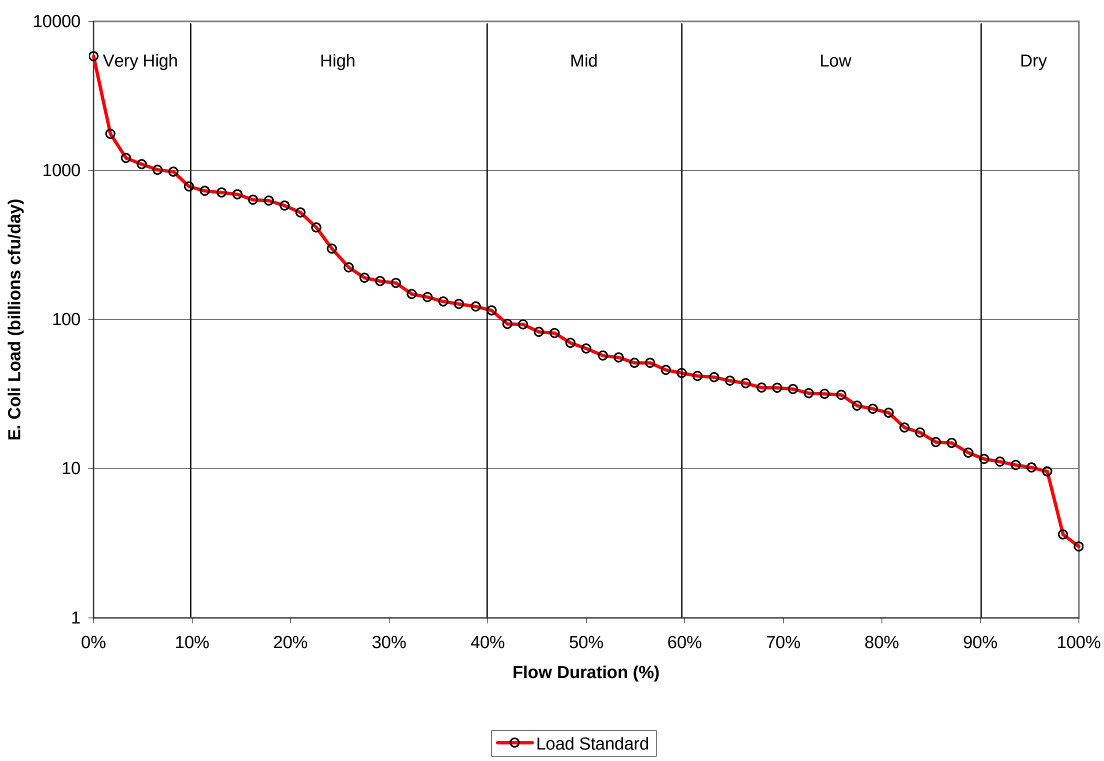
Yellow Bank River-North Fork Yellow Bank River to Minnesota River Bacteria Flow Duration (Reach ID 07020001-525)



Note: Figure uses flow duration developed for bottom of reach and bacteria concentrations from station(s) as shown

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Yellow Bank\07020001_525_Bacteria_FlowDuration.xlsFigure_S003-091

Yellow Bank River-North Fork Yellow Bank River to Minnesota River Bacteria Load Duration (Reach ID 07020001-525)

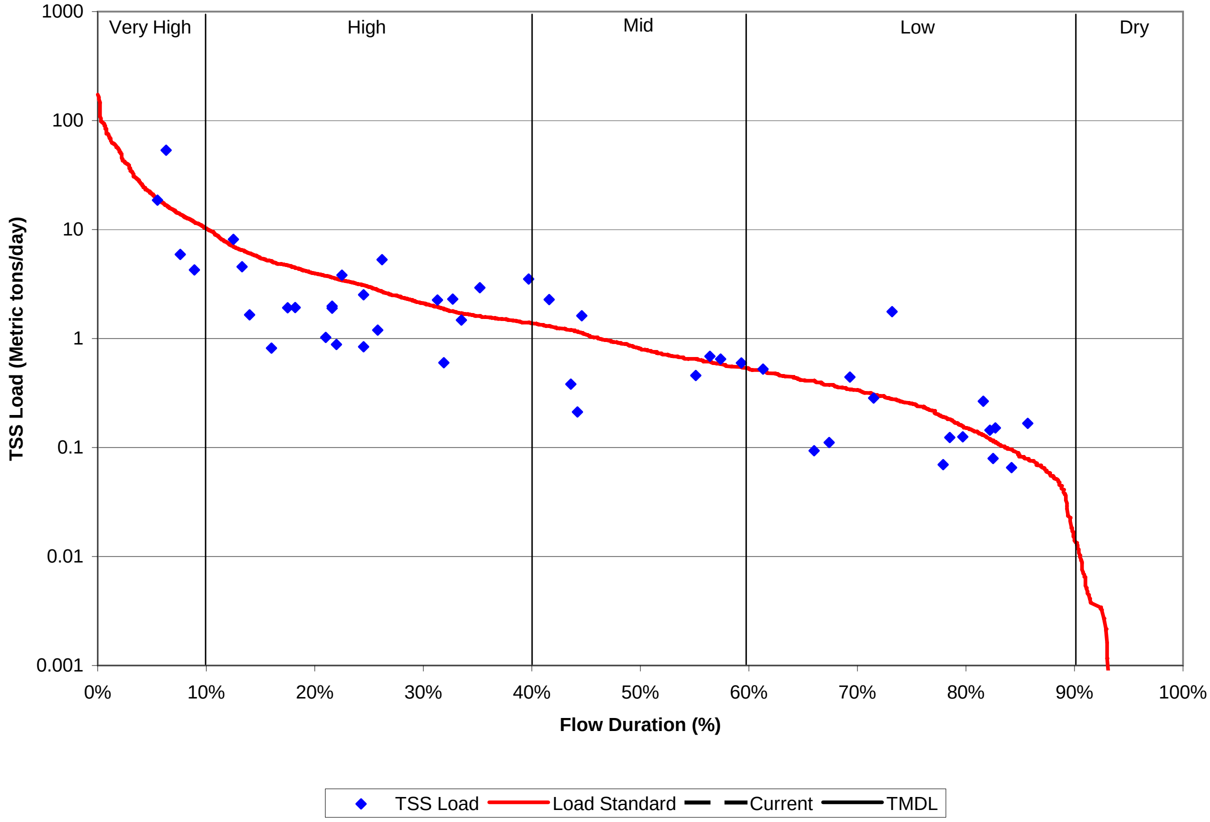


Note: Figure uses flow duration developed for entire reach and TSS concentrations from S003-091.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Yellow Bank\07020001_525_Bacteria_allocations.xlsFigure_S003-091

Appendix D

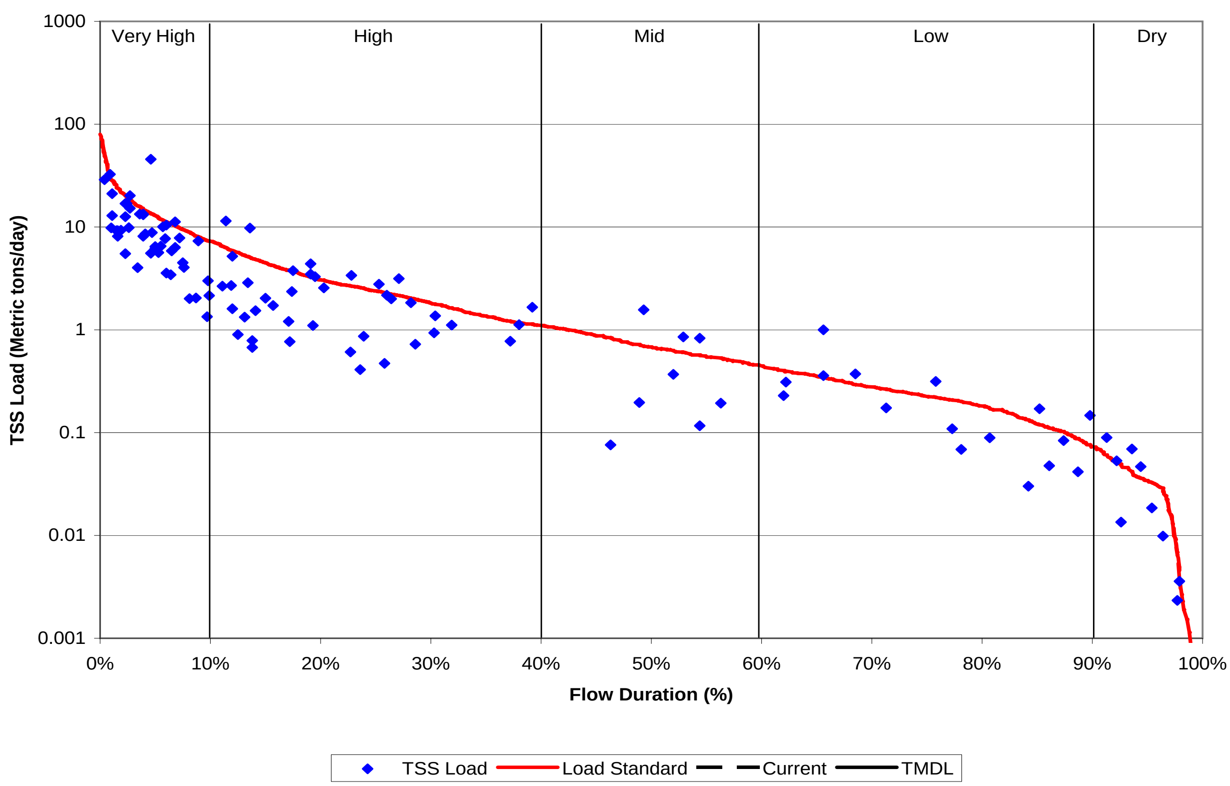
Florida Creek-South Dakota Border to West Branch Lac qui Parle River Sediment Load Duration (Reach ID 07020003-521)



Note: Figure uses flow frequency developed for entire reach and TSS concentrations from S003-088.

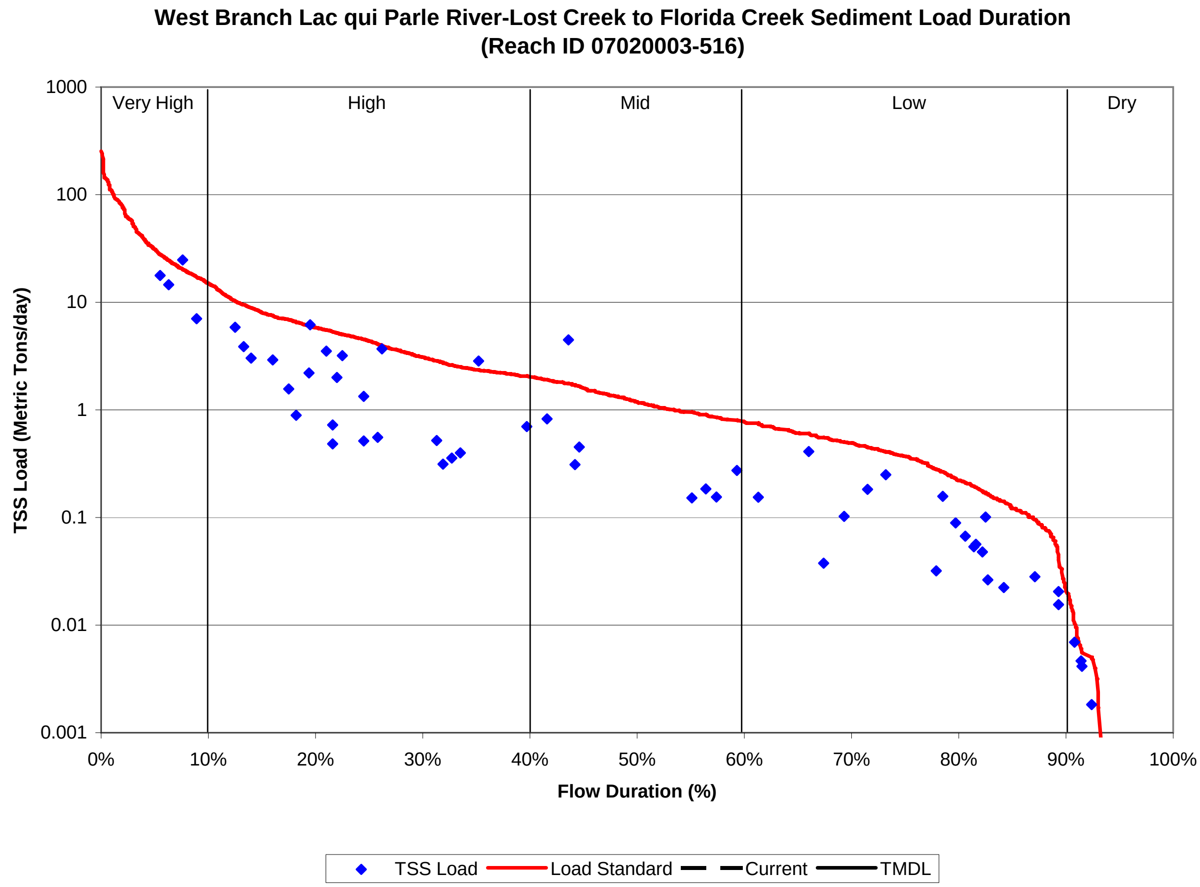
T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Florida Creek\Revised_09232010_521_Sediment_allocationsLoad Duration

Lazarus Creek-Canby Creek to Lac qui Parle River Sediment Load Duration (Reach ID 07020003-508)



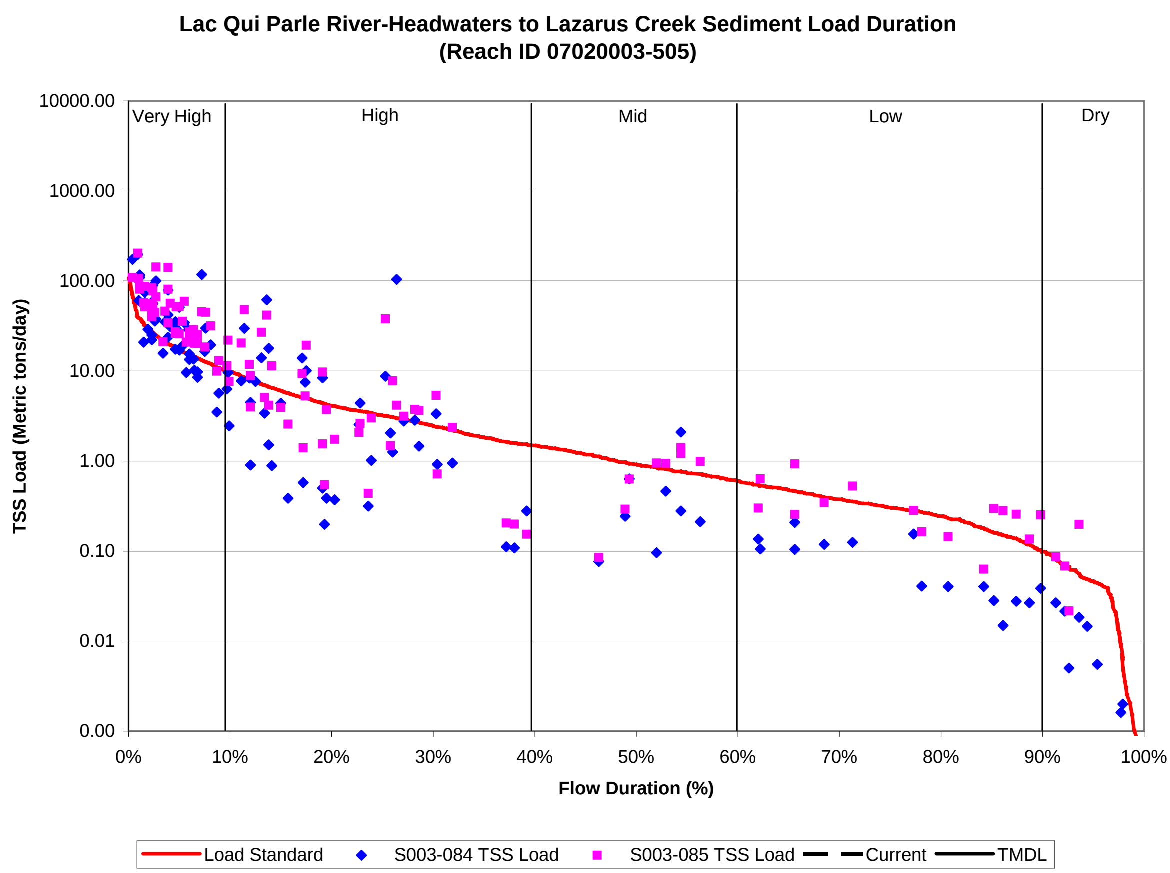
Note: Figure uses flow frequency developed for entire reach and TSS concentrations from S003-074.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\lazarus Creek\Revised_09232010_508_Sediment_allocationsLoad Duration



Note: Figure uses flow frequency developed for entire reach and TSS concentrations from S003-086.

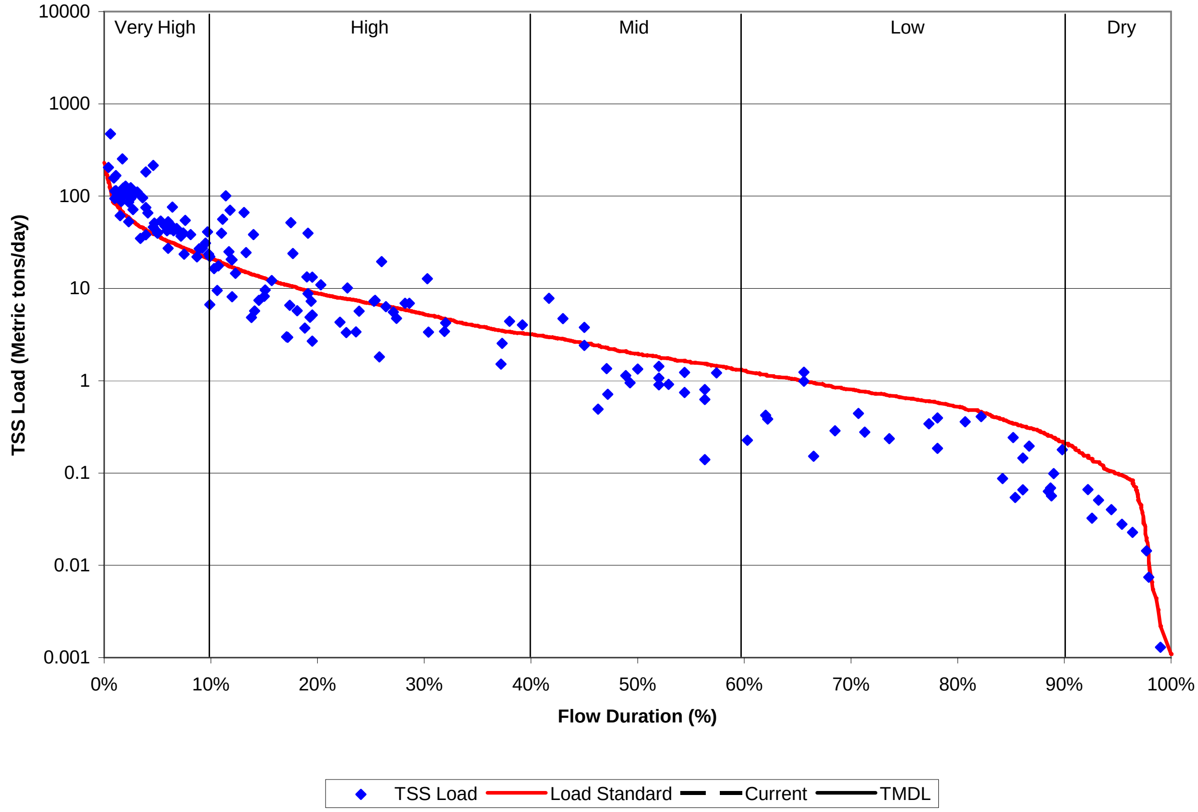
T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\W Br Laq Qui Parle\Revised_09232010_516_Sediment_allocationsLoad Duration



Note: Figure uses flow frequency developed for entire reach and TSS concentrations from S003-084 and S003-085.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Lac Qui Parle\Revised_09232010_505_Sediment_allocationsLoad Duration

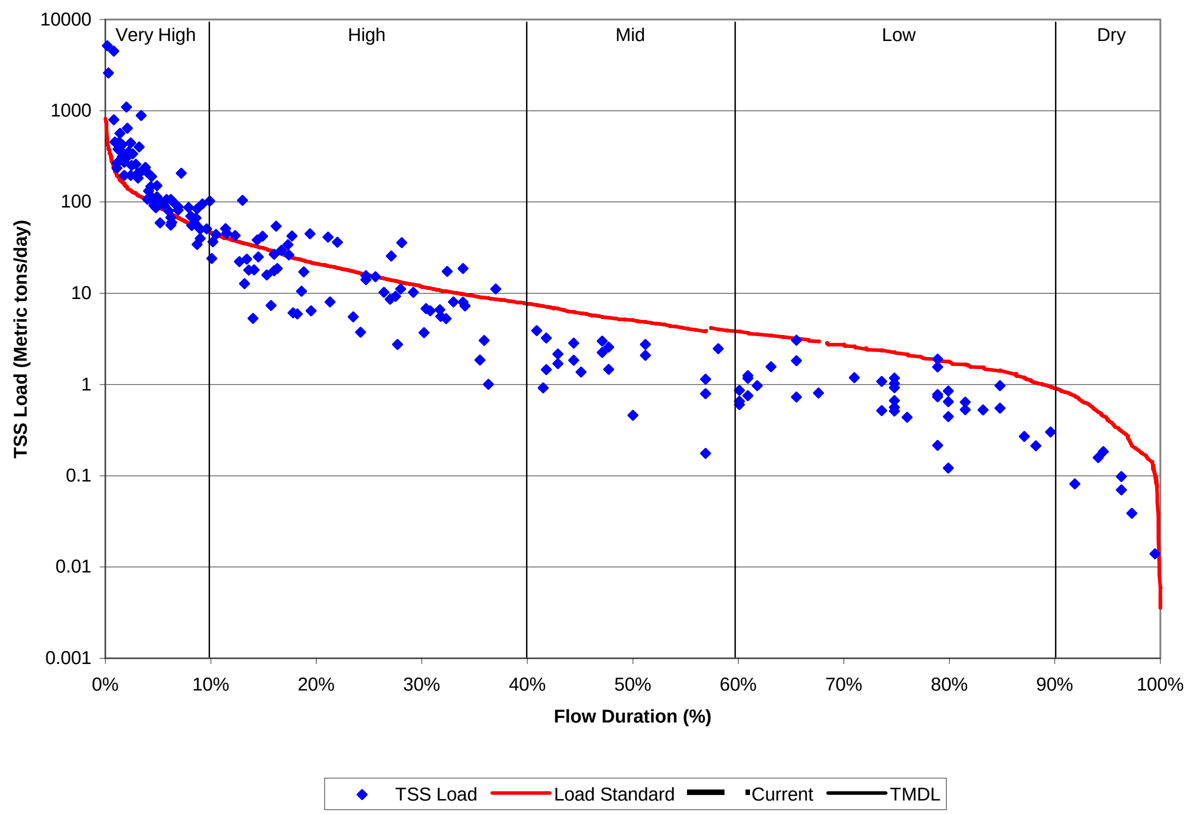
Lac Qui Parle River-Lazarus Creek to West Branch Lac qui Parle River Sediment Load Duration (Reach ID 07020003-506)



Note: Figure uses flow frequency developed for entire reach and TSS concentrations from S003-079.

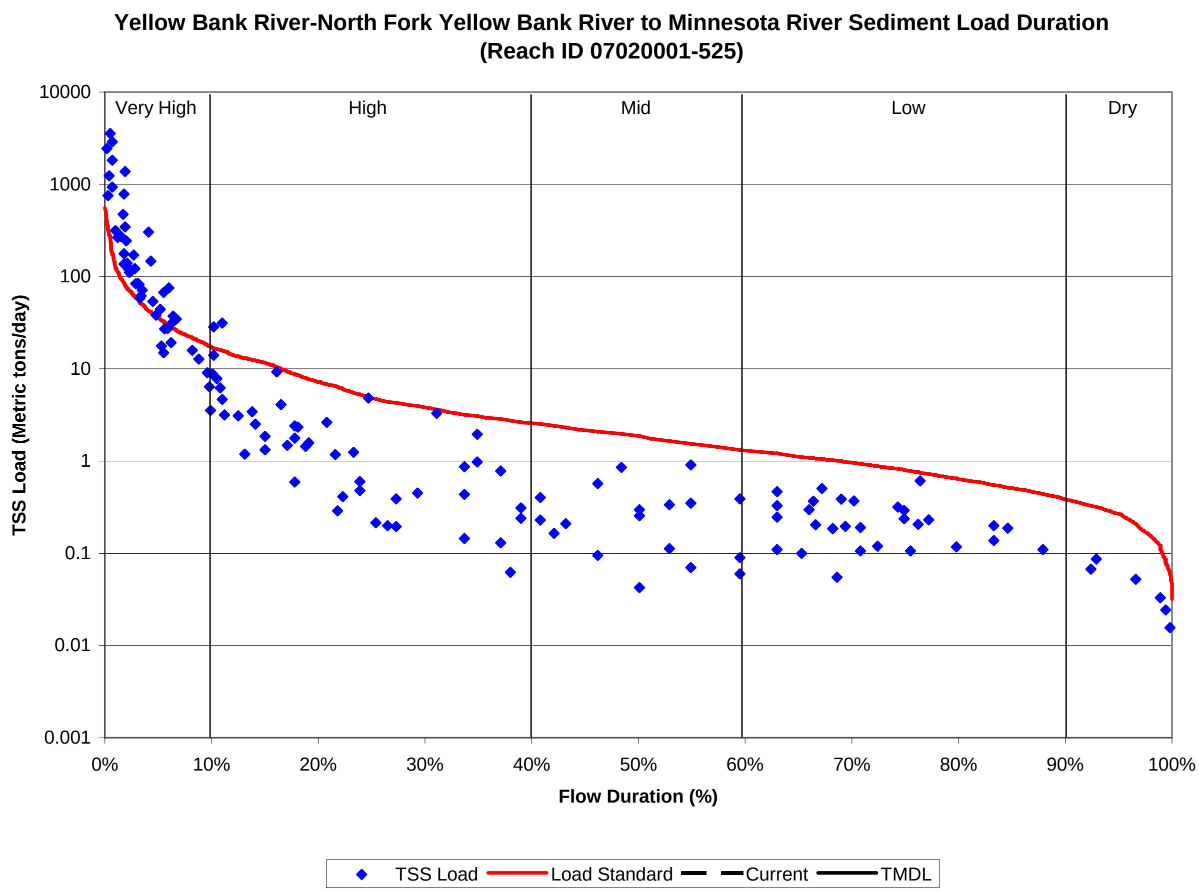
T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Lac Qui Parle\Revised_092320010_506_Sediment_allocationsLoad Duration

Lac Qui Parle River-West Branch Lac qui Parle River to Ten-Mile Creek Sediment Load Duration (Reach ID 07020003-501)



Note: Figure uses flow frequency developed for entire reach and TSS concentrations from S003-087.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Lac Qui Parle\Revised_09232010_501_Sediment_allocationsLoad Duration



Note: Figure uses flow duration developed for entire reach and TSS concentrations from S003-091.

T:\2297 Lac qui Parle\01_LQP TMDL\WQ Data and Analyses\Data_Processing\Yellow Bank\07020001_525_Sediment_allocations.xlsLoad Duration

APPENDIX E

Appendix E
Table 1: 2009 Water Quality Data

Date Time	Location ID	Temp [C]	Specific Conductivity [mS/cm]	pH [S.U.]	DO [mg/L]	%Sat	Wenck Gauged Discharge (cfs)	Water Surface Elevation (ft)
9/9/09 9:30 AM	tLqP-12.8 CD4-1.4	19.46	1816	7.5	3.61	39.3	**0.0174**	**1004.789**
9/9/09 10:40 AM	LqP-14	21.1	1131	7.94	6.21	70	**4.518**	**978.516**
9/9/09 10:43 AM	LqP-14	21.17	1131	7.91	5.75	64.5		
9/9/09 10:45 AM	LqP-14	21.13	1131	7.92	5.94	66.9		
9/9/09 10:46 AM	LqP-14	21.15	1131	7.89	5.46	61.4		
9/9/09 10:48 AM	LqP-14	21.13	1132	7.93	5.93	66.9		
9/9/09 10:50 AM	LqP-14	21.13	1131	7.93	5.91	66.5		
9/9/09 10:52 AM	LqP-14	21.13	1131	7.92	5.85	66		
9/9/09 10:54 AM	LqP-14	21.12	1330	7.95	6.21	---		
9/9/09 10:55 AM	LqP-14	21.12	1330	7.95	6.08	---		
9/9/09 10:58 AM	LqP-14	21.11	1130	7.95	6.25	70		
9/9/09 11:00 AM	LqP-14	21.11	1130	7.95	6.22	70.1		
9/9/09 11:10 AM	LqP-14	21.21	1054	7.98	6.51	73.6		
9/9/09 11:24 AM	LqP-14.5	21.34	1131	8.07	7.4	83.6		
9/9/09 11:26 AM	LqP-14.5	21.37	1130	8.06	7.33	83.1		
9/9/09 11:30 AM	LqP-14.5	21.35	1131	8.07	7.25	82	---	**981.149**
9/9/09 12:07 PM	LqP-22	21.46	1212	8.33	7.74	88.2		
9/9/09 12:07 PM	LqP-22	21.46	1212	8.32	7.67	87		
9/9/09 12:10 PM	LqP-22	21.48	1212	8.33	7.72	87.8	**3.23**	**1005.378**
9/9/09 12:12 PM	LqP-22	21.54	1212	8.34	7.96	89.3		
9/9/09 12:12 PM	LqP-22	21.54	1212	8.34	7.85	89.3		
9/9/09 12:13 PM	LqP-22	21.58	1211	8.34	7.95	90.5		
9/9/09 12:13 PM	LqP-22	21.58	1211	8.34	8	90.5		
9/9/09 12:15 PM	LqP-22	21.6	1211	8.34	8.08	90.3		
9/9/09 12:15 PM	LqP-22	21.6	1211	8.34	7.93	90.3		
9/9/09 12:18 PM	LqP-22	21.67	1134	8.34	8	91.1		
9/9/09 12:18 PM	LqP-22	21.67	1134	8.34	8.1	92.3		
9/9/09 2:47 PM	LqP-27.9	22.83	1227	8.29	11.61	135.8	**3.692**	**1018.334**
9/9/09 2:50 PM	LqP-27.9	22.74	1223	8.3	12.41	144.5		
9/9/09 2:51 PM	LqP-27.9	22.77	1224	8.3	12.59	146.6		
9/9/09 2:52 PM	LqP-27.9	22.82	1224	8.29	12.35	144		
9/9/09 2:54 PM	LqP-27.9	22.87	1224	8.28	12.1	140.8		
9/9/09 4:22 PM	LqP-7.5	22.99	1095	8.15	11.53	134.7		
9/9/09 4:24 PM	LqP-7.5	22.91	1095	8.1	11.62	135.7	**4.072**	---
9/9/09 4:26 PM	LqP-7.5	22.99	1094	8.1	11.74	137.8		
9/9/09 4:27 PM	LqP-7.5	23.09	1095	8.11	11.84	134		
9/9/09 4:29 PM	LqP-7.5	23.11	1094	8.12	12.01	140.8		
9/9/09 5:31 PM	tLqP-29.0 SB-0.90	22.94	1152	8.34	10.68	124.9	**0.818**	**1024.177**
9/9/09 5:32 PM	tLqP-29.0 SB-0.90	22.89	1150	8.32	10.67	124.9		
9/9/09 5:35 PM	tLqP-29.0 SB-0.90	23	1149	8.36	11.72	137.4		
9/9/09 5:59 PM	tLqP-29.0 WB1.1	26.5	1506	7.98	8.08	100.8	**1.955**	---
9/9/09 6:00 PM	tLqP-29.0 WB1.1	26.5	1515	7.96	7.86	98		
9/9/09 6:01 PM	tLqP-29.0 WB1.1	26.52	1515	7.95	7.83	97.9		
9/9/09 6:03 PM	tLqP-29.0 WB1.1	26.56	1516	7.94	7.77	97.1		
9/9/09 6:03 PM	tLqP-29.0 WB1.1	26.56	1515	7.94	7.78	97.1		
9/9/09 6:05 PM	tLqP-29.0 WB1.1	26.57	1512	7.93	7.73	96.7		
9/9/09 6:06 PM	tLqP-29.0 WB1.1	26.55	1510	7.93	7.74	96.8		
9/9/09 6:35 PM	tLqP-23.4 CD27-0.4	20.86	2464	8.26	9.22	103.9	**0.158**	---
9/9/09 6:36 PM	tLqP-23.4 CD27-0.4	20.86	2463	8.25	9.23	104		
9/9/09 7:02 PM	LqP-14	23.28	1125	8.34	10.94	128.5	---	---
9/9/09 7:06 PM	LqP-14	23.25	1124	8.34	11.24	132		

Appendix E
Table 1: 2009 Water Quality Data

Date Time	Location ID	Temp [C]	Specific Conductivity [mS/cm]	pH [S.U.]	DO [mg/L]	%Sat	Wenck Gauged Discharge (cfs)	Water Surface Elevation (ft)
9/10/09 8:23 AM	tLqP-29.0 WB1.1	23.67	1435	7.67	3.99	47.3	---	**1024.957**
9/10/09 8:24 AM	tLqP-29.0 WB1.1	23.7	1423	7.7	3.92	46.5		
9/10/09 8:25 AM	tLqP-29.0 WB1.1	23.75	1418	7.72	3.9	46.3		
9/10/09 8:42 AM	Dawson Dam Pool	20.96	950	8.3	6.68	75.1	---	---
9/10/09 8:44 AM	Dawson Dam Downstream	20.8	955	8.26	7.26	81.3	---	---
9/10/09 8:51 AM	tLqP-29.0 SB-0.90	20.07	1147	8.11	7.48	82.6	---	---
9/10/09 9:14 AM	LqP-22	20.1	1297	8.05	6.33	69.7	---	---
9/10/09 9:48 AM	LqP-27	21.11	1215	8.29	10.06	113.5	---	---
9/10/09 9:49 AM	LqP-27	21.11	1215	8.28	10.22	115.3		
9/10/09 9:50 AM	LqP-27	21.12	1216	8.28	10.35	116.9		
9/10/09 9:51 AM	LqP-27	21.18	1125	8.28	10.38	117.2		
9/10/09 10:30 AM	LqP-12.2	20.72	1130	7.97	6.94	77.7	5.405	---
9/10/09 10:31 AM	LqP-12.2	20.76	1129	7.95	6.78	75.9		
9/10/09 10:32 AM	LqP-12.2	20.75	1129	7.95	6.93	77.6		
9/10/09 10:35 AM	LqP-12.2	20.73	1127	7.94	7.01	78.5		
9/10/09 10:36 AM	LqP-12.2	20.59	1143	7.94	7.04	78.6		
9/10/09 11:18 AM	LqP-7.5	20.05	1111	7.83	6.8	75	1.408	---
9/10/09 11:19 AM	LqP-7.5	20.41	1109	7.84	7.14	79.7		
9/10/09 11:20 AM	LqP-7.5	20.48	1109	7.84	7.03	78.2		
9/10/09 11:21 AM	LqP-7.5	20.3	1109	7.83	6.9	76.6		
9/10/09 12:11 PM	LqP-22	21.82	1228	8.43	9.36	107.2	3.221	---
9/10/09 12:12 PM	LqP-22	21.78	1227	8.42	9.28	105.8		
9/10/09 12:13 PM	LqP-22	21.81	1228	8.41	9.13	104.4		
9/10/09 12:14 PM	LqP-22	21.78	1228	8.4	9.15	104.5		
9/10/09 12:39 PM	LqP-24.3	22.28	1272	8.29	12.04	139.1	3.069	---
9/10/09 12:40 PM	LqP-24.3	22.29	1272	8.26	12.06	139.1		
9/10/09 12:41 PM	LqP-24.3	22.42	1271	8.26	12.05	139.4		
9/10/09 12:42 PM	LqP-24.3	22.4	1271	8.26	12.08	139.8		
9/10/09 12:43 PM	LqP-24.3	22.41	1271	8.26	12.09	139.9		
9/10/09 12:44 PM	LqP-24.3	22.49	1271	8.26	12.12	140.5		
9/10/09 12:45 PM	LqP-24.3	22.52	1271	8.27	12.17	141		
9/10/09 1:26 PM	tLqP-29.0 tWB-1.3 JD4-0.1	34.23	1624	7.67	4.78	68.1	---	---
9/10/09 1:51 PM	tLqP-29.0 WB1.1	26.9	1373	8.13	11.26	141.7	---	---
9/10/09 1:35 AM	LqP-27	23.48	1220	8.38	11.45	135.2	---	---
9/10/09 2:28 PM	LqP-16.6	21.39	1155	8.19	8.11	91.9	2.727	---
9/10/09 2:30 PM	LqP-16.6	24.05	1158	8.3	9.25	110		
9/10/09 2:31 PM	LqP-16.6	23.69	1155	8.27	9.58	112.1		
9/10/09 2:32 PM	LqP-16.6	23.13	1152	8.24	9.07	106.1		
9/10/09 2:35 PM	LqP-16.6	23.9	1155	8.28	9.61	114.5		
9/10/09 2:39 PM	LqP-16.6	22.08	1155	8.2	8.5	97.7		
9/10/09 3:05 PM	LqP-7.5	23.49	1095	8.1	11.05	130.9	2.112	---
9/10/09 3:07 PM	LqP-7.5	24.05	1108	8.14	11.21	133.9		
9/10/09 3:08 PM	LqP-7.5	24.06	1107	8.14	11.2	133.6		
9/10/09 3:09 PM	LqP-7.5	23.97	1108	8.13	11.09	132		
9/10/09 3:10 PM	LqP-7.5	23.97	1108	8.13	11.02	131.3		
9/10/09 3:12 PM	LqP-7.5	23.99	1106	8.12	11.08	132		
9/10/09 3:13 PM	LqP-7.5	24.06	1106	8.12	11.08	132.2		
9/10/09 3:48 PM	LqP-5.7	23.97	1087	8.13	10.47	124.7	2.699	945.351
9/10/09 3:49 PM	LqP-5.7	23.96	1087	8.12	10.48	124.8		
9/10/09 3:51 PM	LqP-5.7	24.09	1068	8.1	10.49	125	---	946.371
9/10/09 4:00 PM	LqP-5.7	24.5	1087	8.14	11.6	139.6	---	947.092
9/10/09 4:33 PM	LqP-27	23.41	1240	8.38	11.14	131.4		

Appendix E
Table 2: 2005 Water Quality Data

Site ID	Sample Date	Site Name	Site Type	Impairment	Sample Type	Time	Seasonal PondDischargePeriod	CBOD 5-day (mg/L)	CBOD 40-day (mg/L)	Chla (ug/L)	CSMP Transparency Tube-60 cm (cm)	Dissolved oxygen (mg/L)	sample ID aka	Est. depth (feet)	substrate	algae growth	pH	temp (deg C)
S003-674	8/4/2005	tLqP-29.0 WB-8.9	EDA	FC, tDO	Routine Sample/Observation	**9:35**	no	2.8	6.7		11.5	4.2	LS15	0.5	rocky/silt	20%	7.89	23.4
S002-065	8/4/2005	tLqP-29.0 WB1.9		FC, tDO		**9:04**	no				33	5.47	LS12	3.5	silty/muddy	none	8.1	24.7
S003-089	8/4/2005	tLqP-29.0 WB1.6		FC, tDO		**8:51**	no				27	5.34	LS06	3.5	silty/muddy	none	8.33	25.2
S001-114	8/4/2005	tLqP-29.0 WB-1.1		FC, tDO		**8:21**	no				28	2.67	LS05	1	rock/sand	25%	8.06	24.4
S003-380	8/4/2005	LqP-28.4	EDA	DO	Routine Sample/Observation	**7:42**	no	1		8.05	18	4.01	LS04	1	silty/muddy	20%	8.07	23.7
S001-112	8/4/2005	LqP-27.8	EDA	DO	Routine Sample/Observation	**7:27**	no	1.7		7.71	18	4.75	LS03	1	silty/muddy	30%	8.23	23.9
S003-676	8/4/2005	LqP-24.4	EDA	DO	Routine Sample/Observation	**7:13**	no	2.6		36.7	20	4.36	LS18	2.5	silty/muddy	little	8.35	23.8
S003-675	8/4/2005	LqP-16.6	EDA	DO	Routine Sample/Observation	**6:35**	no	3.6		40.1	19.5	4.21	LS17	2.5	silty/muddy	none	8.28	24.3
S003-087	8/4/2005	LqP-7.5		DO		**5:45**	no			47.10	14.5	4.62	LS01	1.5	silty/muddy	very little	8.36	24.2
S003-087	8/4/2005	LqP-7.5	USGS															
S003-381	8/4/2005	tLqP-29.0 WB1.3C JD4 (us WWTP)		FC, tDO		**8:36**	no				> 60	4	LS07	0.5	sandy	none	7.93	31.4
S001-113	8/4/2005	tLqP-29.0 SB-0.90	EDA	tDO	Routine Sample/Observation	**8:00**	no	0.9			22	3.61	LS11	1.75	silt/sand	10%	8.04	22.7
S003-379	8/4/2005	tLqP-23.4 CD27-0.4		tDO		**6:52**	no			3.61	60	1.84	LS02	0.5	sandy	25%	7.92	21.1
S001-841	8/4/2005	tLqP-12.8 CD4-1.4	EDA	tDO	Routine Sample/Observation	**6:09**	no	2.5		2.56	11.5	4.63	LS16	0.5	cobbles/silt		7.89	21.6

Site ID	Sample Date	Site Name	Site Type	Impairment	Sample Type	Time	Seasonal PondDischargePeriod	CBOD 5-day (mg/L)	CBOD 40-day (mg/L)	Chla (ug/L)	CSMP Transparency Tube-60 cm (cm)	Dissolved oxygen (mg/L)	sample ID aka	Est. depth (feet)	substrate	algae growth	pH	temp (deg C)
S003-674	8/15/2005	tLqP-29.0 WB-8.9	EDA	FC, tDO	Routine Sample/Observation	**9:03**	no	1.3	5.5	14.3	12.5	4.96	LS15	1	rock/silt	20%	8.32	19.3
S002-065	8/15/2005	tLqP-29.0 WB1.9		FC, tDO		**8:41**	no				30	4.76	LS12	4	silty/muddy	none	8.56	21
S003-089	8/15/2005	tLqP-29.0 WB1.6		FC, tDO		**8:33**	no			35.00	27	4.1	LS06	4	silty/muddy	none	8.49	21.2
S001-114	8/15/2005	tLqP-29.0 WB-1.1		FC, tDO		**8:00**	no			47.30	37.5	5.19	LS05	1	rock/sand	25%	8.2	21.4
S001-112	8/15/2005	LqP-27.8	EDA	DO	Routine Sample/Observation	**7:33**	no	1		12.3	20.5	6.81	LS03	1	silty/muddy	25%	8.17	19.2
S003-676	8/15/2005	LqP-24.4	EDA	DO	Routine Sample/Observation	**7:20**	no	2.1		43.6	16.5	7.04	LS18	3	silty/muddy	little	8.63	19.9
S003-675	8/15/2005	LqP-16.6	EDA	DO	Routine Sample/Observation	**6:50**	no	2.2		47.9	15.5	5.93	LS17	3	silty/muddy	very little	8.62	19.8
S003-087	8/15/2005	LqP-7.5		DO		**6:15**	no			20.00	16.5	5.45	LS01	1	silty/mud	very little	8.68	18.8
S003-087	8/15/2005	LqP-7.5	USGS															
S003-381	8/15/2005	tLqP-29.0 WB1.3C JD4 (us WWTP)		FC, tDO	Routine Sample/Observation	**8:06**	no	0.9		1.46	52	4.64	LS07	1	sandy	none	7.51	27.9
S001-113	8/15/2005	tLqP-29.0 SB-0.90	EDA	tDO	Routine Sample/Observation	**7:45**	no	1.5		9.05	12	5.13	LS11	2	silty/muddy	little	8.04	18.5
S003-379	8/15/2005	tLqP-23.4 CD27-0.4		tDO		**7:09**	no			6.33	60	2.45	LS02	1	sandy	25%	8.21	17.2
S001-841	8/15/2005	tLqP-12.8 CD4-1.4	EDA	tDO	Routine Sample/Observation	**6:36**	no	0.8		6.66	15	5.1	LS16	1	cobles/silt	very little	8.29	16.9

Appendix E
Table 2: 2005 Water Quality Data

Site ID	Sample Date	CBOD 5-day (mg/L)	Ammonia Nitrogen (ug/L)	Kjeldahl Nitrogen (ug/L as N)	NO2 3 (ug/L)	TP mg/L as P ug/L	Ortho-phosphorus (ug/L)	Stream Width (ft)	X-Section (ft2)	Velocity Max (fps)	Velocity Ave (fps)	Depth Max (ft)	Depth Ave (ft)	Total Q (cfs)	Sp. Cond. (umhos)
S003-674	8/4/2005	2.8	90	1190	80	225	131	48	12.7	1.25	0.347	0.5	0.264	7.3	
S002-065	8/4/2005														
S003-089	8/4/2005	1.8	110	1370	25	239	165								
S001-114	8/4/2005	1.5	250	1340	1000	258	197								
S003-380	8/4/2005	1.0	110	1140	410	191	133								
S001-112	8/4/2005	1.7	150	1140	460	184	129								
S003-676	8/4/2005	2.6	90	1280	320	192	96								
S003-675	8/4/2005	3.6	25	1250	25	173	61								
S003-087	8/4/2005	3.1	25	1390	60	166	44								
S003-087	8/4/2005													17	
S003-381	8/4/2005	0.9	110	1420	1000	111	46								
S001-113	8/4/2005	0.9	25	890	160	117	42	20	11.3	0.956	0.567	0.9	0.564	8.85	
S003-379	8/4/2005	1.5	0	1040	480	1320	1260	3	2.6	0.458	0.39	0.9	0.85	1	
S001-841	8/4/2005	2.5	200	1650	1800	451	367								

Site ID	Sample Date	CBOD 5-day (mg/L)	Ammonia Nitrogen (ug/L)	Kjeldahl Nitrogen (ug/L as N)	NO2 3 (ug/L)	TP mg/L as P ug/L	Ortho-phosphorus (ug/L)	Stream Width (ft)	X-Section (ft2)	Velocity Max (fps)	Velocity Ave (fps)	Depth Max (ft)	Depth Ave (ft)	Total Q (cfs)	Sp. Cond. (umhos)
S003-674	8/15/2005	1.3		970	910	198	98	32	6.7	0.81	0.37	0.5	0.21	3.9	1199
S002-065	8/15/2005														1085
S003-089	8/15/2005	2.6	230	1700	80	546	419								1182
S001-114	8/15/2005	2	120	1160	1400	268	187								1016
S001-112	8/15/2005	1	80	1080	140	202	118								1290
S003-676	8/15/2005	2.1		1190	420	173	45								1164
S003-675	8/15/2005	2.2		1290		196	49								1144
S003-087	8/15/2005														1261
S003-087	8/15/2005													8.2	
S003-381	8/15/2005	0.9	300	1300	11000	1080	963								1193
S001-113	8/15/2005	1.5		1140	360	120	32	18	9	0.654	0.49	0.8	0.5	5.1	1201
S003-379	8/15/2005	0.7		950	90	1260	1210	3	2.6	0.405	0.37	0.9	0.85	0.9	1266
S001-841	8/15/2005	0.8	90	1250	1500	204	116								2002