Long Prairie River Watershed Pollutant Reduction Project Total Maximum Daily Load Study For Nutrients and Bacteria

Minnesota Pollution Control Agency

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Acronyms

ac-ft/yr	acre feet per year
AUID	Assessment Unit ID
BMP	Best Management Practice
BD-P	Bicarbonate Dithionite Extractable Phosphorus
CAFO	Concentrated Animal Feeding Operation
cfu	colony-forming unit
Chl-*a*	Chlorophyll-*a*
CSO	Combined Sewer Overflow
DNR	Minnesota Department of Natural Resources
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency
EQuIS	Environmental Quality Information System
GIS	Geographic Information System
HSPF	Hydrologic Simulation Program-FORTRAN
IBI	Index of Biological Integrity
ISTS	Individual Sewage Treatment System
ITPHS	Imminent Threat To Public Health And Safety
kg/day	kilogram per day
kg/yr	kilogram per year
km^2	square kilometer
LA	Load Allocation
Lb	pound
lb/day	pounds per day
lb/yr	pounds per year
LDC	Load Duration Curve
m	meter
mg/L	milligrams per liter
mg/m^2-day	milligram per square meter per day
mL	milliliter
MOS	Margin of Safety

MPCA	Minnesota Pollution Control Agency
MPN	Most Probable Number (of bacteria organisms)
MS4	Municipal Separate Storm Sewer Systems
NCHF	Northern Central Hardwood Forests
NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NWI	National Wetlands Inventory
SID	Stressor Identification
SSTS	Subsurface Sewage Treatment Systems
SWCD	Soil and Water Conservation District
SWPPP	Stormwater Pollution Prevention Plan
TMDL	Total Maximum Daily Load
TP	Total phosphorus
µg/L	microgram per liter
USGS	U.S. Geological Survey
WLA	Wasteload Allocation
WRAPS	Watershed Restoration and Protection Strategies
WWTF	Wastewater Treatment Facility

Executive Summary

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

This TMDL study includes seven lakes impaired by excess nutrients and three streams impaired by high levels of bacteria located in the Long Prairie River Watershed (HUC 07010108), a tributary to the Mississippi River in central Minnesota, that are on the 2014 EPA 303(d) list of impaired waters.

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

- All available water quality data over the past 10 years
- Sediment phosphorus concentrations
- Fisheries surveys
- Plant surveys
- Stream field surveys
- Stressor identification (SID) investigations
- Hydrologic Simulation Program-FORTRAN (HSPF) watershed model
- Stakeholder input

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

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

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

1 Project Overview

1.1 Purpose

This TMDL study addresses aquatic recreation use impairments due to eutrophication (phosphorus) in seven lakes, and aquatic recreation use impairments due to *Escherichia coli (E. coli)* in three streams in the Long Prairie River Watershed in central Minnesota (Table 1, Figure 1). The goal of this TMDL is to provide wasteload allocations (WLAs) and load allocations (LAs) and to quantify the pollutant reductions needed to meet the state water quality standards. These TMDLs are being established in accordance with section 303(d) of the Clean Water Act, because the state of Minnesota has determined that these lakes and streams exceed the state established standards.

The findings from this TMDL study will be used to aid the selection of implementation activities as part of the Long Prairie River WRAPS process. The purpose of the WRAPS report is to support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning. Following completion, the WRAPS report will be publically available on the MPCA Long Prairie River Watershed website: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/watersheds/long-prairie-river.html.

1.2 Identification of Waterbodies

This TMDL study addresses seven lakes and three streams within the Long Prairie River Watershed (HUC-07010108) that are on the 2014 303(d) list of impaired waters for aquatic recreation use impairments due to eutrophication and *E. coli* (Table 1; Figure 1). Another TMDL project (Lake Winona TMDL) is currently in progress that addresses the nutrient impairment in Lake Winona, and therefore, will not be addressed in this TMDL study. Lake Winona is the headwater lake of the Winona-Agnes-Henry Lake chain in the city of Alexandria. Preliminary modeling conducted as part of the Lake Winona Nutrient TMDL and the Long Prairie River Watershed TMDL indicate that the in-lake phosphorus concentrations of Lake Agnes and Lake Henry are strongly influenced by the water quality of Lake Winona. However, as discussed in greater detail in the Lake Winona Nutrient TMDL, Lake Winona is a shallow lake and strongly influenced by sediment internal load and in-lake biological processes that are difficult to model using available tools. Therefore, the nutrient impairments in Lake Agnes and Lake Henry are being deferred until the Lake Winona TMDL is fully implemented. The MPCA will use an adaptive management approach for the Winona-Agnes-Henry Lake chain by first addressing the Lake Winona nutrient impairment, and then assessing the impacts of Lake Winona water quality improvements on downstream Lake Agnes and Lake Henry water quality.

Additional monitoring is needed to address the chloride impairments for Lake Winona, Agnes and Henry; these TMDLs will be completed at a future date. None of the four streams designated as impaired based on fish/macroinvertebrate bioassessments were determined to be caused by a pollutant based stressor during the SID process and will not be addressed in this TMDL study. These impairments will be addressed with implementation activities as part of the WRAPS process. The Long Prairie River is also impaired by Low Dissolved Oxygen and a TMDL was approved by the EPA on August 5, 2005. Implementation activities are currently underway.

1.3 Priority Ranking

The MPCA projected schedule for TMDL completions, as indicated on the 303(d) impaired waters list, implicitly reflects Minnesota 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. Impaired lakes and streams in the Long Prairie River Watershed

AUID/ Lake ID	Name	Location/Reach Description	Designated Use Class	Listing Year	Target Start/ Completion	Impairment addressed by:	Affected Use: Pollutant/Stressor
21-0053	Lake Agnes	In Alexandria	2B, 3C				
21-0051	Lake Henry	At Alexandria	2B, 3C	2010	2011/2017	Future TMDL	*Aquatic Life:* Chloride
21-0081	Lake Winona	In Alexandria	2B, 3C				
21-0081	Lake Winona	In Alexandria	2B, 3C	2002	2012/2017	Lake Winona TMDL, in progress	
21-0053	Lake Agnes	In Alexandria	2B, 3C	2014	2011/2015	Future TMDL	
21-0051	Lake Henry	At Alexandria	2B, 3C	2014	2011/2015	Future TMDL	
21-0199-02	Crooked Lake (East)	1 mile NW of Holmes City	2B, 3C				*Aquatic Recreation*: Nutrient/ Eutrophication Biological Indicators (Phosphorus)
21-0157	Echo Lake	2 miles W of Carlos	2B, 3C				
56-0066	Fish Lake	W of Parkers Prairie	2B, 3C				
21-0055	Jessie Lake	4 miles E of Alexandria	2B, 3C	2014	2011/2015	This TMDL	
77-0105	Latimer Lake	3 miles S of Long Prairie	2B, 3C				
56-0065	Nelson Lake	W of Parkers Prairie	2B, 3C				
56-0067	Twin Lake	W of Parkers Prairie	2B, 3C				
07010108-507	Eagle Creek	Headwaters to Long Prairie River	2B, 3C				
07010108-511	Moran Creek	Headwaters to Long Prairie River	2B, 3C	2014	2011/2015	This TMDL	*Aquatic Recreation*: *E. coli*
07010108-552	Unnamed Creek	CD11 to Lake Miltona	2B, 3C				
07010108-512	Spruce Creek	T131 R36W S31, north line to Unnamed Lake 21-0034	1B, 2A, 3B				
07010108-568	Venewitz Creek	Charlotte Lake to Long Prairie River	2B, 3C	2014	2011/2015	WRAPS process	*Aquatic Life:* Fish or macroinvertebrate bioassessments
07010108-592	Harris Creek	Unnamed creek to Eagle Creek	2B, 3C				
07010108-595	Unnamed Creek	Headwaters to Lake Miltona	2B, 3C				
07010108-501	Long Prairie River	Fish Trap Creek to Crow Wing River	2B, 3C	2002	TMDL approved 2005 Implementation underway		*Aquatic Life:* Dissolved oxygen
07010108-502	Long Prairie River	Moran Creek to Fish Trap Creek	2B, 3C				
07010108-503	Long Prairie River	Turtle Creek to Moran Creek	2B, 3C				
07010108-504	Long Prairie River	Eagle Creek to Turtle Creek	2B, 3C	2002	TMDL approved 2005 Implementation underway		*Aquatic Life:* Dissolved oxygen
07010108-505	Long Prairie River	Spruce Creek to Eagle Creek	2B, 3C				
07010108-506	Long Prairie River	Lake Carlos to Spruce Creek	2B, 3C				

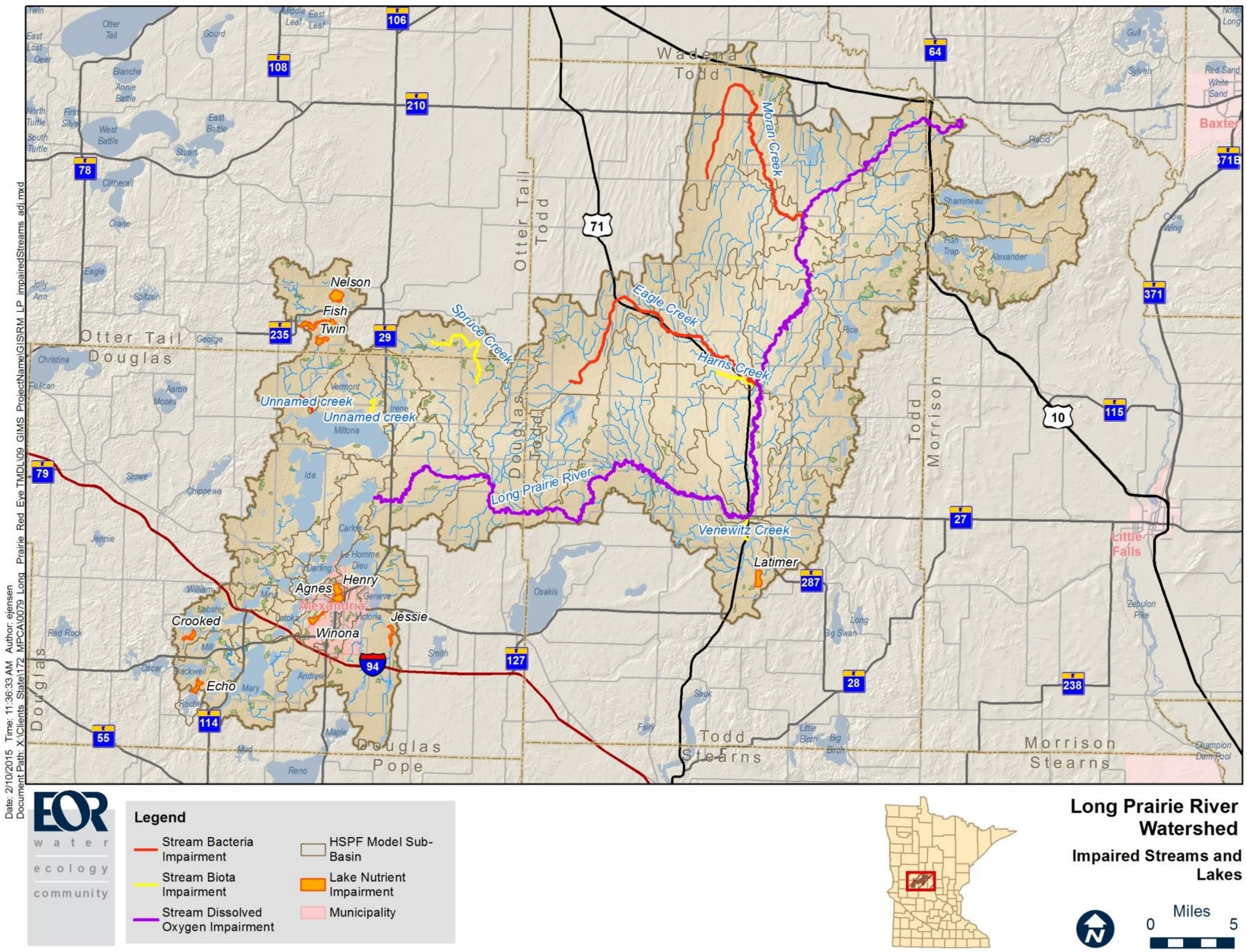


Figure 1. Long Prairie River Watershed impaired waters

1.4 Stressor Identification Summary

The fish or macroinvertebrate bioassessment impairments in the Long Prairie River Watershed were characterized by low index of biological integrity (IBI) scores for fish and/or macroinvertebrates. The presence of a healthy, diverse, and reproducing aquatic community is a good indication that the aquatic life beneficial use is being supported by a lake, stream, or wetland. The aquatic community integrates the cumulative impacts of pollutants, habitat alteration, and hydrologic modification on a waterbody over time. Monitoring of the aquatic community is accomplished using an IBI which incorporates multiple attributes of the aquatic community, called metrics, to evaluate complex biological systems. For further information regarding the development of stream IBIs, refer to the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment: 305(b) Report and 303(d) List* (MPCA 2012).

A SID study was completed by MPCA (2014) to determine the cause of low fish and macroinvertebrate scores in the Long Prairie River Watershed. The four biologically impaired Assessment Unit IDs (AUIDs) and the weight of evidence information for each stressor are listed below in Table 2. A + symbol indicates a positive response for that stressor category and is likely causing the lack of biotic integrity at that AUID sampling location.

None of the biological impairments were determined to be caused primarily by a pollutant-based stressor through the MPCA SID process. These impairments will be addressed with implementation activities as part of the WRAPS process.

Table 2. Long Prairie River Watershed SID Study Summary

Summary of Stressors	Harris Creek	Spruce Creek	Venowitz Creek	Unnamed Creek
Loss of Habitat due to Channelization/Ditching	+	+	+	+
Total Suspended Solids	0	0	0	0
Deposited and Bedded Sediments	+	+	+	+
Pesticide Toxicity	NE	NE	NE	NE
Nitrate-Nitrite Toxicity	-	-	-	-
Chloride Toxicity	NE	NE	NE	NE
Dissolved Oxygen	+	0	+	0
Irrigation – Flow Alteration	+	0	0	0
Connectivity – Loss of fish passage	+	+	0	+
Increased Nutrients (Total Phosphorus)	0	-	-	-

* Key: + is a positive indicator, - is negative indicator, 0 is neutral, NE is No Evidence

2 Applicable Water Quality Standards and Numeric Water Quality Targets

2.1 Designated Use

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

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

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

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

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

2.2 Lakes

2.2.1. Eutrophication

Total phosphorus (TP) is often the limiting factor controlling primary production in freshwater lakes: as in-lake phosphorus concentrations increase, algal growth increases resulting in higher chlorophyll-*a* (Chl-*a*) concentrations and lower water transparency. In addition to meeting phosphorus limits, Chl-*a* and Secchi transparency depth standards must also be met. In developing the lake nutrient standards for Minnesota lakes (Minn. R. ch. 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state ecoregions (Heiskary and Wilson 2005). Clear relationships were established between the causal factor total phosphorus (TP) and the response variables Chl-*a* and Secchi transparency. Based on these relationships it is expected that by meeting the phosphorus target in each lake, the Chl-*a* and Secchi standards will likewise be met. The impaired lakes within the Long Prairie River Watershed are located within the Northern Central Hardwood Forests Ecoregion (NCHF). The applicable water quality standards by ecoregion are listed in Table 3.

In the NCHF Ecoregion, a separate water quality standard was developed for shallow lakes, which tend to have poorer water quality than deeper lakes in this ecoregion. According to the MPCA definition of shallow lakes, a lake is considered shallow if its maximum depth is less than 15 feet, or if the littoral zone (area where depth is less than 15 feet) covers at least 80% of the lake surface area. Fish, Nelson, and Twin Lakes are shallow according to this definition.

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

Table 3. Lake Eutrophication Standards

Lake Type	TP (ppb)	Chl-a (ppb)	Secchi (m)
North Central Hardwood Forests: General Crooked (East), Echo, Jessie, Latimer	< 40	< 14	> 1.4
North Central Hardwood Forests: Shallow Lakes Fish, Nelson, Twin	< 60	< 20	> 1.0

2.3 Streams

2.3.1. Bacteria

Numeric water quality standards have been developed for bacteria (Minn. R. 7050.0222), in this case *E. coli*, which are protective concentrations for short- and long-term exposure to pathogens in water. The past fecal coliform and current *E. coli* numeric water quality standards for Class 2 waters are shown in Table 4. *E. coli* and fecal coliform are fecal bacteria used as indicators for waterborne pathogens that have the potential to cause human illness. Although most are harmless themselves, fecal indicator bacteria are used as an easy-to-measure surrogate to evaluate the suitability of recreational and drinking waters, specifically, the presence of pathogens and probability of illness. Pathogenic bacteria, viruses, and protozoa pose a health risk to humans, potentially causing illnesses with gastrointestinal symptoms (nausea, vomiting, fever, headache, and diarrhea), skin irritations, or other symptoms. Pathogen types and quantities vary among fecal sources; therefore, human health risk varies based on the source of fecal contamination.

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

E. coli - Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than 10% of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.

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

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

Table 4. Past and current numeric water quality standards of bacteria (fecal coliform and *E. coli*) for the beneficial use of aquatic recreation (primary and secondary body contact)

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

3 Watershed and Waterbody Characterization

The impaired lakes and streams included in this study are located within the Long Prairie River Watershed (HUC 07010108), a tributary to the Mississippi River in the Upper Mississippi River Basin in central Minnesota. The Long Prairie River Watershed drains approximately 885 square miles (566,612 acres) in all or parts of Douglas, Otter Tail, Todd, Morrison, and Wadena Counties. The Long Prairie River begins in Douglas County and flows through Todd and Morrison counties before entering the Crow Wing River south of Motley. No tribal lands are located within the Long Prairie River Watershed.

3.1 Lakes

The physical characteristics of the impaired lakes are listed in Table 5. Lake surface areas, lake volumes, mean depths, and littoral areas (less than 15 feet) were calculated using Minnesota Department of Natural Resources (DNR) depth contours; maximum depths were reported from the DNR Lake Finder website; and watershed areas and watershed to surface area ratios were calculated using HSPF subbasins (AquaTerra 2013) and U.S. Geological Survey (USGS) StreamStats (http://water.usgs.gov/osw/streamstats/).

Table 5. Impaired lake physical characteristics

Lake	Surface area (ac)	Littoral area (% total area)	Volume (acre-feet)	Mean depth (feet)	Maximum depth (feet)	Watershed area (incl. lake area) (ac)	Watershed area: Surface area
Crooked (East)	102	73%	935	9.2	25	1,051	10:1
Echo	126	72%	1,422	11.3	40	1,897	15:1
Fish	489	98%	3,262	6.7	17	10,919	22:1
Jessie	110	62%	1,255	11.4	26	8,923	81:1
Latimer	202	41%	3,378	16.8	30.5	1,991	10:1
Nelson	272	100%	***1,360***	***5***	***7***	4,433	16:1
Twin	134	100%	***804***	***6***	***15***	12,016	90:1

* Note that the watershed area includes the surface area of the lake. Lake depths were not available for Nelson and Twin; bolded and italicized values are estimates based on best professional judgment of average depth of shallow lakes in this region.

3.2 Subwatersheds

The individual impaired lake and stream subwatersheds are illustrated in Figure 2 through Figure 8 below.

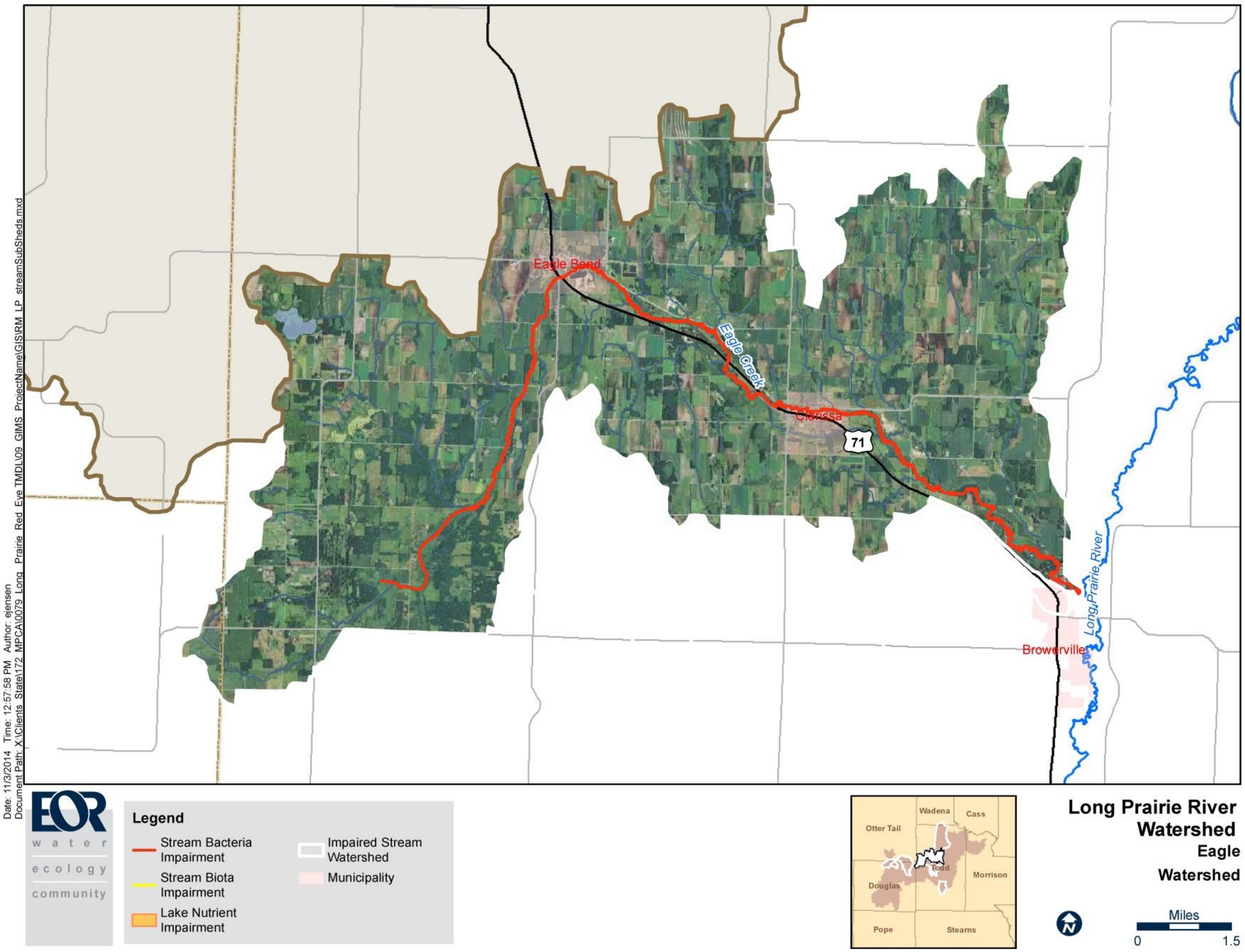


Figure 2. Eagle Creek (07010108-507) Subwatershed

Figure 3. Moran Creek (07010108-511) Subwatershed

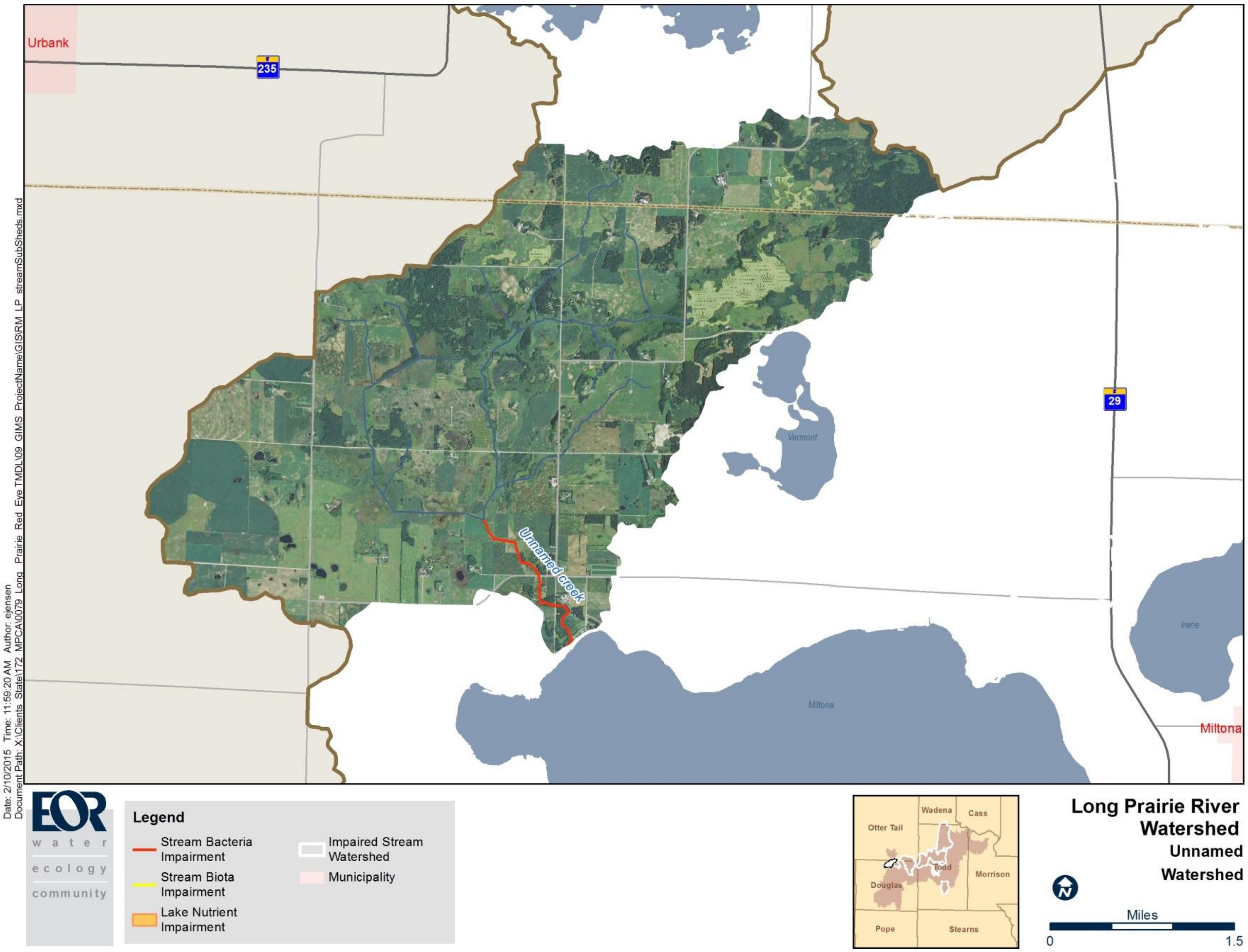


Figure 4. Unnamed Creek (07010108-552) Subwatershed

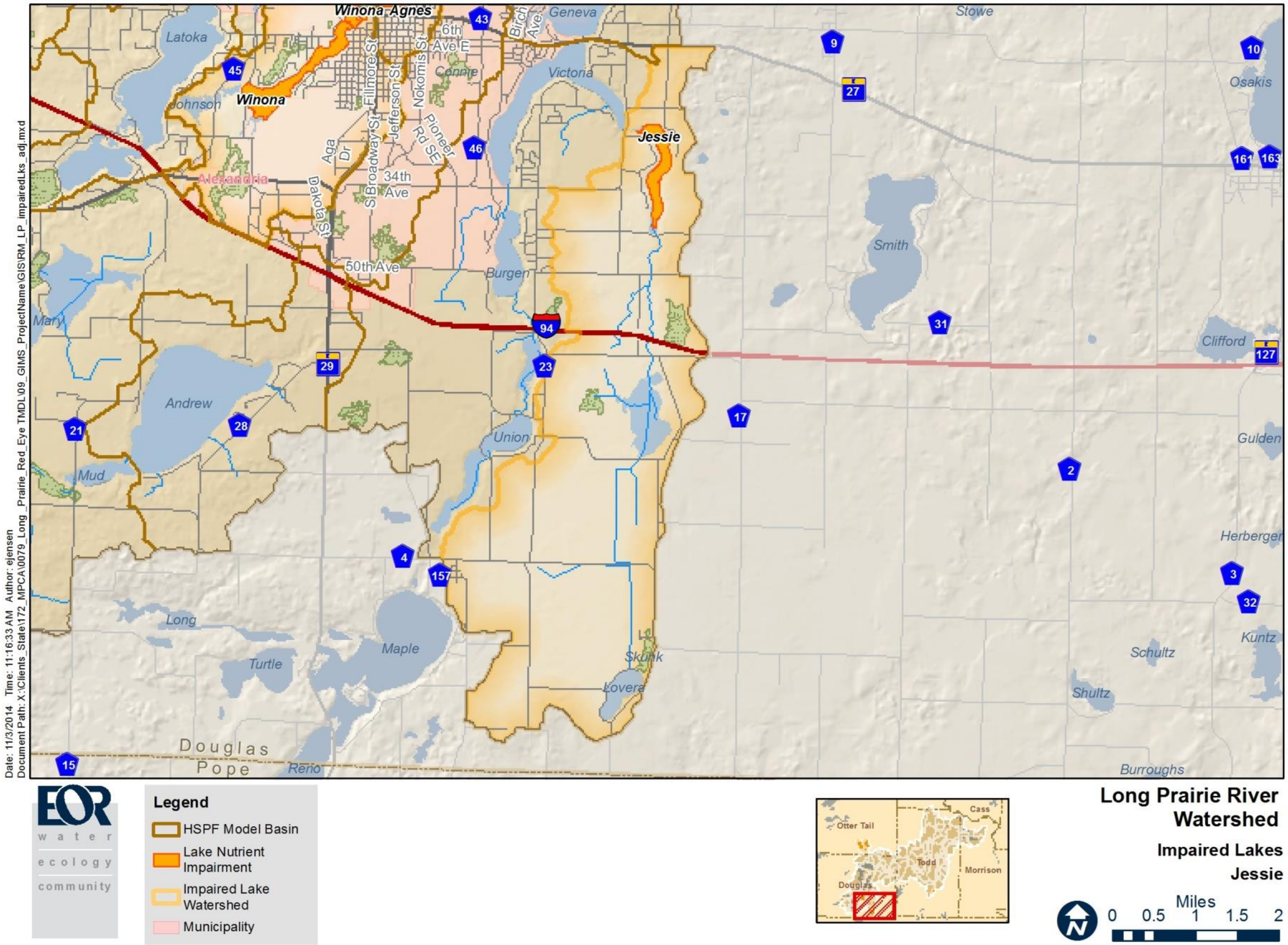


Figure 5. Jessie Lake Subwatershed

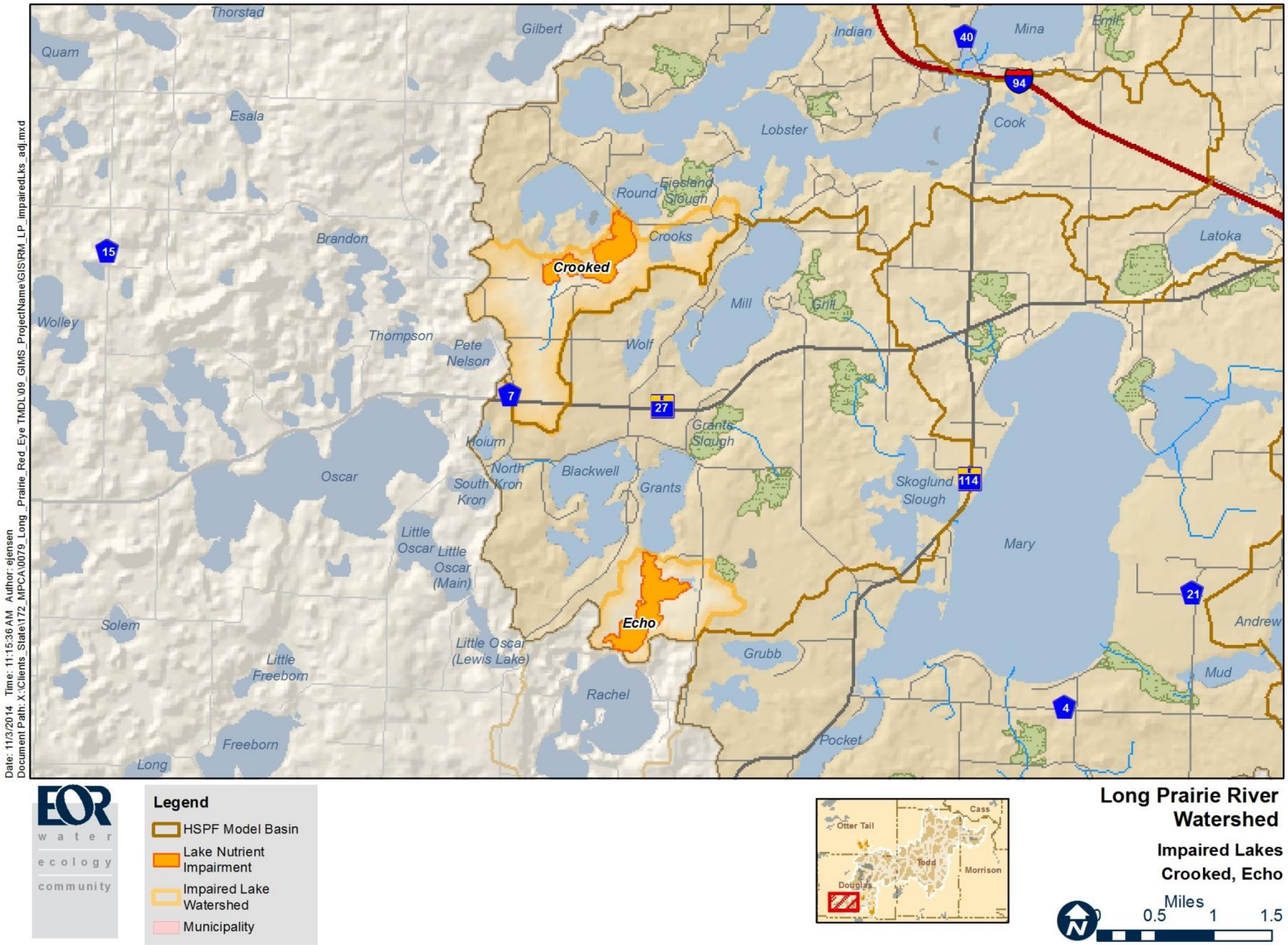


Figure 6. Crooked (East) and Echo Lakes Subwatersheds

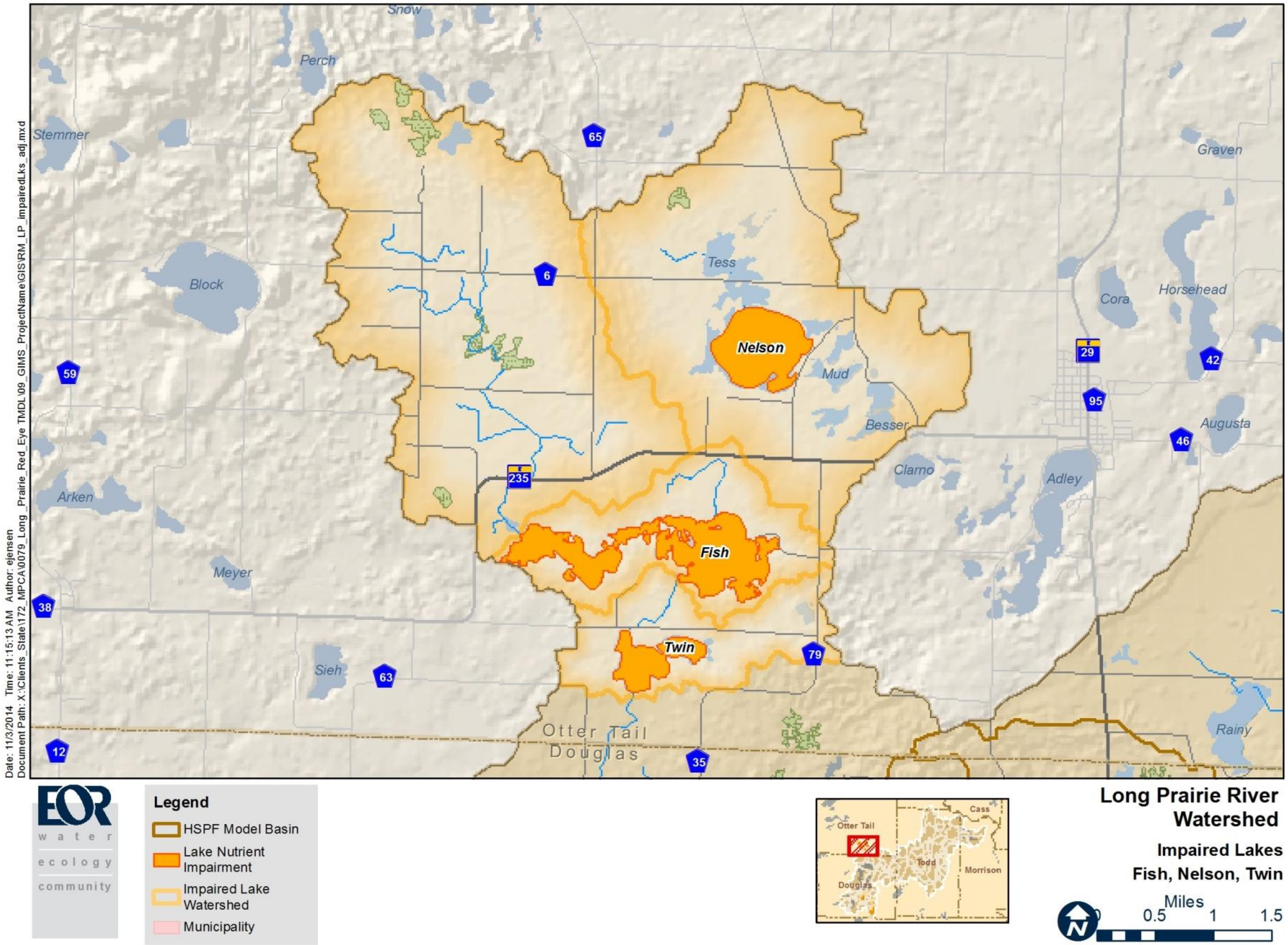


Figure 7. Nelson, Fish and Twin Lakes Subwatersheds

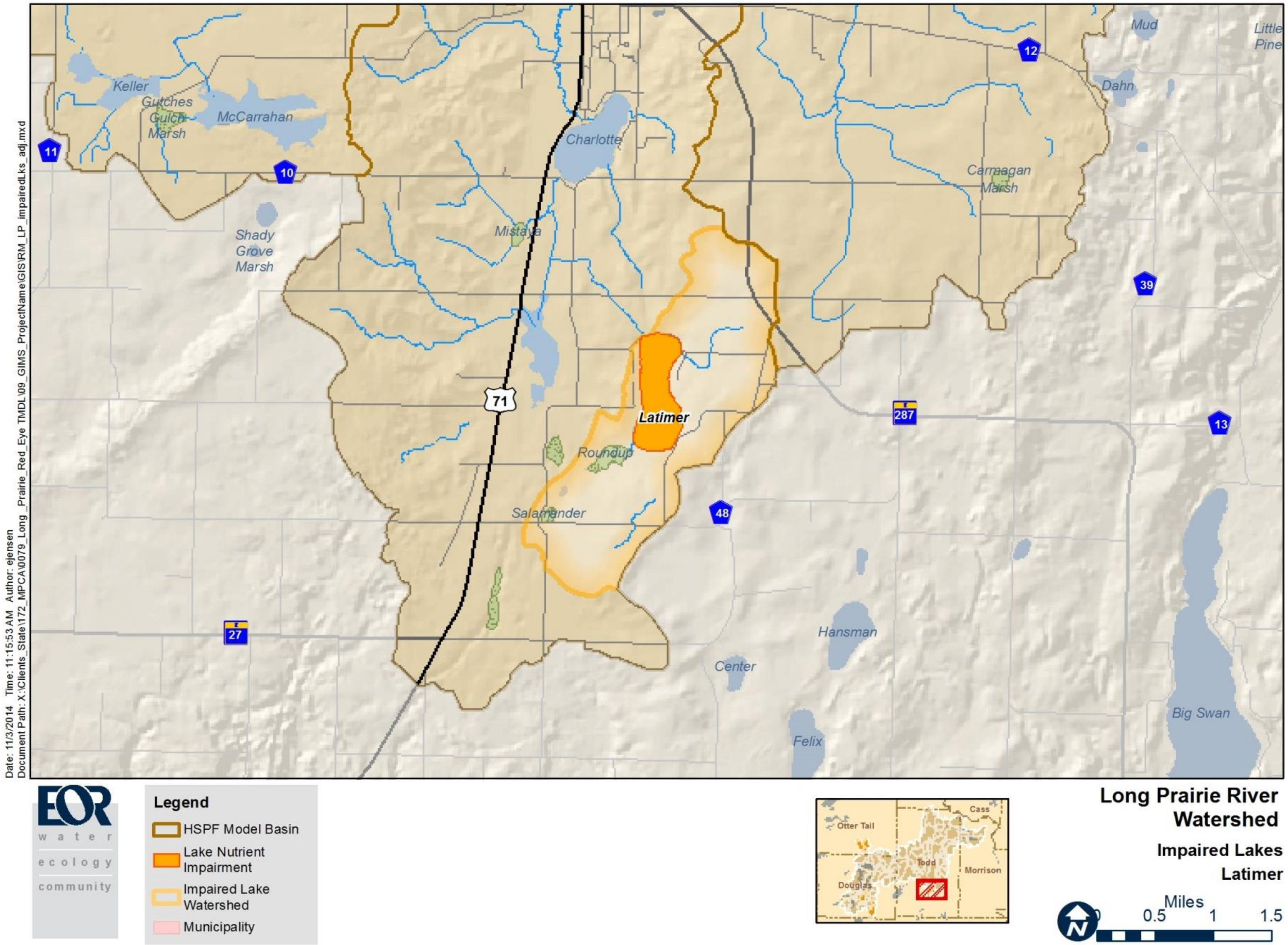


Figure 8. Latimer Lake Subwatershed

3.3 Land Use

Land cover in the Long Prairie River Watershed was assessed using the Multi-Resolution Land Characteristics Consortium 2011 National Land Cover Dataset (http://www.mrlc.gov/nlcd2011.php). This information is necessary to draw conclusions about pollutant sources and best management practices (BMPs) that may be applicable within each subwatershed. The land cover distribution within impaired lake and stream watersheds is summarized in Table 6. This data was simplified to reduce the overall number of categories. Woodland includes: evergreen forests, deciduous forests, mixed forests, and shrub/scrub. Developed includes: developed open space, and low, medium and high density developed areas. Grassland includes: native grass stands. Pasture includes: alfalfa, clover, long term hay, and pasture. Cropland includes: all annually planted row crops (corn, soybeans, wheat, oats, barley, etc.), and fallow crop fields. Wetland includes: wetlands, and marshes. Open water includes: all lakes and rivers. The primary land covers within the Long Prairie River Watershed are cropland (27%), pasture (21%), and woodland (21%). Most of the impaired lake subwatersheds tend to be dominated by cropland and grassland (Table 6). The impaired stream reaches also have high percentages of cropland and grassland in their subwatersheds.

Table 6. Long Prairie River Watershed and Impaired Waterbody Subwatershed Land Cover (NLCD 2011)

Waterbody Name	Developed	Cropland	Grassland	Pasture	Woodland	Open Water	Wetlands
Crooked Lake (East)	4%	32%	9%	12%	22%	20%	2%
Echo Lake	4%	23%	10%	13%	20%	30%	0%
Fish Lake	5%	24%	5%	31%	23%	8%	3%
Jessie Lake	6%	46%	4%	17%	14%	3%	10%
Latimer Lake	6%	28%	2%	44%	6%	11%	3%
Nelson Lake	4%	37%	3%	20%	19%	13%	3%
Twin Lake	5%	24%	8%	22%	27%	13%	2%
Unnamed Creek	4%	37%	6%	24%	19%	6%	5%
Eagle Creek	6%	31%	3%	35%	17%	<1%	7%
Moran Creek	4%	17%	4%	28%	27%	1%	19%
Long Prairie River Watershed	**7%**	**26%**	**6%**	**21%**	**22%**	**8%**	**10%**

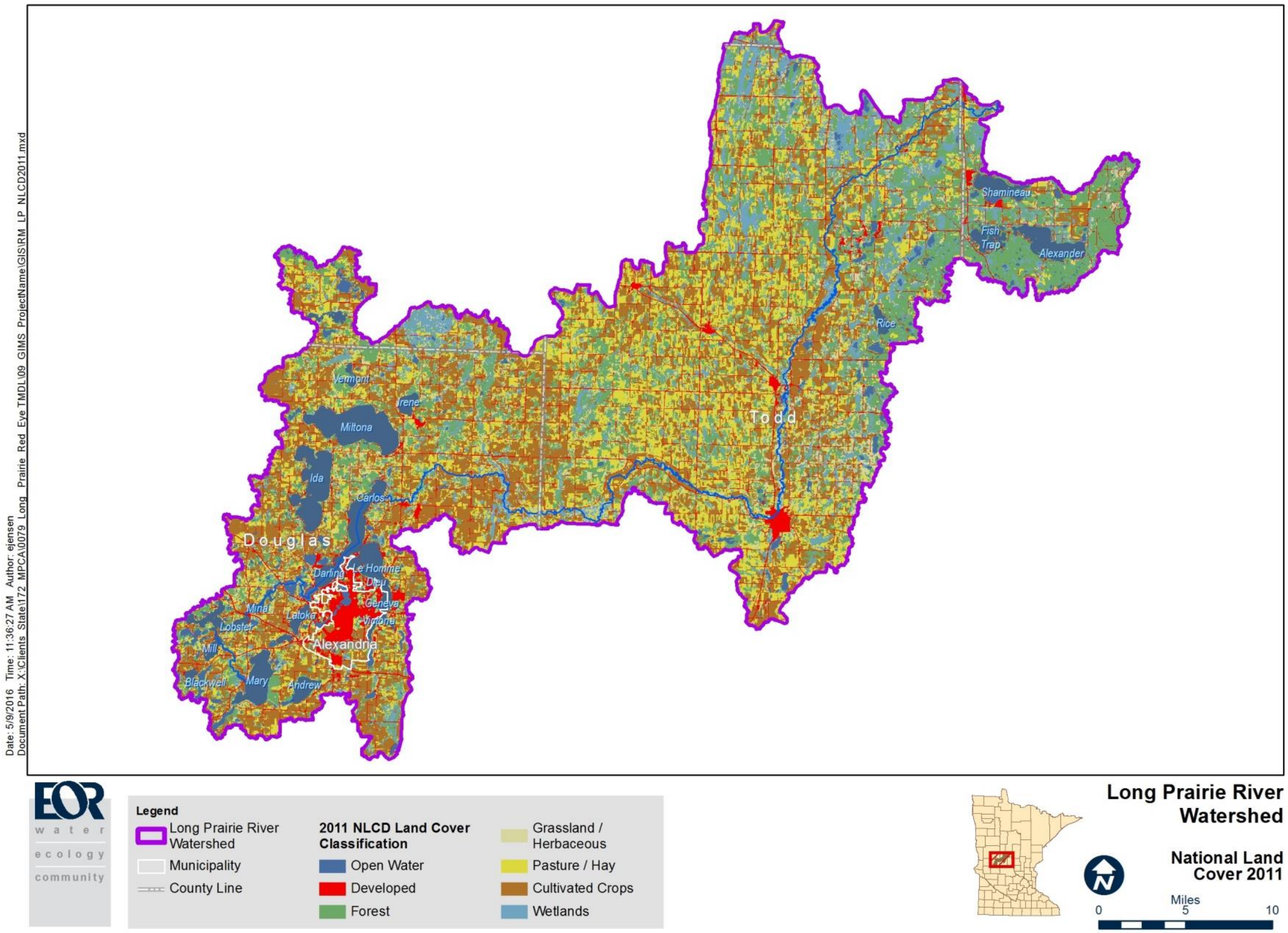


Figure 9. Land cover in the Long Prairie River Watershed (NLCD 2011)

3.4 Current/Historic Water Quality

The existing in-lake and in-stream water quality conditions were quantified using data downloaded from the MPCA Environmental Quality Information System (EQuIS) database and available for the most recent 10-year time period (2004 to 2013), which corresponds to the time period that MPCA used to assess these lakes and streams (MPCA 2012).

3.4.1. Lake Eutrophication (Phosphorus)

Growing season means of TP, Chl-*a*, and Secchi depth were calculated using monitoring data from June through September over a 10-year period (Table 7). Water quality trends, aquatic plants, and fish data are summarized by lake in Appendix A: Lake Summaries.

Table 7. 10-year growing season mean TP, Chl-*a*, and Secchi, 2004n to 2013

Lake Name	10-year Growing Season Mean (June to September)					
	TP		Chl-*a*		Secchi	
	(µg/L)	CV (%)	(µg/L)	CV (%)	(m)	CV (%)
NCHF – Shallow Lakes Standard	**< 60**	**--**	**< 20**	**--**	**> 1.0**	**--**
Fish	83.1	11%	52.5	24%	1.1	15%
Nelson	73.0	15%	36.9	24%	1.0	17%
Twin	81.6	8%	42.2	15%	1.3	26%
NCHF – General Lakes Standard	**< 40**	**--**	**< 14**	**--**	**> 1.4**	**--**
Crooked (East)	43.3	9%	28.2	16%	1.1	14%
Echo	47.7	8%	18.8	12%	1.5	8%
Jessie	55.2	13%	30.3	16%	1.5	4%
Latimer	71.1	17%	48.0	11%	1.2	4%

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

3.4.2. Stream *Escherichia coli*

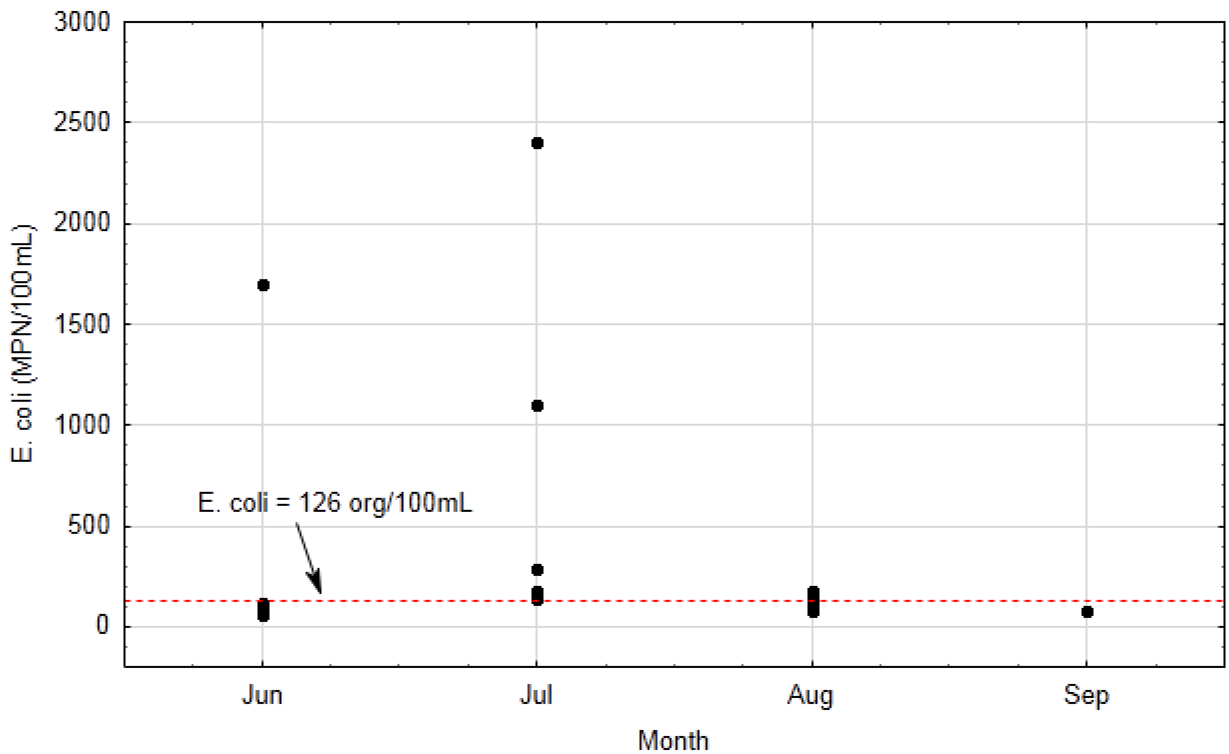
Using data from the most recent 10-year period (2004 to 2013), geometric mean *E. coli* concentrations were calculated by month for each impaired stream reach.

3.4.2.1. Eagle Creek (07010108-507)

Table 8. 10-year geometric mean *E. coli* (org/100mL) concentrations by month, 2004 to 2013

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S000-723	June	5	**160**	60-1,700
	July	5	**454**	140-2,400
	August	5	122	78-180
	September	1	82	82-82

* Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold red font.



* The dashed line represents the stream water quality standard (126 org/100mL)

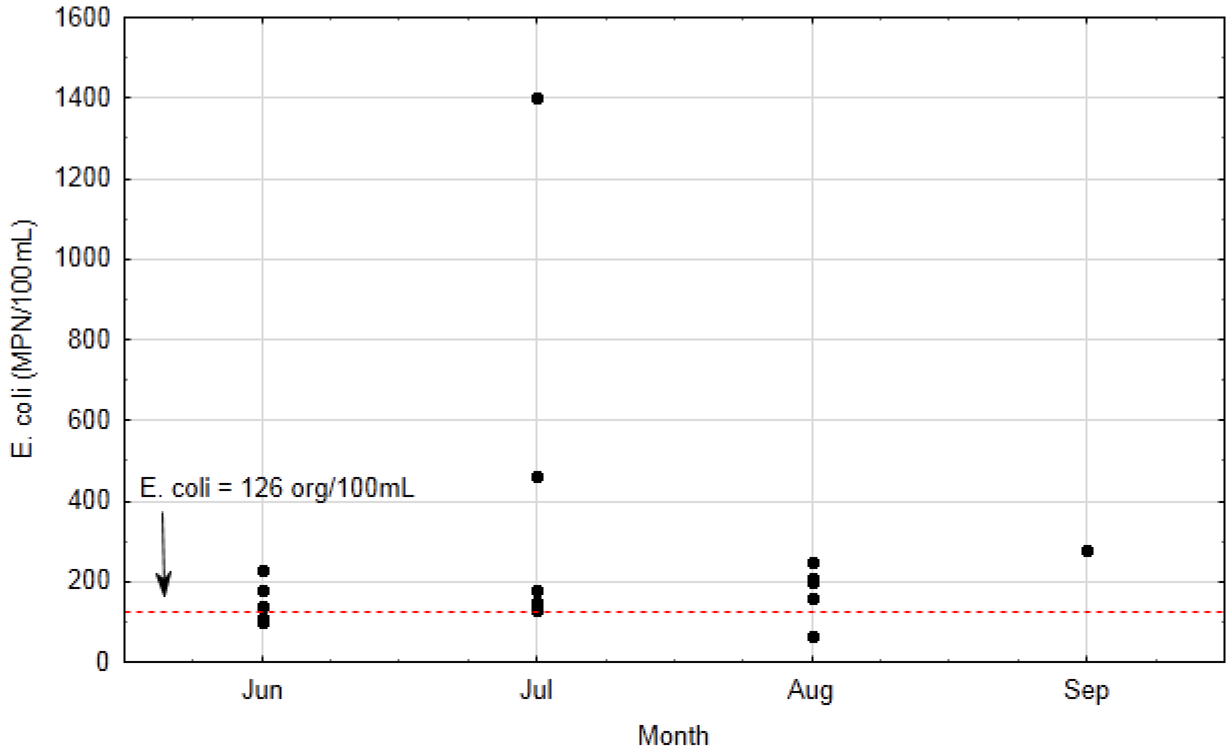
Figure 10. *E. coli* (MPN/100mL) by month in Eagle Creek at monitoring station S000-723, 2004 to 2013

3.4.2.2. Moran Creek (07010108-511)

Table 9. 10-year geometric mean *E. coli* (org/100mL) concentrations by month, 2004 to 2013

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S002-903	June	5	**145**	99-230
	July	5	**296**	130-1,400
	August	5	**161**	65-250
	September	1	280	280-280

* Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold red font.



* The dashed line represents the stream water quality standard (126 org/100mL)

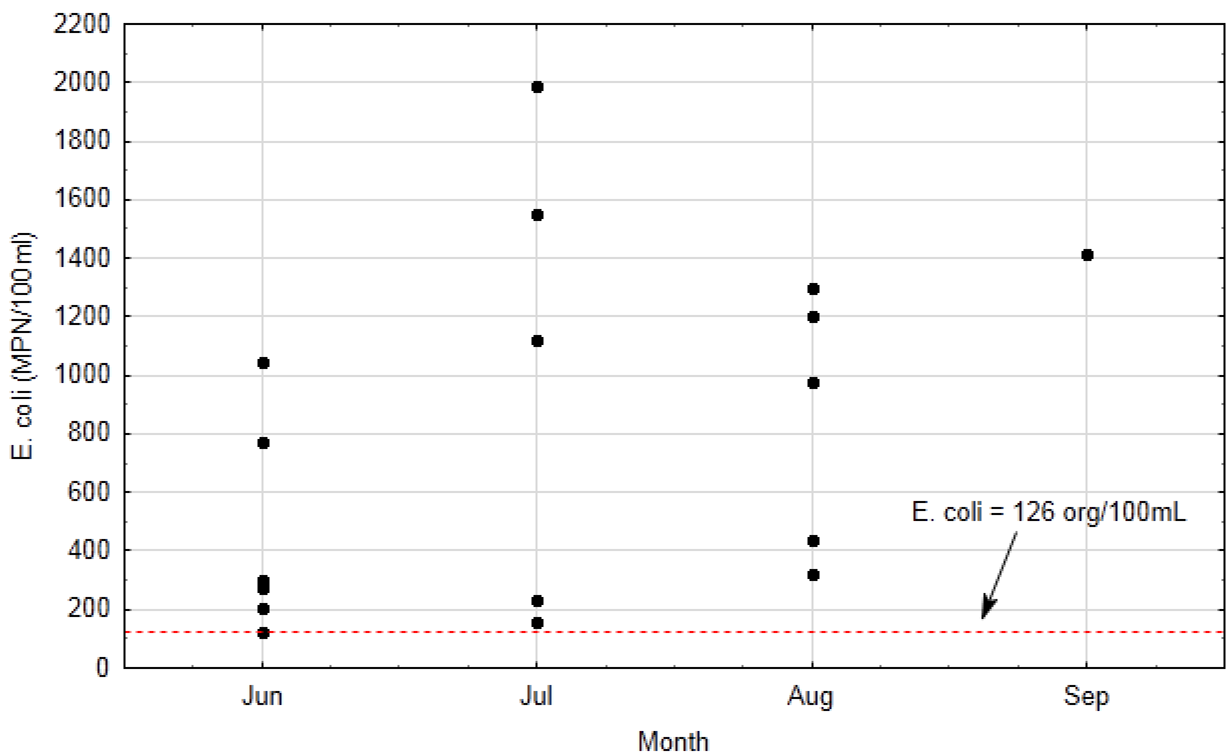
Figure 11. *E. coli* (MPN/100mL) by month in Moran Creek at monitoring station S002-903, 2004 to 2013

3.4.2.3. Unnamed Creek (07010108-552)

Table 10. 10-year geometric mean *E. coli* (org/100mL) concentrations by month, 2004 to 2013

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S001-780	June	6	**344**	121-1,046
	July	5	**661**	155-1,986
	August	6	**770**	318-1,300
	September	1	1,414	1,414-1,414

* Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least five samples are highlighted in bold red font.



* The dashed line represents the stream water quality standard (126 org/100mL)

Figure 12. *E. coli* (MPN/100mL) by month in Unnamed Creek at monitoring station S001-780, 2004 to 2013

3.5 Pollutant Source Summary

A key component to developing a nutrient or bacteria TMDL is understanding the sources contributing to the impairment. This section provides a brief description of the potential sources in the watershed contributing to excess nutrients and bacteria in the impaired lakes and streams addressed in this TMDL. The following sections discuss the major pollutant sources that have been quantified using collected monitoring data and water quality modeling to both assess the existing contributions of pollutant sources and target pollutant load reductions.

3.5.1. Lake Phosphorus

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

3.5.1.1. National Pollutant Discharge Elimination System Permitted

The regulated sources of phosphorus within the watersheds of the eutrophication impairments addressed in this TMDL study include construction stormwater and industrial stormwater. Phosphorus loads from National Pollutant Discharge Elimination System (NPDES) Permitted stormwater were accounted for using the methods described in Section 4.1.1 below.

3.5.1.2. Non-NPDES permitted

The following sources of phosphorus not requiring NPDES Permit coverage were evaluated:

- Watershed runoff
- Upstream lakes
- Runoff from feedlots not requiring NPDES Permit coverage
- Subsurface Sewage Treatment Systems ((SSTS) or septic systems)
- Atmospheric deposition
- Lake internal loading

Watershed runoff

An HSPF model was used to estimate watershed runoff volumes and TP loads from the direct drainage area of impaired lakes (AquaTerra 2013). The HSPF model generates overland runoff flows and phosphorus loads on a daily time step for 47 individual subwatersheds in the Long Prairie River Watershed based on land cover and soil type and was calibrated using meteorological data from 2000 through 2009. A 6-year (2004 to 2009) average annual flow was calculated for lake BATHTUB models to correspond with the 10-year (2004 to 2013) BATHTUB calibration period. The watersheds of Nelson, Twin, Fish, Latimer, Jessie, Crooked, and Echo lakes were smaller than the HSPF subwatershed, and their individual direct drainage flows and loads were area weighted from the total subwatershed flow and load.

Phosphorus loads from specific sources within the watershed (upstream waters, feedlots not requiring NPDES Permit coverage, and SSTS) were also independently estimated to determine their relative contributions for implementation planning purposes.

Table 11. Annual average HSPF flow volumes and TP loads for the direct drainages of impaired lakes (2004 to 2009)

Impaired lake	Direct drainage area (ac)	Flow (ac-ft/yr)	TP Conc. (ppb)	TP Load (kg/yr)
Crooked (East)	949	371	150.4	**68**
Echo	1,771	1,329	130.0	**211**
Fish	5,997	3,403	106.0	**441**
Jessie Lake	8,813	3,810	152.8	**712**
Latimer	1,790	1,369	167.3	**280**
Nelson	4,161	2,326	111.6	**317**
Twin	963	576	109.5	**77**

* Note that these values exclude point sources.

Upstream Lakes

Upstream lakes can contribute significant phosphorus loads to downstream impaired lakes and streams. Water quality monitoring data and flow from upstream lakes were used to estimate their phosphorus loads to downstream impaired waters and are summarized in Table 12.

Table 12. Existing upstream phosphorus loads to impaired lakes and streams

Impaired lake	Upstream Lake (Lake ID)	Flow (ac-ft/yr)	TP (ppb)	TP Load (kg/yr)
Fish	Nelson Lake (56-0065-00)	2,083	73.0	**186**
Twin	Fish Lake (56-0066-00)	5,049	83.1	**513**

Feedlots not requiring NPDES Permit coverage

Runoff during precipitation and snow melt can carry phosphorus from uncovered feedlots to nearby surface waters. For the purpose of this study, non-permitted feedlots are defined as being all registered feedlots without an NPDES/State Disposal System (SDS) Permit that house under 1,000 animal units (AUs). While these feedlots do not fall under NPDES regulation, other regulations still apply. Phosphorus loads from non-permitted registered feedlots were estimated based on assumptions described in the *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds* (MPCA 2004) and MPCA registered feedlot data listed in Table 13.

Table 13. Feedlot assumptions and phosphorus loads to impaired lakes

Parameter	Unit	Crooked (East)	Echo	Fish	Jessie Lake	Latimer	Nelson	Twin
Beef cattle	AU	71	0	0	15	33.2	396	64
	lb/ AU-yr	33.5	33.5	33.5	33.5	33.5	33.5	33.5
Dairy cows	AU	0	0	0	0	1,720	3	0
	lb/ AU-yr	47.8	47.8	47.8	47.8	47.8	47.8	47.8
Swine	AU	0	0	0	1.2	1.5	270	0
	lb/ AU-yr	26.6	26.6	26.6	26.6	26.6	26.6	26.6
Total P generated	lb/yr	2,379	0	0	534	83,368	20,591	2,144
Fraction of feedlots contributing to waters	%	0.35	0.35	0.35	0.35	0.35	0.35	0.35
P fraction lost to surface waters (average flow)	%	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044
Total Annual Feedlot Load	lb/yr	3.7	0.0	0.0	0.8	128.4	31.7	3.3
	kg/yr	**1.7**	**0.0**	**0.0**	**0.4**	**58.2**	**14.4**	**1.5**

* Adapted from the method described in MPCA 2004

Subsurface sewage treatment systems

Phosphorus loads from SSTS were estimated based on assumptions described in the *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds* (MPCA 2004) and county specific estimates of failing septic systems as listed in Table 14. The number and failure rate of SSTS are provided by county in the *2012 SSTS Annual Report* (MPCA 2013). In 2012, Douglas County inspected 5,203 individual septic systems representing 97% of all systems in the county. Of the systems inspected 728, or 14%, were found to be failing. Otter Tail County inspected 20,074 individual septic systems representing 92% of all systems in the county. Of the systems inspected, 5,019, or 25%, were found to be failing. Todd County inspected 7,993 individual septic systems representing 93% of all systems in the county. Of the systems inspected, 1,599, or 20%, were found to be failing. Lake specific failure rate estimates were available from Douglas Soil and Water Conservation District (SWCD) and Todd SWCD and were used for the applicable lakes in this TMDL (Crooked East, Echo, Jessie, and Latimer). A failure rate of 0% was assigned to Fish, Twin, and Nelson Lakes as the number of shoreline septic systems was too small to apply a county specific failure rate (i.e. 5% failure rate of 4 homes is approximately 0).

Table 14. SSTS phosphorus loads to impaired lakes and assumptions (MPCA 2004)

Parameter	Unit	Crooked (East)	Echo	Fish	Jessie	Latimer	Nelson	Twin
Shoreline SSTS	#	11	10	4	11	44	6	3
Seasonal Residence (4 mo/yr)	%	0%	0%	0%	0%	0%	0%	0%
Permanent Residence	%	100%	100%	100%	100%	100%	100%	100%
Conforming Systems	%	64%	60%	100%	73%	95.5%	100%	100%
Failing Systems	%	36%	40%	0%	27%	4.5%	0%	0%
Capita per Residence	#	2.23	2.23	2.27	2.23	2.41	2.27	2.27
P Production per Capita	lb/yr	1.95	1.95	1.95	1.95	1.95	1.95	1.95
Conforming SSTS %P "passing"	%	20%	20%	20%	20%	20%	20%	20%
Failing SSTS %P "passing"	%	43%	43%	43%	43%	43%	43%	43%
Conforming Systems	#	7	6	4	8	42	6	3
Failing Systems	#	4	4	0	3	2	0	0
P Load Conforming SSTS	lb/yr	6	5	4	7	39	5	3
P Load Failing SSTS	lb/yr	7	7	0	6	4	0	0
Total Shoreline SSTS P Load	lb/yr	13.6	12.7	3.6	12.6	43.5	5.4	2.7
	kg/yr	6.2	5.8	1.6	5.7	19.7	2.4	1.2
Total Shoreline SSTS P Load due to Failing	**kg/yr**	**1.8**	**1.8**	**0**	**1.4**	**1.0**	**0**	**0**

Atmospheric Deposition

Atmospheric deposition represents the phosphorus that is bound to particulates in the atmosphere and is deposited directly onto surface waters. Average phosphorus atmospheric deposition loading rates were ~0.24 lb/ac of TP per year for an average rainfall year for the Upper Mississippi River Basin (Barr 2007 addendum to MPCA 2004). This rate was applied to the lake and stream surface area to determine the total atmospheric deposition load per year to the impaired lakes.

Table 15. Atmospheric deposition phosphorus loads to impaired lakes [MPCA 2004]

Parameter	Unit	Crooked (East)	Echo	Fish	Jessie	Latimer	Nelson	Twin
Atmospheric Deposition	**kg/yr**	**11**	**14**	**53**	**12**	**22**	**29**	**15**

Internal Loading

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

1. *Chemical release from the sediments*

   Caused by anoxic (lack of oxygen) conditions in the overlying waters or high pH (greater than nine). If a lake hypolimnion (bottom area) remains anoxic for a portion of the growing season, the phosphorus released due to anoxia will be mixed throughout the water column when the lake loses its stratification at the time of fall mixing. In shallow lakes, the periods of anoxia can last for short periods of time and occur frequently.

2. *Physical disturbance of the sediments*

   Caused by bottom-feeding fish behaviors (such as carp and bullhead), motorized boat activity, and wind mixing. This is more common in shallow lakes than in deeper lakes.

3. *Decaying plant matter*

   Specifically, curly-leaf pondweed (*Potamogeton crispus*), which is an invasive plant that dies back mid-summer which is during the season to which the TMDL will apply and when water temperatures can accelerate algal growth.

Internal loading due to the anoxic release from the sediments of each lake was estimated in this study based on the expected release rate of phosphorus from the lakebed sediment, the lake anoxic factor, and the lake area. Lake sediment samples were taken and tested for concentration of TP and bicarbonate dithionite extractable phosphorus (BD-P), which analyzes iron-bound phosphorus. Phosphorus release rates were calculated using statistical regression equations developed using measured release rates and sediment phosphorus concentrations from a large set of North American lakes (Nürnberg 1988; Nürnberg 1996). Internal loading due to physical disturbance and decaying curly-leaf pondweed is difficult to estimate reliably and was therefore not included in the lake phosphorus analyses. In lakes where internal loading due to these sources is believed to be substantial, the internal load estimates derived from lake sediment data presented here are likely an underestimate of the actual internal load.

Because some amount of internal loading is explicit in the BATHTUB lake water quality model and uncertainty exists around the amount of internal loading estimated by the Nurnberg regression equations, the estimated total sediment phosphorus release rates per anoxic day converted to a 365-calendar day were used as a reference point for calibrating each impaired lake BATHTUB model to observed in-lake phosphorus concentrations (see Section 4.1.1.1: Internal Load). Moreover, the internal loading rates estimated by the Nurnberg regression equations represent the total potential sediment release rate while the calibrated internal loading rates from the BATHTUB model represents the excess sediment release rate beyond the average background release rate accounted for by the model development lake dataset.

The estimated sediment phosphorus release rates using the Nurnberg regression equations are typically smaller than the calibrated BATHTUB release rates for shallow lakes because the BATHTUB model development lake dataset is less representative of this lake type and therefore accounts for less implicit internal loading in shallow lakes. This was the case for Twin Lake and Fish Lake. Latimer Lake is not considered shallow but does show a distinct pattern of internal loading during the summer months (Figure 38).

For Nelson Lake, Crooked East Lake, and Echo Lake, the calibrated BATHTUB release rates were less than the estimated sediment phosphorus release rates using the Nurnberg regression equations, indicating that some or all of the internal loading in these lakes was accounted for by average background release rates from the model development dataset.

Table 16. Internal phosphorus load assumptions and summary (Nurnberg 1988, 1996)

Lake	Lake Type	Sediment P Concentration (mg/kg dry)		Anoxic Factor	Estimated Total Sediment P Release Rate NA Lakes Dataset (mg/m^2-anoxic day)			Average Estimated Total Sediment P Release Rate NA Lakes Dataset	BATHTUB Calibrated Excess Release Rate	BATHTUB Calibrated Excess Internal Load
		Iron P (BD-P)	Total P (TP)	(days)	BD-P	TP	Average	(mg/m^2-calendar day)	(mg/m^2-calendar day)	(kg/yr)
Crooked (East)	Deep	160	1100	49	1.62	0.00	0.81	0.11	0.0	**0.0**
Echo	Deep	150	700	52	1.48	0.00	0.74	0.11	0.0	**0.0**
Fish*	Shallow	No data							0.812	**587.3**
Jessie Lake	Deep	550	1700	55	6.97	2.23	4.60	0.69	0.0	**0.0§**
Latimer	Deep	340	1100	61	4.08	0.00	2.04	0.36	0.93	**277.0**
Nelson*	Shallow	No data							0.232	**93.3**
Twin*	Shallow	No data							1.17	**231.7**

* No sediment core sample collected due to early ice on

§ Reductions of internal load are needed to meet the TMDL goal; these reductions are from internal load accounted for by the BATHTUB model

3.5.2. Stream Bacteria

Humans, pets, livestock, and wildlife all contribute bacteria to the environment. These bacteria, after appearing in animal waste, are dispersed throughout the environment by an array of natural and man-made mechanisms. Bacteria fate and transport is affected by disposal and treatment mechanisms, methods of manure reuse, imperviousness of land surfaces, and natural decay and die-off due to environmental factors such as ultraviolet (UV) exposure and detention time in the landscape. The following discussion highlights sources of bacteria in the environment and mechanisms that drive the delivery of bacteria to surface waters.

To evaluate the potential sources of bacteria to surface waters a desktop analysis was conducted for sources that are potentially contributing *E. coli* in the watershed. These populations may include livestock, humans, companion animals (horses, cats, and dogs), and wildlife (deer, geese, ducks, and raccoons).

Populations were calculated using published estimates for each source on an individual subwatershed basis in the TMDL Project Area. This is typically a Geographic Information System (GIS) exercise where population estimates are clipped to the individual subwatershed boundaries. In some cases, these population estimates are clipped to individual land uses (defined using the 2006 National Land Cover Dataset, NLCD) within a subwatershed. For example, duck population estimates are assigned to open water land uses.

Bacteria production estimates are based on the bacteria content in feces and an average excretion rate (with units of colony forming units (cfu)/day-head; where *head* implies an individual animal). Bacteria content and excretion rates vary by animal type, as shown in Table 17. All production rates obtained from the literature are for fecal coliform rather than *E. coli* due to the lack of *E. coli* data. The fecal coliform production rates were converted to *E. coli* production rates based on 200 fecal coliforms to 126 *E. coli* per 100 mL (see discussion of *E. coli* water quality standard in Section 2.3).

Table 17. Bacteria production by source

Source Category	Producer	*E. coli* Production Rate [cfu/day-head]	Literature Source
Humans & Pets	Humans	1.26×10^{9}	Metcalf and Eddy 1991
	Dogs	3.15×10^{9}	Horsley and Witten 1996
Livestock	Horses	2.65×10^{10}	Zeckoski et al. 2005
	Cattle	2.08×10^{10}	Zeckoski et al. 2005
	Dairy Cows	1.58×10^{10}	Zeckoski et al. 2005
	Sheep	7.56×10^{9}	Zeckoski et al. 2005
	Hogs	6.93×10^{9}	Zeckoski et al. 2005
	Turkeys	5.86×10^{7}	Zeckoski et al. 2005
	Chickens	5.61×10^{7}	Zeckoski et al. 2005
Wildlife	Deer	2.21×10^{8}	Zeckoski et al. 2005
	Geese	5.04×10^{8}	Zeckoski et al. 2005
	Ducks	1.51×10^{9}	Zeckoski et al. 2005

3.5.2.1. NPDES Permitted

MS4

Wastewater Treatment Facilities

The WWTFs are required to test fecal coliform bacteria levels in effluent twice per week during discharge. Dischargers to Class 2 waters are required to disinfect from April through October. Wastewater disinfection is required during all months for dischargers within 25 miles of a water intake for a potable water supply system (Minn. R. 7053.0215, subp. 1). The geometric mean for all samples collected in a month must not exceed 200 cfu/ 100 mL fecal coliform bacteria. The WWTFs located in the Long Prairie River Watershed with surface water discharges are summarized in Table 18. These WWTFs are all pond systems. Bacteria loads from NPDES-permitted WWTFs were estimated based on the design flow and permitted bacteria effluent limit of 200 org/ 100 mL.

Table 18. WWTF design flows and permitted bacteria loads

Impaired Stream Reach	Facility Name, Permit #	6" per day discharge volume (mgd)	Permitted Bacteria Load as Fecal Coliform: 200 org/ 100 mL [billion org/day]	Equivalent Bacteria Load as *E. coli*: 126 org / 100 mL[1] [billion org/day]
-507	Eagle Bend WWTP, MN0023248	1.47	11.10	6.99
-507	Clarissa WWTP, MNG580008	1.49	11.27	7.10

Land Application of Biosolids

The application of biosolids from the WWTFs is highly regulated, monitored, and tracked (see Minn. R. ch. 7041 *Sewage Sludge Management*). Biosolids disposal methods that inject or incorporate within 24-hours of land application result in minimal possibility for mobilization of bacteria to downstream surface waters. While surface application could conceivably present a risk to surface waters, little to no runoff and bacteria transport is expected if permit restrictions are followed. Therefore, land application of biosolids was not included as a source of bacteria.

Concentrated Animal Feeding Operations

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

Livestock manure is often either surface applied or incorporated into farm fields as a fertilizer and soil amendment. This land application of manure has the potential to be a substantial source of fecal contamination, entering waterways from overland runoff and drain tile intakes. Research being conducted in southern Minnesota shows high concentrations of fecal bacteria leaving fields with incorporated manure and open tile intakes (Jamieson *et al.* 2002). Minn. R. ch. 7020 contains manure application setback requirements based on research related to phosphorus transport, and not bacterial transport, and the effectiveness of these current setbacks on bacterial transport to surface waters is not known.

There are nine active NPDES permitted CAFOs in the Long Prairie River Watershed, two of which are located in the subwatersheds of *E. coli* impaired streams. Manure from these facilities is applied to nearby fields. The bacteria loads produced by animals at these operations were estimated based on the total number of animals (Table 19) and the bacteria production rate of each animal (Table 17).

Table 19. NPDES permitted CAFO animal units (AUs)

Stream Reach	Feedlot Name	Permit #	Beef AUs	Hog AUs
-511	Twin Eagle Dairy LLP	MN0070068	1,450	0
-507	Jerry & Linda Korfe Hog Farm	MNG440982	0	4,400

3.5.2.2. Non-NPDES Permitted

Humans

Sewered and unsewered populations and number of households were determined using the 2010 Census data (U.S. Census Bureau 2011). Total population and the number of households were obtained for each subwatershed using block groups[1]; census block groups that overlap subwatershed boundaries were distributed between each applicable subwatershed on an area-weighted basis. Populations located in a sewered community were estimated from census block group data and boundaries of municipalities serviced by a WWTF (Table 18). A summary of the sewered and unsewered population and households by subwatershed are shown in Table 20.

Table 20. Sewered and unsewered population and households by subwatershed

Stream Reach	Population			Households		
	Sewered	Unsewered	Total	Sewered	Unsewered	Total
-507	1,219	968	2,187	614	411	1,025
-511	0	890	890	0	364	364
-552	0	295	295	0	160	160

Combined Sewer Overflows

Combined sewer systems are designed to collect sanitary sewage and stormwater runoff in a single pipe system. These systems overflow occasionally when heavy rain or melting snow causes the wastewater volume to exceed the capacity of the sewer system or treatment plant. An overflow event is called a combined sewer overflow (CSO), which entails a mix of raw sewage and stormwater runoff (from

[1] A census block in an urban area typically corresponds to individual city blocks bounded by streets; blocks in rural areas may include many square miles and may have some boundaries that are not streets. A block group is a group of census blocks. A block group is smaller than a census tract, which is a small statistical subdivision of a county (e.g. a municipality or a portion of a large city).

buildings, parking lots, and streets) flowing untreated into surface waters. The occurrence of CSOs is not known to be an issue in the Long Prairie River Watershed.

Illicit Discharges from Unsewered Communities

In many cases, onsite or small community cluster systems to treat wastewater are installed and forgotten until problems arise. Residential lots in small communities throughout Minnesota cannot accommodate modern septic systems that meet the requirements of current codes due to small lot size and/or inadequate soils. In addition, many small communities are characterized by outdated, malfunctioning septic systems serving older residences. Small lots, poor soils, and inadequate septic system designs and installations may be implicated in bacterial contamination of groundwater but the link to surface water contamination is tenuous.

"Failing" SSTS are specifically defined as systems that are failing to protect groundwater from contamination. Failing SSTS were not considered a source of fecal pollution to surface water. However, systems which discharge partially treated sewage to the ground surface, road ditches, tile lines, and directly into streams, rivers and lakes are considered an imminent threat to public health and safety (ITPHS). ITPHS systems also include illicit discharges from unsewered communities (sometimes called straight-pipes). Straight pipes are illegal and pose an imminent threat to public health as they convey raw sewage from homes and businesses directly to surface water. Community straight pipes are more commonly found in small rural communities.

The MPCA 2012 SSTS Annual Report identifies the percentage of systems in unsewered communities that are ITPHS for each county in Minnesota (MPCA 2013; Table 21). Bacteria load from ITPHS was estimated by subwatershed based on these percentages, the unsewered population (Table 20), and the bacteria production rate of humans (Table 17). Note that ITPHS data are derived from surveys of county staff and county level SSTS status inventories. The specific locations of ITPHS systems are not known. The table is not intended to suggest that ITPHS systems contribute excess bacteria to specific waterbodies addressed in this report; rather it suggests that, in general, ITPHS are believed to occur in the project area.

Table 21. Estimate of % Imminent Threat to Public Health & Safety Systems (ITPHSS) as reported by each county

County	% ITPHSS
Douglas	1%
Morrison*	4%
Otter Tail	5%
Todd	4%
Wadena	6%

*No data was available for Morrison County. The average failure rate of surrounding counties was applied.

Land Application of Septage

A state SSTS license applicable to the type of work being performed is required for any business that conducts work to design, install, repair, maintain, operate, or inspect all or part of an SSTS. A license is also required to land spread septage and operate a sewage collection system discharging to an SSTS. Disposal contractors are required to properly treat and disinfect septage through processing or lime stabilization. Treated septage may then be disposed of onto agricultural and forest lands. Standards Section 503 provides general requirements, pollutant limits, management practices, and operational standards for the final use or disposal of septage generated during the treatment of domestic sewage in a treatment works.

The MPCA does not directly regulate the land application of septage, but management guidelines entail site suitability requirements with respect to soil conditions, slope, and minimum separation distances (MPCA 2002). Some cities and townships have SSTS septage ordinances (a list is available at http://www.pca.state.mn.us/index.php/view-document.html?gid=10139); these were not reviewed as a part of this study, and application of septage was not included as a source of fecal pollution in this study.

Pets

Human pets (dogs and cats) can contribute bacteria to a watershed when their waste is not properly managed. When this occurs, bacteria can be introduced to waterways from:

- Dog parks
- Residential yard runoff (spring runoff after winter accumulation)
- Rural areas where there are no pet cleanup ordinances
- Animal elimination of excrement directly into waterbodies

Dog waste can be a significant source of pathogen contamination of water resources (Geldreich 1996). Dog waste in the immediate vicinity of a waterway could be a significant local source with local water quality impacts. However, it is generally thought that these sources may be only minor contributors of fecal contamination on a watershed scale because the estimated magnitude of this source is very small compared to other sources. According to the American Veterinary Medical Association 2006 data, 34.2% of Minnesota households own dogs with a mean number of 1.4 dogs in each of those households (AVMA 2007). In addition, it was assumed that only 38% of dog waste is not collected by owners and can contribute fecal pollution to surface waters (TBEP 2012). Bacteria load from dogs was estimated based on total households in each subwatershed (Table 20), the assumptions mentioned in this paragraph, and the bacteria production rate of dogs (Table 17).

Domestic cats, even those that spend some time outdoors, are most likely to have their waste collected indoors and were not considered a source of bacteria for this study. Feral cats may contribute to bacteria levels in urban streams and rivers (Ram et al. 2007). However, feral cat populations are unknown and were not included in this study.

Livestock

Livestock have the potential to contribute bacteria to surface water through grazing activities or if their manure is not properly managed or stored. Livestock manure is typically collected and applied to nearby fields through injection, which significantly reduces the transport of bacteria contained in manure to surface waters. The population estimates provided in this study is meant to identify areas where large numbers of livestock are located. These areas should be monitored closely by each county to ensure proper management and storage of manure.

The bacteria load from grazing livestock was estimated based on the number of animals (Table 22) and the bacteria production rate of those animals (Table 17).

Table 22. MPCA registered feedlot animals by subwatershed

Stream Reach	Beef	Dairy	Horses	Hog	Sheep	Turkey	Chickens
-507	5,079	6,434	291	965	201	14	11,499
-511	3,847	2,018	167	292	260	45,008	426
-552	1,777	424	3	1,794	20	0	0

Wildlife

Bacteria can be contributed to surface water by wildlife (e.g. deer, geese, and ducks) dwelling in waterbodies, within conveyances to waterbodies, or when their waste is carried to stormwater inlets, creeks, and ditches during stormwater runoff events. Areas such as DNR designated wildlife management areas, state parks, national parks, national wildlife refuges, golf courses, and state forests provide wildlife habitat encouraging congregation and could be potential sources of higher fecal coliform due to the high densities of animals. There are likely many areas within the project area where wildlife congregates, especially in the wetland-dominated northeast portion of the watershed.

Wildlife populations were estimated based on DNR population data for permit areas and zones. Because permit areas or zones do not align with subwatershed boundaries, population data for any single permit area or zone were distributed among subwatersheds on an area-weighted basis (Table 23). Populations of wildlife (deer, ducks, and geese) were estimated from the data sources and assumptions listed in Table 24. Bacteria loads from wildlife were estimated based on the population (Table 23) and bacteria production rates of wildlife (Table 17).

Table 23. Wildlife population estimates by subwatershed

Stream reach	Deer	Ducks	Geese
-507	1,138	29	171
-511	1,454	51	198
-552	476	15	366

Table 24. Population estimate data sources and habitat assumptions for wildlife

Wildlife	Population Estimate Data Sources and Habitat Assumptions
Ducks	According to a presentation by Steve Cordts of the Minnesota DNR Wetland Wildlife Population and Research Group at the 2010 Minnesota DNR Roundtable, Minnesota's annual breeding duck population averaged 550,000 between the years 2005-2009. While the breeding range of the canvasback and lesser scaup is typically outside of the project area, the majority of the breeding duck population (including blue-winged teal, mallards, ring-necked ducks, and wood ducks) has a state-wide breeding range. Statewide there is approximately 90,555,611 acres of suitable open water NWI habitat, equivalent to 0.061 ducks per acre of open water. This duck population density was distributed over all suitable open water NWI land covers plus a 100-foot buffer within each subwatershed on an area-weighted basis.
Deer	The DNR report Status of Wildlife Populations, Fall 2009, includes a collection of studies that estimate wildlife populations of various species (Dexter 2009). Pre-fawn deer densities were reported by DNR deer permit area. Permit area deer population densities over all 2006 NLCD land covers except open water within each subwatershed on an area-weighted basis.

Wildlife	Population Estimate Data Sources and Habitat Assumptions
Geese	The DNR report Status of Wildlife Populations, Fall 2009, also includes a collection of studies that estimate wildlife populations of various species by Minnesota ecoregion (Dexter 2009). Geese population data were distributed over and within a 100 foot buffer of all open water areas (PWI basins, streams, ditches and rivers, and 2006 NLCD *Open Water*) on an area-weighted basis within each subwatershed.

3.5.2.3. Strengths and Limitations

The bacteria production estimates are provided at the subwatershed scale. The results inform stakeholders as to the types and relative magnitude of bacteria produced in their watershed. This information is a valuable tool for the planning and management of water bodies with respect to bacteria contamination. The potential bacteria source estimates in the project area were calculated using a GIS-based approach. However, available data sources are at different scales and have different boundaries than that of the study subwatersheds. A limitation to the estimation process is that population data at a statewide or ecoregion scale must be distributed to the subwatershed scale based on average population density. As a result, there is a probable minimum scale at which bacteria production estimates are useful.

A significant portion of bacteria producers were accounted for in the potential bacteria sources. However, several animals were not included: birds other than geese and ducks (e.g. song birds and wading birds) and many wild animals (e.g. beavers, bear, and wild turkey). Data, resource limitations, and consideration for the major bacteria producers in the project area led to the selected set of bacteria producers accounted for in these estimates. The project area estimates of potential bacteria sources is also limited by the fact that bacteria delivery is not addressed (e.g. treatment of human waste at WWTFs prior to discharge to receiving waters, pet waste management, zero discharge feedlot facilities, incorporation of manure into soil, geese gathering directly on stormwater ponds). The potential bacteria source estimates also do not account for the relative risk among different types of bacteria. Instead, *E. coli* production is estimated as an indicator of the likelihood of pathogen contamination of our waterbodies.

Two Minnesota studies described the potential for the presence of naturalized or indigenous *E. coli* in watershed soils (Ishii et al. 2006) and ditch sediment and water (Sadowsky et al. 2010). The authors suggested that some background percentage of *E. coli* may be present or remain in the stream regardless of the control measures taken by traditional implementation strategies. It was not within the scope of this project to sample for or confirm the extent of any *E. coli* reproduction within impaired segments.

3.5.2.4. Summary

Refer to Section 3.3 for boundaries of the contributing watersheds to each impaired stream reach. Bacteria production estimates by subwatershed are listed by producer in Table 25 and for all producers in Table 26.

Table 25. Annual *E. coli* production estimates by producer

Impaired Stream Reach	Humans & Pets			Livestock							Wildlife		
	WWTF Effluent	ITPHS SSTS	Dogs	Cattle	Dairy	Turkey	Chickens	Hogs	Sheep	Horses	Deer	Ducks	Geese
-507	14	48	587	105,592	101,336	1	645	37,179	1,520	7,700	251	44	86
-511	0	46	209	79,979	54,621	2,637	24	2,024	1,966	4,419	321	77	100
-552	0	12	91	36,944	6,678	0	0	12,432	151	79	105	23	184

Table 26. Total annual *E. coli* production estimates

Impaired Stream Reach	Area	Total	Total	Humans	Livestock	Wildlife
	(ac)	(billion org/d)	(billion org/ac/d)	(% Total)		
-507	45,280	255,027	5.63	0.3%	99.6%	0.1%
-511	47,442	146,446	3.09	0.2%	99.5%	0.3%
-552	23,358	56,712	2.66	0.2%	99.2%	0.6%

4 TMDL Development

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

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

Where:

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

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

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

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

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

4.1 Phosphorus

4.1.1 Loading Capacity

4.1.1.1. Lake Response Model

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

Summary of Model Applications

For the lake TMDL derivations, flows and TP loads from the HSPF model (AquaTerra 2013) were used to estimate existing watershed phosphorus loading to the impaired lakes. The watershed phosphorus loads served as input to BATHTUB models, which were used to estimate in-lake water quality. The BATHTUB models were calibrated to existing in-lake water quality data (10-year growing season means) and were then used to identify the phosphorus load reductions needed to meet state in-lake water quality standards.

System Representation in Model

In typical applications of BATHTUB, lake and reservoir systems are represented by a set of segments and tributaries. Segments are the basins (lakes, reservoirs, etc.) or portions of basins for which water quality parameters are being estimated, and tributaries are the defined inputs of flow and pollutant loading to a particular segment. For this study, the direct drainage area and outflow from an upstream lake for which TP concentration is known were defined as separate tributaries to each lake (i.e. segment).

Model Inputs

The input required to run the BATHTUB model includes lake geometry, climate data, and water quality and flow data for runoff contributing to the lake. Observed lake water quality data are also entered into the BATHTUB program in order to facilitate model verification and calibration. Lake segment inputs are listed in Table 27, and tributary inputs are listed in Table 11 and Table 12 from Section 3.5.1.2. Precipitation rates were estimated at 0.69 m/yr and evaporation rates were estimated to be 0.82 m/yr based on data from the Minnesota Hydrology Guide (SCS 1992). Precipitation and evaporation rates apply only to the lake surface areas. Average phosphorus atmospheric deposition loading rates were estimated to be 0.24 lb/ac-yr for the Upper Mississippi River Basin (Barr 2007), applied over each lake's surface area. See discussion titled *Atmospheric Deposition* in *Section 3.5.1* for more details.

Table 27. BATHTUB segment input data. Note that the mean depths of Nelson Lake and Twin Lake are bold and italicized to indicate that they are estimates.

Impaired Lake	Surface area (sq km)	Lake fetch (km)	Mean depth (m)	Total Phosphorus	
				(ppb)	CV (%)
Crooked (East)	0.4116	1.0226	2.80	43.3	9%
Echo	0.5111	1.3021	3.43	47.7	8%
Fish	1.9803	1.6353	2.03	83.1	11%
Jessie	0.4461	1.6343	3.47	55.2	13%
Latimer	0.8154	1.6240	5.11	71.1	17%
Nelson	1.1007	1.2439	***1.52***	73.0	15%
Twin	0.5423	1.0653	***1.83***	81.6	8%

Model Equations

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

Model Calibration

The models were calibrated to existing water quality data according to Table 28, and then were used to determine the phosphorus loading capacity (TMDL) of each lake. When the predicted in-lake TP concentration was lower than the average observed (monitored) concentration, an explicit additional load was added to calibrate the model. It is widely recognized that Minnesota lakes in agricultural and urban regions have histories of high phosphorus loading and/or very poor water quality. For this reason, it is reasonable that internal loading may be higher than that of the lakes in the data set used to derive the Canfield-Bachmann lakes formulation. It is also possible that the watershed model loading estimates do not account for certain hot spots of phosphorus loading, such as above average application of lawn fertilizer runoff and/or pet waste. When the predicted in-lake TP concentration was higher than the average monitored concentration; the phosphorus calibration coefficient was increased to calibrate the model.

Table 28. Model calibration summary for the impaired lakes

Impaired Lake	P Sedimentation Model	Calibration Mode	Calibration Value
Crooked (East)	Canfield & Bachmann, Lakes	TP Calibration Factor	1.148
Echo	Canfield & Bachmann, Lakes	TP Calibration Factor	1.23
Fish	Canfield & Bachmann, Lakes	Added Internal Load	0.812 mg/m^2-day
Jessie	Canfield & Bachmann, Lakes	TP Calibration Factor	2.048*
Latimer	Canfield & Bachmann, Lakes	Added Internal Load	0.93 mg/m^2-day
Nelson	Canfield & Bachmann, Lakes	Added Internal Load	0.232 mg/m^2-day
Twin	Canfield & Bachmann, Lakes	Added Internal Load	1.17 mg/m^2-day

* Note that the HSPF modeled load to Jessie Lake resulted in a predicted in-lake TP concentration greater than the observed TP concentration. However, additional reductions from internal load were needed to meet the TMDL goal. This suggests that the HSPF model is over predicting the watershed phosphorus load to Jessie Lake, located upstream of an explicitly modeled lake in HSPF.

Determination of Lake Loading Capacity (TMDL)

Using the calibrated existing conditions model as a starting point, the phosphorus concentrations associated with tributaries were reduced until the model indicated that the TP state standard was met, to the nearest tenth of a whole number.

First, upstream impaired lake phosphorus concentrations were assumed to meet lake water quality standards. Next, the direct drainage flow weighted mean TP concentration was reduced to no less than 100 parts per billion (ppb) until in-lake phosphorus concentration met the lake water quality standard. A flow weighted mean concentration goal of 100 ppb was chosen to represent natural background conditions from the mostly rural and agricultural watershed. No reductions of the direct drainage flow weighted mean TP concentration were made if the calibrated existing condition was less than or equal to 100 ppb.

If further reductions were needed, any added internal loads were reduced until the in-lake phosphorus concentration met the lake water quality standard. In the case of Jessie Lake, lake water quality standards were not met when the direct drainage flow weighted mean TP concentration was reduced to 100 ppb due to the very high phosphorus sedimentation coefficient needed to calibrate the model.

Therefore, additional internal loading was added outside of the BATHTUB model in order to reach the in-lake water quality TP standard for deep lakes after accounting for a 10% MOS. Sediment phosphorus release rates were assumed to be equal to the release rates estimated by the Nurnberg regression equations. These rates were then reduced to meet the water quality standard.

Minnesota lake water quality standards assume that once the TP goals are met, the Chl-*a* and Secchi transparency standards will likewise be met (see *Section 2.1.1 Applicable Water Quality Standards*). With this process, a series of models were developed that included a level of phosphorus loading consistent with lake water quality state standards, or the TMDL goal. Actual load values are calculated within the BATHTUB software, so loads from the TMDL goal models could be compared to the loads from the existing conditions models to determine the amount of load reduction required.

4.1.2. Load Allocation Methodology

The LA includes all sources of phosphorus that do not require NPDES Permit coverage: watershed runoff, internal loading, atmospheric deposition, and any other identified loads described in Section 3.6.1. The remainder of the loading capacity (TMDL) after subtraction of the MOS and calculation of the WLA was used to determine the LA for each impaired lake, on an areal basis.

4.1.3. Watershed Allocation Methodology

4.1.3.1. Regulated Construction Stormwater

Construction stormwater is regulated by NPDES Permits for any construction activity disturbing a) one acre or more of soil, b) less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre, or c) less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. The WLA for stormwater discharges from sites where there are construction activities reflects the number of construction sites $\geq$ 1 acre expected to be active in the impaired lake subwatershed at any one time. See Section 7.1.2 for more information regarding the NPDES Construction Stormwater Permit.

A categorical WLA was assigned to all construction activity in the each impaired lake subwatershed. First, the median annual fraction of the impaired lake subwatershed area under construction activity over the past five years was calculated based on MPCA Construction Stormwater Permit data from January 1, 2007, to October 6, 2012, (Table 29) area weighted based on the fraction of the subwatershed located in each county. This percentage was multiplied by the watershed runoff load which is equal to the total TMDL (loading capacity) minus the sum of the atmospheric load, sediment load, and MOS to determine the construction stormwater WLA.

Table 29. Average Annual NPDES/SDS Construction Stormwater Permit Activity by county (January 1, 2007 to October 6, 2012)

County	Total Area (ac)	Median Annual Construction Activity (% Total Area)
Douglas	460,946	2.04%
Otter Tail	1,423,972	0.04%
Todd	626,776	0.01%

4.1.3.2. Regulated Industrial Stormwater

Industrial stormwater is regulated by NPDES Permits if the industrial activity has the potential for significant materials and activities to be exposed to stormwater discharges. The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in an impaired lake subwatershed for which NPDES Industrial Stormwater Permit coverage is required. See Section 7.1.3 for more information regarding the NPDES Industrial Stormwater Permit.

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

4.1.3.3. Municipal Separate Storm Sewer Systems Regulated Stormwater

If Municipal Separate Storm Sewer Systems (MS4) communities come under permit coverage in the future, a portion of the LA will be shifted to the WLA to account for the regulated MS4 stormwater. The MS4 permits for state (MnDOT) and county road authorities apply to roads within the U.S. Census Bureau Urban Area. None of the impaired lake subwatersheds are located within the U.S. Census Bureau Urban Area. Therefore, no roads are currently under permit coverage and no WLAs were assigned to the corresponding road authorities. If, in the future, the U.S. Census Bureau Urban Area extends into an impaired lake subwatershed and these roads come under permit coverage, a portion of the LA will be shifted to the WLA.

There are no regulated MS4 communities that discharge stormwater to an impaired water body addressed by this TMDL.

4.1.3.4. Feedlots Requiring NPDES/SDS Permit Coverage

Animal waste containing phosphorus can be transported in watershed runoff to surface waters. The primary goal of the state feedlot program is to ensure that surface waters are not contaminated by runoff from feedlots, manure storage or stockpiles, and cropland with improperly applied manure. Feedlots that either (a) have a capacity of 1,000 AUs or more, or (b) meet or exceed the EPA CAFO threshold, are required to apply for coverage under an NPDES/SDS Permit for livestock production from the MPCA.

There are no NPDES permitted feedlots in any of the impaired lake watersheds.

4.1.3.5. Municipal and Industrial Waste Water Treatment Systems

No WWTFs discharge to a phosphorus impaired lake that is addressed by this TMDL.

4.1.4. Margin of Safety

An explicit 10% MOS was accounted for in the TMDL for each impaired lake except Nelson Lake and Twin Lake. A 15% MOS was appointed to these lakes because the mean depths were estimated based on approximate maximum depths and comparison to similar surrounding lakes and topography. The mean depth affects the modeled in-lake TP concentration within BATHTUB and therefore an increased MOS was employed based upon those uncertainties. This MOS is sufficient to account for uncertainties in predicting phosphorus loads to lakes and predicting how lakes respond to changes in phosphorus loading. This explicit MOS is considered to be appropriate based on the generally good agreement between the water quality models' predicted and observed values. In addition, the models were based on loading inputs from a detailed watershed hydrology and water quality model (HSPF) and calibrated to a robust in-lake monitoring dataset.

4.1.5. Seasonal Variation

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

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

4.1.6. Future Growth Consideration/Reserve Capacity

Potential changes in population and land use over time in the Long Prairie River Watershed could result in changing sources of pollutants. Possible changes and how they may or may not impact TMDL allocations are discussed below.

4.1.6.1. New or Expanding Permitted MS4 WLA Transfer Process

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

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

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL (see Section 4.1.3). One transfer rate was defined for each impaired lake as the total watershed runoff LA (kg/day) divided by the watershed area downstream of any upstream impaired waterbody (acres). In the case of a load transfer, the amount transferred from the LA to the WLA will be based on the area (acres) of land coming under permit coverage multiplied by the transfer rate (kg/ac-day). The MPCA will make these allocation shifts. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment.

Table 30. Transfer rates for any future MS4 discharger in the impaired lake watersheds

Lake name	Flow Component	LA to WLA transfer rates	
		(kg/ac-yr)	(kg/ac-day)
Echo Lake	Direct Drainage	0.0874	0.000239
Crooked East Lake	Direct Drainage	0.0507	0.000139
Nelson Lake	Direct Drainage	0.0536	0.000147
Fish Lake	Direct Drainage	0.0582	0.000159
Twin Lake	Direct Drainage	0.0600	0.000164
Latimer Lake	Direct Drainage	0.0507	0.000139
Jessie Lake	Direct Drainage	0.0149	0.000041

4.1.7. TMDL Summary

4.1.7.1. Crooked Lake East (21-0199-02) TP TMDL

Table 31. Crooked Lake (East) TP TMDL and Allocations

Crooked Lake (East) Load Component		Existing	TMDL		Reduction	
		(kg/yr)	(kg/yr)	(kg/day)	(kg/yr)	(%)
Wasteload Allocations	Construction stormwater (MNR100001)	1.058	1.058	0.003	0.0	0%
	Industrial stormwater (MNR50000)	1.058	1.058	0.003	0.0	0%
	Total WLA	**2.1**	**2.1**	**0.006**	**0.0**	
Load Allocations	*Watershed runoff*	*62.6*	*48.1*	*0.132*	*14.5*	*23%*
	Livestock	*1.7*	*1.7*	*0.005*	*0.0*	*0%*
	Failing septic systems	*1.8*	*0.0*	*0.000*	*1.8*	*100%*
	Total Watershed/In-lake	66.1	49.8	0.136	16.3	25%
	Atmospheric	11.0	11.0	0.030	0.0	0%
	Total LA	**77.1**	**60.8**	**0.166**	**16.3**	
MOS			**7.0**	**0.019**		
TOTAL		**79.2**	**69.9**	**0.191**	**16.3**	**21%**

*LA components are broken down for guidance in implementation planning; loading goals for these components may change through the adaptive implementation process, but the total LA for each lake will not be modified from the total listed in the table above.

Phosphorus Source Summary

- Approximately 42% of the watershed is cropland or developed.
- There are approximately 71 beef cattle AUs in the watershed.

- There are approximately 11 shoreline private on-site septic systems, which are estimated to have a 36% failure rate.

4.1.7.2. Echo Lake (21-0157-00) TP TMDL

Table 32. Echo Lake TP TMDL and Allocations

Echo Lake Load Component		Existing (kg/yr)	TMDL (kg/yr)	TMDL (kg/day)	Reduction (kg/yr)	Reduction (%)
Wasteload Allocations	Construction stormwater (MNR100001)	2.9	2.9	0.008	0.0	0%
	Industrial stormwater (MNR50000)	2.9	2.9	0.008	0.0	0%
	Total WLA	**5.8**	**5.8**	**0.016**	**0.0**	
Load Allocations	*Watershed runoff*	*203.7*	*137.4*	*0.376*	*66.3*	*33%*
	Failing septic systems	*1.8*	*0.0*	*0.000*	*1.8*	*100%*
	Total Watershed/In-lake	205.5	137.4	0.376	68.1	33%
	Atmospheric	13.7	13.7	0.038	0.0	0%
	Total LA	**219.2**	**151.1**	**0.414**	**68.1**	
MOS			**17.4**	**0.048**		
TOTAL		**225.0**	**174.3**	**0.478**	**68.1**	**30%**

*LA components are broken down for guidance in implementation planning; loading goals for these components may change through the adaptive implementation process, but the total LA for each lake will not be modified from the total listed in the table above.

Phosphorus Source Summary

- Approximately 33% of the watershed is cropland or developed
- There are approximately 10 shoreline private on-site septic systems, which are estimated to have a 40% failure rate.

4.1.7.3. Fish Lake (56-0066-00) TP TMDL

Table 33. Fish Lake TP TMDL and Allocations

Fish Lake Load Component		Existing	TMDL		Reduction	
		(kg/yr)	(kg/yr)	(kg/day)	(kg/yr)	(%)
Wasteload Allocations	Construction stormwater (MNR100001)	0.172	0.172	0.0005	0.0	0%
	Industrial stormwater (MNR50000)	0.172	0.172	0.0005	0.0	0%
	Total WLA	**0.3**	**0.3**	**0.001**	**0.0**	
Load Allocations	*Watershed runoff*	*440.9*	*349.1*	*0.956*	*91.8*	*21%*
	Upstream impaired lake (Nelson Lake)	*186.0*	*128.3*	*0.351*	*57.7*	*31%*
	Internal Load	*587.3*	*162.1*	*0.444*	*425.2*	*72%*
	Total Watershed/In-lake	1,214.2	639.5	1.752	574.7	47%
	Atmospheric	53.1	53.1	0.145	0.0	0%
	Total LA	**1,267.3**	**692.6**	**1.897**	**574.7**	
MOS			**122.3**	**0.335**		
TOTAL		**1,267.6**	**815.2**	**2.233**	**574.7**	**45%**

*LA components are broken down for guidance in implementation planning; loading goals for these components may change through the adaptive implementation process, but the total LA for each lake will not be modified from the total listed in the table above.

Phosphorus Source Summary

- Approximately 16% of the watershed is cropland or developed.
- There are approximately six shoreline private on-site septic systems, which are estimated to have a 0% failure rate.
- The lake is shallow with a large littoral zone (98% of surface area) and mixing of sediments into the water column can contribute to internal phosphorus load.

4.1.7.4. Jessie Lake (21-0055-00) TP TMDL

Table 34. Jessie Lake TP TMDL and Allocations

Jessie Lake Load Component		Existing (kg/yr)	TMDL (kg/yr)	TMDL (kg/day)	Reduction (kg/yr)	Reduction (%)
Wasteload Allocations	Construction stormwater (MNR100001)	8.526	8.526	0.023	0.0	0%
	Industrial stormwater (MNR50000)	8.526	8.526	0.023	0.0	0%
	Total WLA	**17.1**	**17.1**	**0.047**	**0.0**	
Load Allocations	*Watershed runoff*	*693.1*	*400.7*	*1.098*	*292.4*	*42%*
	Livestock	*0.4*	*0.4*	*0.001*	*0.0*	*0%*
	Failing septic systems	*1.4*	*0.0*	*0.000*	*1.4*	*100%*
	Internal Load	*112.3*	*84.9*	*0.233*	*27.4*	*24%*
	Total Watershed/In-lake	807.1	486.1	1.332	321.0	40%
	Atmospheric	12.0	12.0	0.033	0.0	0%
	Total LA	**819.1**	**498.1**	**1.365**	**321.0**	
MOS			**57.3**	**0.157**		
TOTAL		**836.2**	**572.5**	**1.569**	**321.0**	**38%**

*LA components are broken down for guidance in implementation planning; loading goals for these components may change through the adaptive implementation process, but the total LA for each lake will not be modified from the total listed in the table above.

Phosphorus Source Summary

- Approximately 39% of the watershed is cropland or developed.
- There are approximately 15 beef cattle AUs, 48 dairy cattle AUs in the watershed.
- There are approximately 11 shoreline private on-site septic systems, which are estimated to have a 27% failure rate.

4.1.7.5. Latimer Lake (77-0105-00) TP TMDL

Table 35. Latimer Lake TP TMDL and Allocations

Latimer Lake Load Component		Existing	TMDL		Reduction	
		(kg/yr)	(kg/yr)	(kg/day)	(kg/yr)	(%)
Wasteload Allocations	Construction stormwater (MNR100001)	0.02	0.02	0.00005	0.0	0%
	Industrial stormwater (MNR50000)	0.02	0.02	0.00005	0.0	0%
	Total WLA	**0.04**	**0.04**	**0.0001**	**0.0**	
Load Allocations	*Watershed runoff*	*220.8*	*90.7*	*0.248*	*130.1*	*59%*
	Livestock	*58.2*	*58.2*	*0.160*	*0.0*	*0%*
	Failing septic systems	*1.0*	*0.0*	*0.000*	*6.9*	*100%*
	Internal Load	*277.0*	*44.5*	*0.122*	*232.5*	*84%*
	Total Watershed/In-lake	557.0	193.5	0.530	363.5	65%
	Atmospheric	21.9	21.9	0.060	0.0	0%
	Total LA	**578.9**	**215.4**	**0.590**	**363.5**	
MOS			**23.9**	**0.065**		
TOTAL		**578.9**	**239.3**	**0.655**	**363.5**	**63%**

*LA components are broken down for guidance in implementation planning; loading goals for these components may change through the adaptive implementation process, but the total LA for each lake will not be modified from the total listed in the table above.

Phosphorus Source Summary

- Approximately 34% of the watershed is cropland or developed.
- There are approximately 33 beef cattle AUs, 1,720 dairy cow AUs, and 2 swine AUs in the watershed.
- There are approximately 44 shoreline private on-site septic systems, which are estimated to have a 4.5% failure rate.

4.1.7.6. Nelson Lake (56-0065-00) TP TMDL

Table 36. Nelson Lake TP TMDL and Allocations

Nelson Lake Load Component		Existing	TMDL		Reduction	
		(kg/yr)	(kg/yr)	(kg/day)	(kg/yr)	(%)
Wasteload Allocations	Construction stormwater (MNR100001)	0.09	0.09	0.0002	0.0	0%
	Industrial stormwater (MNR50000)	0.09	0.09	0.0002	0.0	0%
	Total WLA	**0.17**	**0.17**	**0.0004**	**0.0**	
Load Allocations	*Watershed runoff*	*302.8*	*223.2*	*0.611*	*79.7*	*26%*
	Livestock	*14.4*	*14.4*	*0.039*	*0.0*	*0%*
	Internal Load	*93.3*	*20.1*	*0.055*	*73.2*	*78%*
	Total Watershed/In-lake	410.5	257.7	0.706	152.8	37%
	Atmospheric	29.5	29.5	0.081	0.0	47%
	Total LA	**440.0**	**287.2**	**0.787**	**152.8**	
MOS			**50.7**	**0.139**		
TOTAL		**440.2**	**338.1**	**0.926**	**152.8**	**35%**

*LA components are broken down for guidance in implementation planning; loading goals for these components may change through the adaptive implementation process, but the total LA for each lake will not be modified from the total listed in the table above.

Phosphorus Source Summary

- Approximately 42% of the watershed is cropland or developed.
- There are approximately 396 beef cattle AUs, 3 dairy cow AUs, and 270 swine AUs in the watershed.
- There are approximately six shoreline private on-site septic systems, which are estimated to have a 0% failure rate.
- The lake is extremely shallow (maximum depth of 7 feet) and mixing of the sediments into the water column can contribute to internal phosphorus load.

4.1.7.7. Twin Lake (56-0067-00) TP TMDL

Table 37. Twin Lake TP TMDL and Allocations

Twin Lake Load Component		Existing	TMDL		Reduction	
		(kg/yr)	(kg/yr)	(kg/day)	(kg/yr)	(%)
Wasteload Allocations	Construction stormwater (MNR100001)	0.13	0.13	0.0004	0.0	0%
	Industrial stormwater (MNR50000)	0.13	0.13	0.0004	0.0	0%
	Total WLA	**0.27**	**0.27**	**0.001**	**0.0**	
Load Allocations	*Watershed runoff*	*75.3*	*57.8*	*0.158*	*17.5*	*23%*
	Livestock	*1.5*	*1.5*	*0.004*	*0.0*	*0%*
	Upstream impaired lake (Fish Lake)	*513.1*	*313.5*	*0.859*	*199.6*	*39%*
	Internal Load	*231.7*	*107.3*	*0.294*	*124.4*	*54%*
	Total Watershed/In-lake	821.6	480.1	1.315	341.5	42%
	Atmospheric	14.5	14.5	0.040	0.0	0%
	Total LA	**836.1**	**494.6**	**1.355**	**341.5**	
MOS			**87.3**	**0.239**		
TOTAL		**836.4**	**582.2**	**1.595**	**341.5**	**41%**

*LA components are broken down for guidance in implementation planning; loading goals for these components may change through the adaptive implementation process, but the total LA for each lake will not be modified from the total listed in the table above.

Phosphorus Source Summary

- Approximately 29% of the watershed is cropland or developed.
- There are approximately 64 beef cattle AUs in the watershed.
- There are approximately three shoreline private on-site septic systems, which are estimated to have a 0% failure rate.
- The lake is shallow (estimated maximum depth of 15 feet) and mixing of sediments into the water column can contribute to internal phosphorus load.

4.1.8. TMDL Baseline Year

The TMDLs are based on water quality data through 2013. Any activities implemented during or after 2013 that lead to a reduction in phosphorus loads to the lake or an improvement in lake water quality, may be considered as progress towards meeting a WLA or LA.

4.2 Bacteria

4.2.1. Loading Capacity Methodology

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

For the stream TMDL derivation, HSPF modeled flows for the period 2000 through 2009 were used to develop flow duration curves. The loading capacities were determined by applying the *E. coli* water quality standard (126 org/ 100 mL) to the flow duration curve to produce a bacteria standard curve. Loading capacities presented in the allocation tables represent the median *E. coli* load (in billion org/day) along the bacteria standard curve within each flow regime. A bacteria LDC with modeled data and a TMDL allocation table are provided for each stream in Section 4.2.7. Where an impaired stream reach was located upstream of the outlet of an HSPF modeled subbasin, the flows from the contributing drainage area were area-weighted to account for differences in flow volume at the two locations.

Existing bacteria loads were determined from in-stream water quality monitoring. *E. coli* monitoring data were collected in 2011 through 2012 from all three impaired stream reaches, and stream gage data were collected from Moran and Eagle Creeks in 2011 through 2013. Stream gage data were not available for unnamed creek (AUID 07010108-552) for the water quality monitoring period. To estimate missing flow records for this reach, a regression was developed using 2000 to 2009 mean daily flow records for USGS gage #05245100, and the corresponding HSPF modeled flow records for unnamed creek. The regression equation was then used to predict missing flow records using the 2011 to 2012 records at USGS gage #05245100. The estimated existing load was calculated as the geometric mean of individual, observed *E. coli* loads within each flow regime. The sources of all water quality and stream flow data used in the development of LDCs are described in Appendix C at the end of this report.

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

4.2.2. Load Allocation Methodology

The LAs represent the portion of the loading capacity that is designated for non-regulated sources of *E. coli*, as described in Section 3.6.4.2, that are located downstream of any other impaired waters with

TMDLs located in the watershed. The remainder of the loading capacity (TMDL) after subtraction of the MOS and calculation of the WLA was used to determine the LA for each impaired stream, on an areal basis.

4.2.3. Wasteload Allocation Methodology

4.2.3.1. Municipal Separate Storm Sewer Systems Regulated Stormwater

If Municipal Separate Storm Sewer Systems (MS4) communities come under permit coverage in the future, a portion of the LA will be shifted to the WLA to account for the regulated MS4 stormwater. The MS4 permits for state (MnDOT) and county road authorities apply to roads within the U.S. Census Bureau Urban Area. None of the impaired lake subwatersheds are located within the U.S. Census Bureau Urban Area. Therefore, no roads are currently under permit coverage and no WLAs were assigned to the corresponding road authorities. If, in the future, the U.S. Census Bureau Urban Area extends into an impaired lake subwatershed and these roads come under permit coverage, a portion of the LA will be shifted to the WLA.

There are no regulated MS4 communities that discharge stormwater to an impaired water body addressed by this TMDL.

4.2.3.2. Regulated Construction Stormwater

E. coli WLAs for regulated construction stormwater (permit #MNR100001) were not developed since *E. coli* is not a typical pollutant from construction sites.

4.2.3.3. Regulated Industrial Stormwater

There are no *E. coli* benchmarks associated with the industrial stormwater permit because no industrial sectors regulated under the permit are known to be *E. coli* sources. Therefore, *E. coli* TMDLs will not include an industrial stormwater WLA. Since sites with MNG Permits are not known to be sources of *E. coli*, sites with MNG permits that are within the *E. coli* TMDL Subwatersheds will not receive an *E. coli* WLA.

4.2.3.4. Feedlots Requiring NPDES/SDS Permit Coverage

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

Based on a desktop review of the MPCA data there are two active NPDES permitted CAFOs within an *E. coli* impaired stream reach drainage area. The non-permitted feedlots are referenced in the non-point source inventory section (3.5.2.2 Non-permitted Sources of *E. coli*).

Table 38. NPDES permitted CAFO animal units

Stream Reach	Feedlot Name	Permit #	Beef	Hog
-511	Twin Eagle Dairy LLP	MN0070068	1,450	0
-507	Jerry & Linda Korfe Hog Farm	MNG440982	0	4,400

4.2.3.5. Municipal and Industrial Wastewater Treatment Systems

An individual WLA was provided for all NPDES-permitted WWTFs that have fecal coliform discharge limits (200 org/100mL, April 1 through October 31) and whose surface discharge stations fall within an impaired stream subwatershed. The WWTFs located in the Long Prairie River Watershed with surface water discharges are summarized in Table 39. These WWTFs are all pond systems. The NPDES Permits allow for two discharge windows between April 1 and June 30, and between September 1 and December 15, annually. The WWTFs are only allowed to discharge 6 inches of volume from the secondary pond system in a 24-hour period. The WLA was calculated based on the design flow and a permitted fecal coliform effluent limit of 200 org/ 100 mL (Table 39).

The WLAs are based on *E. coli* loads even though the facilities' discharge limits are based on fecal coliform. If a discharger is meeting the fecal coliform limits of their permit, it is assumed that they are also meeting the *E. coli* WLA in these TMDLs.

Table 39. WWTF design flows and permitted bacteria loads

Impaired Reach	Facility Name	Permit #	Secondary Pond Area (acres)	6" per day discharge volume (mgd)	Permitted Bacteria Load as Fecal Coliform: 200 org/ 100 mL [billion org/day]	Equivalent Bacteria Load as *E. coli*: 126 org / 100 mL[1] [billion org/day]
-507	Eagle Bend WWTP	MN0023248	9.0	1.47	11.10	6.99
-507	Clarissa WWTP	MNG580008	9.14	1.49	11.27	7.10

4.2.4. Margin of Safety

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

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

4.2.5. Seasonal Variation

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

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

4.2.6. Future Growth/Reserve Capacity

Potential changes in population and land use over time in the Long Prairie River Watershed could result in changing sources of pollutants. Possible changes and how they may or may not impact TMDL allocations are discussed below.

4.2.6.1. New or Expanding Permitted MS4 WLA Transfer Process

There are currently no regulated MS4 related to these impairments however, future transfer of watershed runoff loads in this TMDL may be necessary if any of the following scenarios occur within the project watershed boundaries:

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

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL (see Section 4.2.3). One transfer rate was defined for each impaired stream as the total wasteload allocation (billion org/day) divided by the watershed area downstream of any upstream impaired waterbody (acres). In the case of a load transfer, the amount transferred from LA to WLA will be based on the area (acres) of land coming under permit coverage multiplied by the transfer rate (billion org/ac-day). The MPCA will make these allocation shifts. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment. Individual transfer rates for each stream TMDL are listed in Table 40.

Table 40. Transfer rates for any future MS4 discharger in the impaired stream watersheds

Stream name	AUID	LA to WLA transfer rates (billion org/acre/day)				
		High	Wet	Mid	Dry	Low
Eagle Creek	07010108-507	2.98	0.86	0.37	0.09	n/a*
Moran Creek	07010108-511	2.86	1.02	0.49	0.21	0.10
Unnamed Creek	07010108-552	2.23	0.63	0.33	0.18	0.09

The WLA for treatment facilities requiring NPDES Permits is based on the design flow. The WLA exceeded the Very Low flow regime TMDL allocation to Eagle Creek as denoted by ''

4.2.6.2. New or Expanding Wastewater

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

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

4.2.7. TMDL Summary

The individual impaired stream TMDL and allocations are summarized in table format in the following sections. The LDCs used in the determination of loading capacity are included in these sections. For detailed information on potential sources of *E. coli* in watershed runoff see the Bacterial Source Assessment, Section 3.6.4.

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

4.2.7.1. Eagle Creek (07010108-507) *E. coli* TMDL

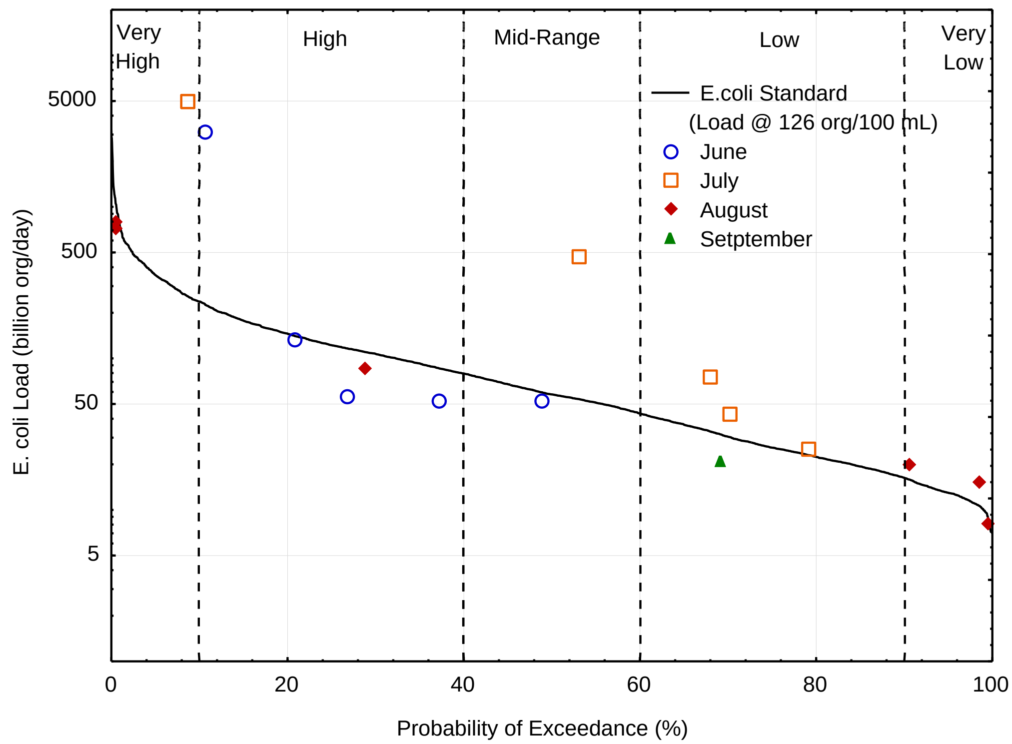


Figure 21. Eagle Creek *E. coli* LDC

Table 35. Eagle Creek *E. coli* TMDL and Allocations

Eagle Creek 07010108-507 Load Component		Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load		*1,930.0*	*160.7*	*156.2*	*36.1*	*13.6*
Wasteload Allocations	*Clarissa WWTP, MNG580008*	7.1	7.1	7.1	7.1	*
	Eagle Bend WWTP, MN0023248	7.0	7.0	7.0	7.0	*
	NPDES permitted feedlots	0.0	0.0	0.0	0.0	0.0
	Total WLA	**14.1**	**14.1**	**14.1**	**14.1**	**0.0**
Load Allocations	*Watershed runoff*	305.4	87.6	38.0	9.1	*
	Total LA	**305.4**	**87.6**	**38.0**	**9.1**	*****
10% MOS		**35.5**	**11.3**	**5.8**	**2.6**	**1.3**
Total Loading Capacity		**355.0**	**113.0**	**57.9**	**25.8**	**13.0**
Estimated Load Reduction (including MOS)		*1,610.5* *83%*	*47.7* *37%*	*104.1* *67%*	*12.9* *36%*	*1.9* *14%*

* The WLA for treatment facilities requiring NPDES Permits is based on the design flow. The WLA exceeded the Very Low flow regime total loading capacity of Eagle Creek as denoted by '*'. The WLA and LA allocations are determined by the formula: *E. coli Allocation = (flow volume contribution from a given source) x (126 org/100mL E. coli)*

4.2.7.2. Moran Creek (07010108-511) *E. coli* TMDL

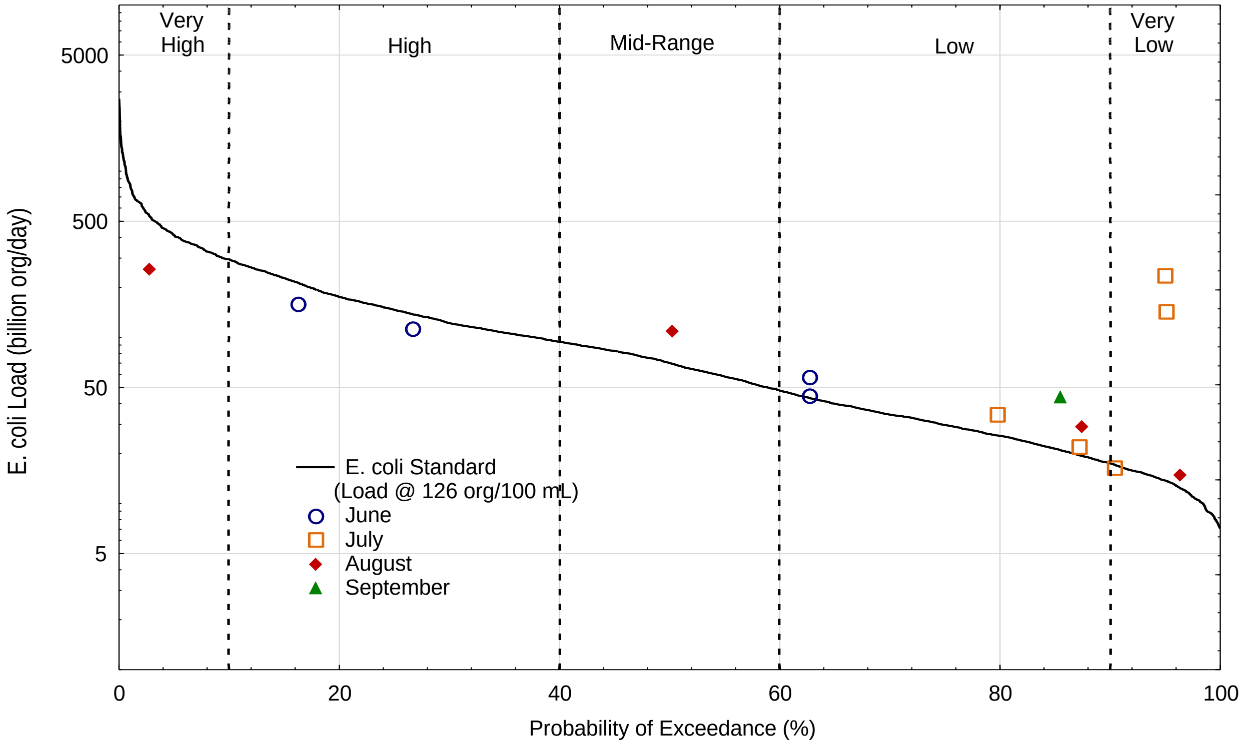


Figure 26. Moran Creek *E. coli* LDC

Table 41. Moran Creek *E. coli* TMDL and Allocations

Moran Creek 07010108-511 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load		*259.8*	*133.5*	*160.0*	*36.8*	*20.1*
Wasteload Allocations	*NPDES permitted feedlots*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
	Total WLA	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load Allocations	*Watershed runoff*	*349.2*	*124.0*	*59.2*	*25.1*	*11.6*
	Total LA	**349.2**	**124.0**	**59.2**	**25.1**	**11.6**
10% MOS		**38.8**	**13.8**	**6.6**	**2.8**	**1.3**
Total Loading Capacity		**388.0**	**137.8**	**65.8**	**27.9**	**12.9**
Estimated Load Reduction (including MOS)		*0* *0%*	*0* *0%*	*100.8* *63%*	*11.7* *32%*	*8.5* *42%*

4.2.7.3. Unnamed Creek (07010108-552) *E. coli* TMDL

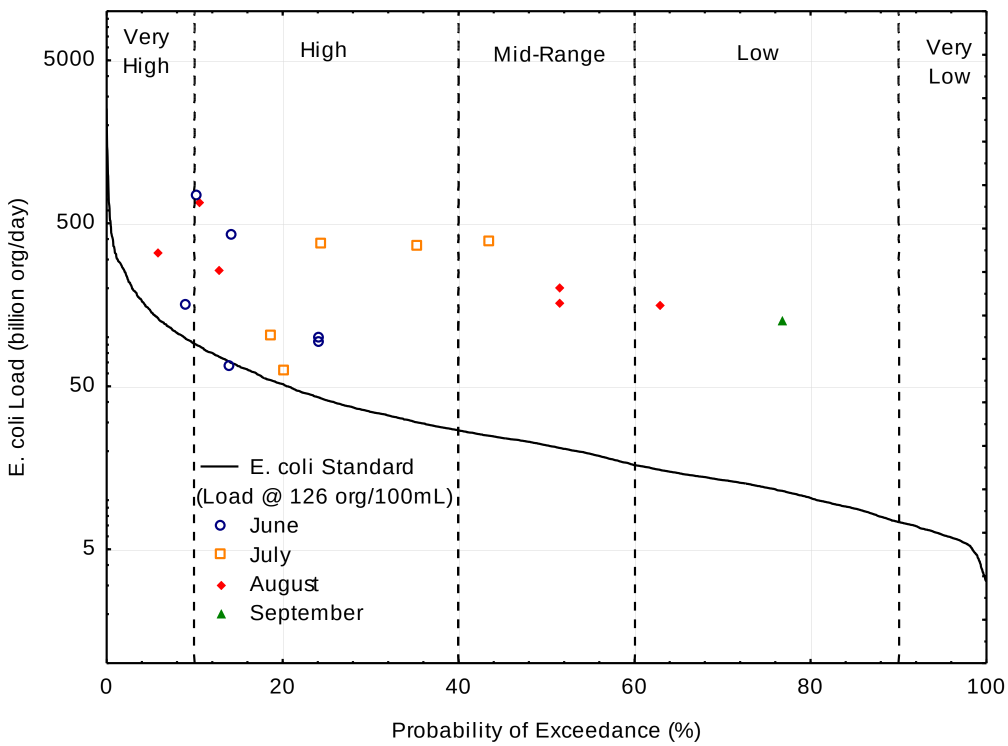


Figure 27. Unnamed Creek *E. coli* LDC

Table 42. Unnamed Creek *E. coli* TMDL and Allocations

Unnamed Creek 07010108-552 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load		*232.3*	*209.4*	*234.7*	*142.6*	*No Data*
Wasteload Allocations		**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load Allocations	*Watershed runoff*	*130.3*	*36.9*	*19.5*	*10.8*	*5.5*
	Total LA	**130.3**	**36.9**	**19.5**	**10.8**	**5.5**
10% MOS		**14.5**	**4.1**	**2.2**	**1.2**	**0.6**
Total Loading Capacity		**144.8**	**41.0**	**21.7**	**12.0**	**6.1**
Estimated Load Reduction (including MOS)		*102.0*	*172.5*	*215.2*	*131.8*	*n/a*
		44%	*82%*	*92%*	*92%*	*n/a*

4.2.8. TMDL Baseline Years

The TMDLs are based on water quality data through 2013. Any activities implemented during or after 2013 that lead to a reduction in *E. coli* loads to an impaired stream, or an improvement in stream water quality, may be considered as progress towards meeting a WLA or LA.

5 Reasonable Assurance

5.1 Non-regulatory

At the local level, the Douglas SWCD, Morrison SWCD, Otter Tail SWCD, Todd SWCD and Wadena SWCD and other local entities currently implement programs that target improving water quality and have been actively involved in projects to improve water quality in the past. Willing landowners within this watershed have implemented many practices in the past including: conservation tillage, buffer strips, urban BMPs, gully stabilizations, prescribed grazing, manure management, etc. It is assumed that these activities will continue. Potential state funding of Restoration and Protection projects include Clean Water Fund grants. At the federal level, funding can be provided through Section 319 grants that provide cost-share dollars to implement activities in the watershed. Various other funding and cost-share sources exist, which will be listed in the Long Prairie River WRAPS report. The implementation strategies described in this plan have demonstrated to be effective in reducing nutrient loading to lakes and streams. There are programs in place within the watershed to continue implementing the recommended activities. Monitoring will continue and adaptive management will be in place to evaluate the progress made towards achieving water quality goals.

5.2 Regulatory

5.2.1. Regulated Construction Stormwater

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

5.2.2. Regulated Industrial Stormwater

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

5.2.3. Municipal Separate Storm Sewer System (MS4) Permits

There are currently no regulated MS4s related to the impairments addressed in this TMDL.

5.2.4. Wastewater & State Disposal System (SDS) Permits

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

5.2.5. Subsurface Sewage Treatment Systems Program

The SSTS, commonly known as septic systems, are regulated by Minn. Stat. §§ 115.55 and 115.56.

These regulations detail:

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

5.2.6. Feedlot Rules

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

There are two primary concerns about feedlots in protecting water:

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

6 Monitoring Plan

6.1. Lake and Stream Monitoring

Lake associations and other groups participate in monitoring activities to meet their specific needs. Volunteers throughout the watershed conduct stream and lake condition monitoring through the MPCA Volunteer Monitoring Program. The MPCA currently monitors the Long Prairie River near Philbrook for Flow, Total Phosphorus, Ortho Phosphorus, Nitrite + Nitrate Nitrogen, Total Kjeldahl Nitrogen, and Total Suspended Solids. This site as well as the Long Prairie River in the city of Long Prairie will also be sampled for the same parameters starting in 2015.

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

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

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

6.2. BMP Monitoring

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

7 Implementation Strategy Summary

7.1 Permitted Sources

7.1.1. MS4

7.1.2. There are currently no regulated MS4 communities related to this TMDL study. Construction Stormwater

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

7.1.3. Industrial Stormwater

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

7.1.4. Wastewater

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

7.2 Non-Permitted Sources

7.2.1. Adaptive Management

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

7.2.2. Best Management Practices

A variety of BMPs to restore and protect the lakes and streams within the Long Prairie Watershed have been outlined and prioritized in the forthcoming WRAPS report. The WRAPS document also provides implementation strategies to protect lakes and streams that are not currently impaired. The implementation plan outlined in the WRAPS is divided into HUC12 watersheds. Each waterbody within the HUC12 where implementation strategies are needed, are specifically identified. Management goals, specific strategies (BMPS), responsible party, timelines and milestones are identified for each waterbody.

The main strategy identified in the Redeye River WRAPS to improve water quality in Crooked, Echo, Jessie and Latimer Lake is to reduce watershed runoff before entering lakes and streams. The strategies that have been identified to mitigate watershed runoff include improving upland and field surface runoff controls, reducing bank/bluff/ravine erosion, increasing vegetative cover and root durations by planting crops and vegetation adjacent to riparian areas, and preventing feedlot runoff by conducting feedlot inspections and ensuring compliance. Reducing the internal load is the main strategy for Fish and Nelson Lake. Reducing the load coming from Fish Lake is the main strategy to improve water quality in Twin Lake.

Strategies were also identified in the WRAPS to reduce bacteria levels in the three impaired stream reaches. The main strategy to accomplish this is to reduce livestock bacteria in surface runoff. Specific practices such as improved field manure (nutrient) management plans, adhering or increasing application setbacks from riparian areas, improving feedlot runoff control and rotational grazing including livestock exclusion.

7.2.3. Education and Outreach

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

7.2.4. Technical Assistance

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

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

7.2.5. Partnerships

Partnerships with counties, cities, townships, citizens, businesses, watersheds, and lake associations are one mechanism through which the Douglas SWCD, Morrison SWCD, Otter Tail SWCD, Todd SWCD and Wadena SWCD will protect and improve water quality. Strong partnerships with state and local government to protect and improve water resources and to bring waters within the Long Prairie River Watershed into compliance with state standards will continue. A partnership with local government units and regulatory agencies such as cities, townships and counties may be formed to develop and update ordinances to protect the areas water resources.

7.3 Cost

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

7.3.1. Phosphorus

A detailed analysis of the cost to implement the phosphorus TMDLs was not conducted. However, as a rough approximation one can use some general results from BMP cost studies across the U.S. For example, an EPA summary of several studies of predominantly developed urban landscapes showed a median cost of approximately $2,200 per pound TP removed per year (Foraste et al. 2012). Multiplying that by the needed 3,500-pound reduction for all the lakes in this study provides a total cost of approximately $7.7M. This estimate will be refined during the WRAPS process.

7.3.2. Bacteria

The cost estimate for bacteria load reduction is based on unit costs for the two major sources of bacteria: livestock and imminent threat to public health septic systems. The unit cost for bringing AUs under manure management plans and feedlot lot runoff controls is $350/AU. This value is based on U.S. Department of Agriculture EQIP payment history and includes buffers, livestock access control, manure management plans, waste storage structures, and clean water diversions. Repair or replacement of

ITPHS SSTS was estimated at $7,500/system (EPA 2011). Multiplying those unit costs by an estimated 36 ITPHSS and 29,422 AU in the impaired reach subwatersheds provides a total cost of approximately $10.6M. This estimate will be refined during the WRAPS process.

8 Public Participation

8.1 Steering Committee Meetings

The Long Prairie Watershed is made up of numerous local partners who have been involved at various levels throughout the project. The steering committee is made up of members representing the DNR, Department of Agriculture, counties and soil and water conservation districts within the watershed, The Nature Conservancy, and the Board of Water and Soil Resources. The following table outlines the meetings that occurred regarding the Long Prairie Watershed monitoring, TMDL development, and WRAPS report planning.

Date	Location	Meeting Focus
3/21/12	SWCD office Alexandria, MN	Quarterly Meeting
10/15/12	County Courthouse Long Prairie, MN	Quarterly Meeting
4/10/13	MPCA office Brainerd, MN	Lake and Stream Assessments
6/5/13	County Courthouse Long Prairie, MN	Quarterly Meeting – Impairment focus
6/19/13	MPCA office Brainerd, MN	Quarterly Meeting – HSPF focus
12/11/13	MPCA in Brainerd, MN	Quarterly Meeting
12/10/14	County Courthouse Long Prairie, MN	Quarterly Meeting
1/28/15	County Courthouse Long Prairie, MN	Quarterly Meeting – draft TMDL focus

8.2 Public Meetings

The MPCA along with the local partners and agencies in the Long Prairie Watershed recognize the importance of public involvement in the watershed process. The following table outlines the opportunities used to engage the public and targeted stakeholders in the watershed.

Date	Location	Meeting Focus
4/12/11	Community Center Parkers Prairie, MN	Watershed Project Kick-Off
3/12/14	Public Works Alexandria, MN	Impairments in Douglas County
3/21/14	County Courthouse Long Prairie, MN	Impairments in Todd County
12/17/14	County Courthouse Long Prairie, MN	TMDL status and WRAPS discussion

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Appendix A: Lake Summaries

A.1 Crooked (East) Lake

Crooked (East) Lake (DNR Lake ID 21-0199-02) and its entire watershed are located in Douglas County. The watershed is located in the southwest portion of the Long Prairie River Watershed and is a headwater lake. Figure 13 illustrates the available bathymetry, and Figure 14 shows the 2013 aerial photograph.

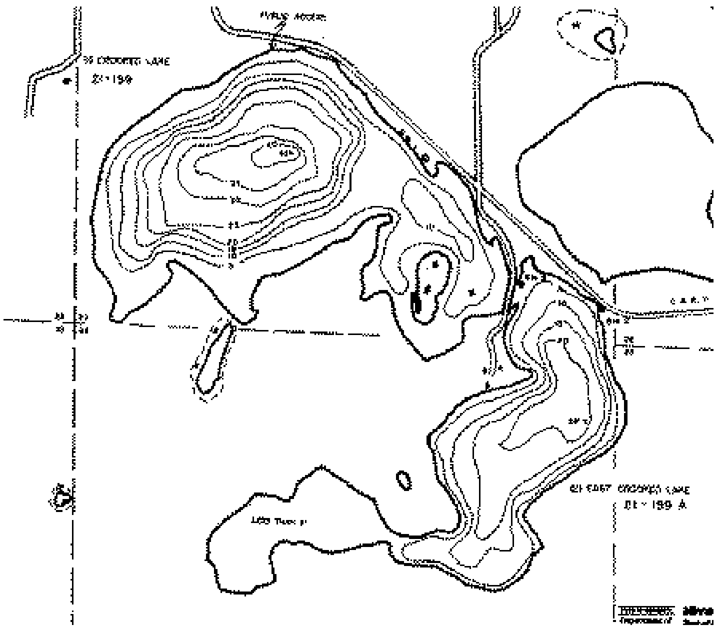
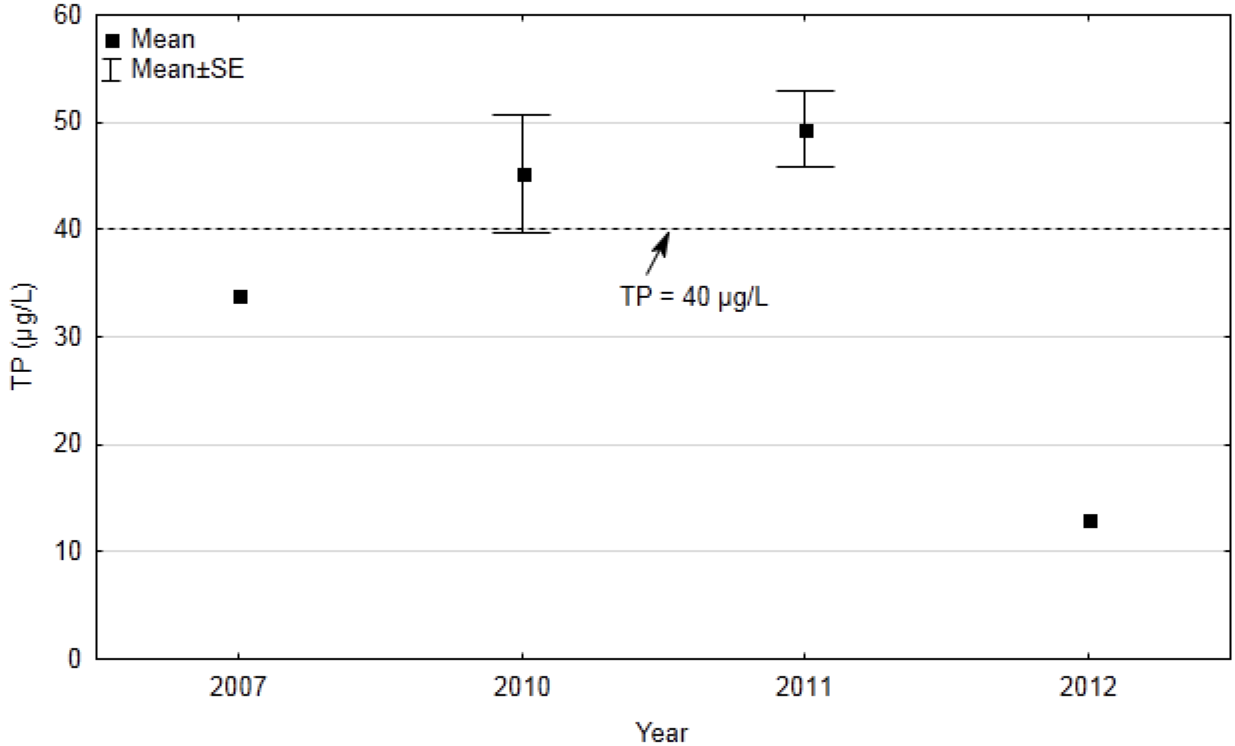


Figure 13. Crooked (East) Lake Bathymetry (DNR)

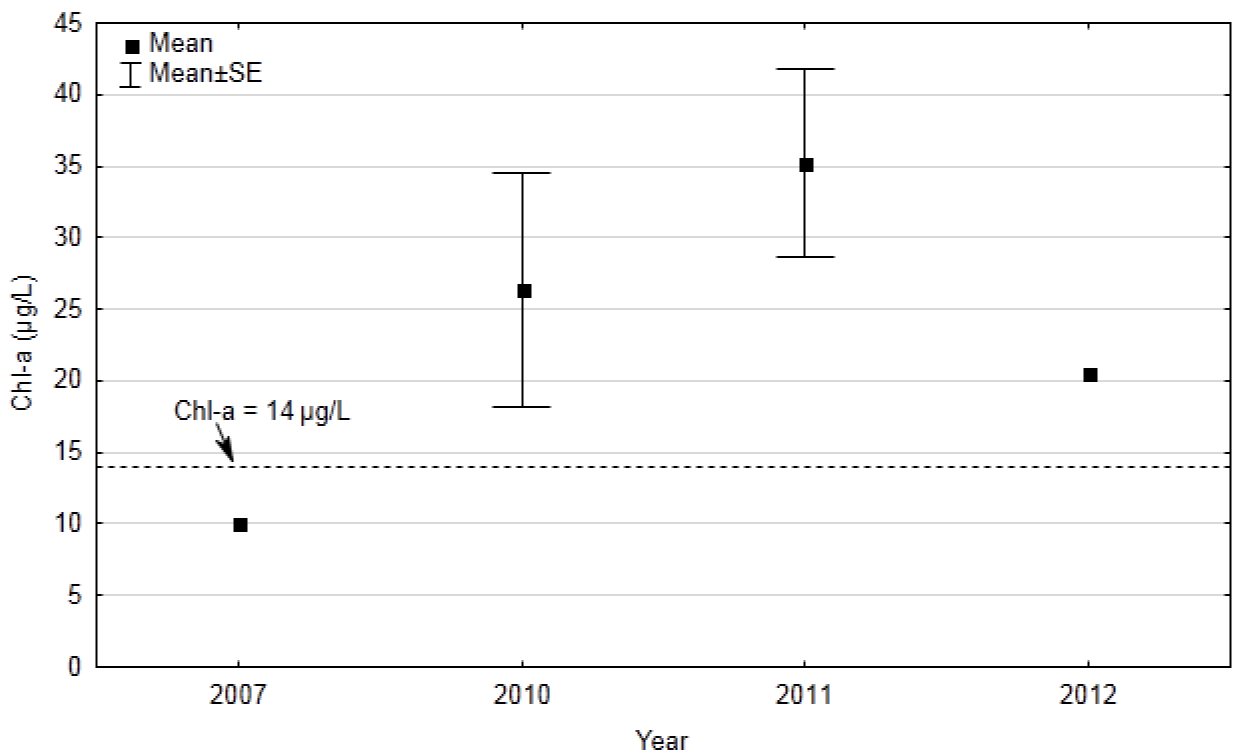
Figure 14. Aerial photograph of Crooked (East) Lake (Google Earth, May 2013)

A.1.1 Water Quality Trends



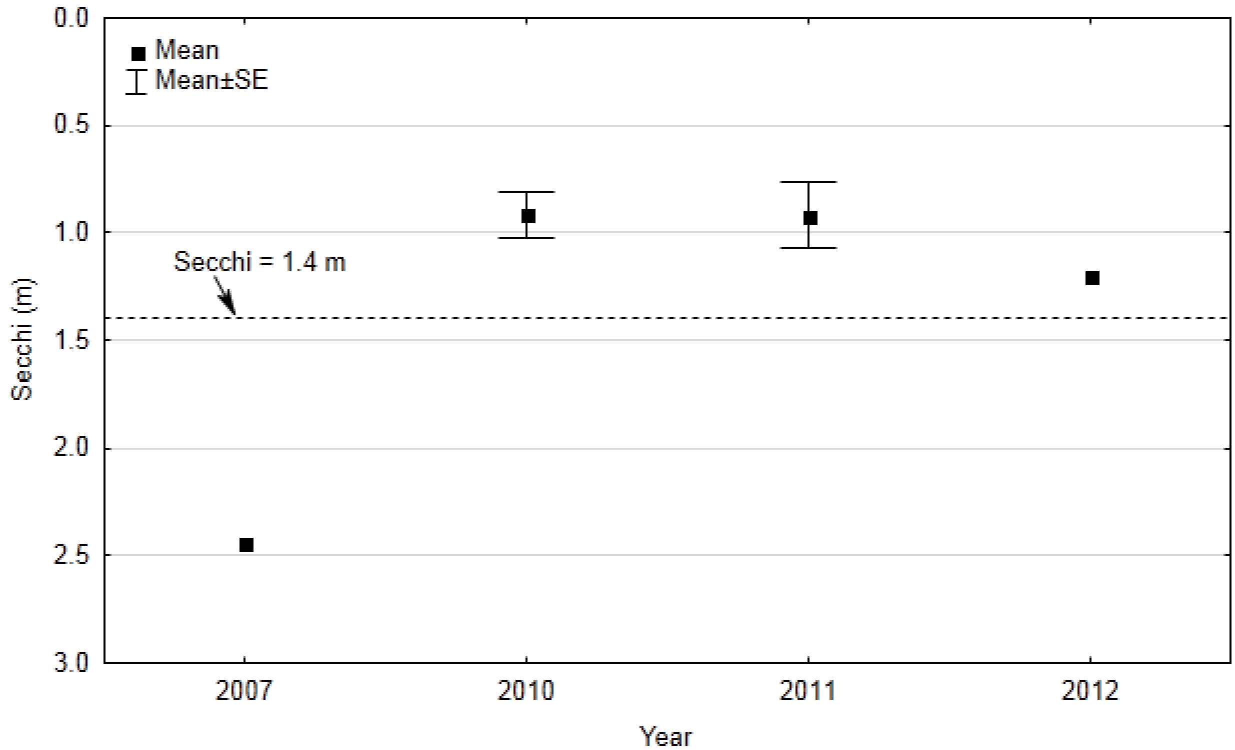
The dashed line represents the water quality standard for TP (40 µg/L).

Figure 15. Growing Season Means ± SE of Total Phosphorus for Crooked (East) Lake by Year.



The dashed line represents the water quality standard for Chl-*a* (14 µg/L).

Figure 16. Growing Season Means ± SE of Chl-*a* for Crooked (East) Lake by Year.



The dashed line represents the lake water quality standard for transparency (1.4 m).

Figure 17. Growing Season Means ± SE of Secchi transparency for Crooked (East) Lake by Year

A.1.2 Aquatic Plants

No recent macrophyte survey has been conducted for Crooked East Lake.

A.1.3 Fish

No recent fish survey has been conducted for Crooked East Lake.

A.2 Echo Lake

Echo Lake (DNR Lake ID 21-0157-00) and its entire watershed are located in Douglas County. The watershed is located in the southwest portion of the Long Prairie River Watershed and is a headwater lake. Figure 18 illustrates the available bathymetry, and Figure 19 shows an aerial photograph.

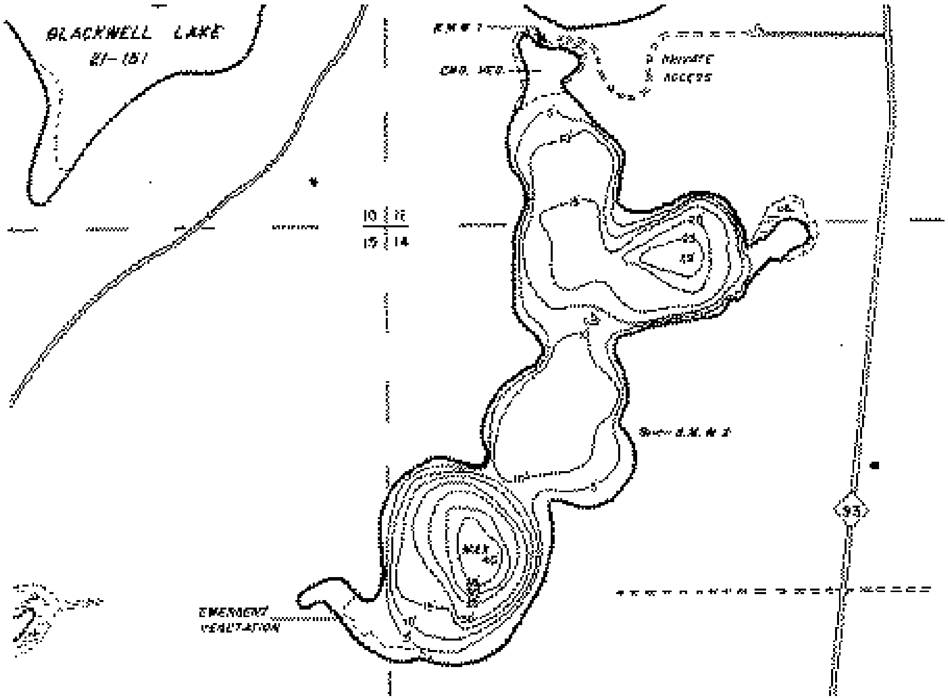
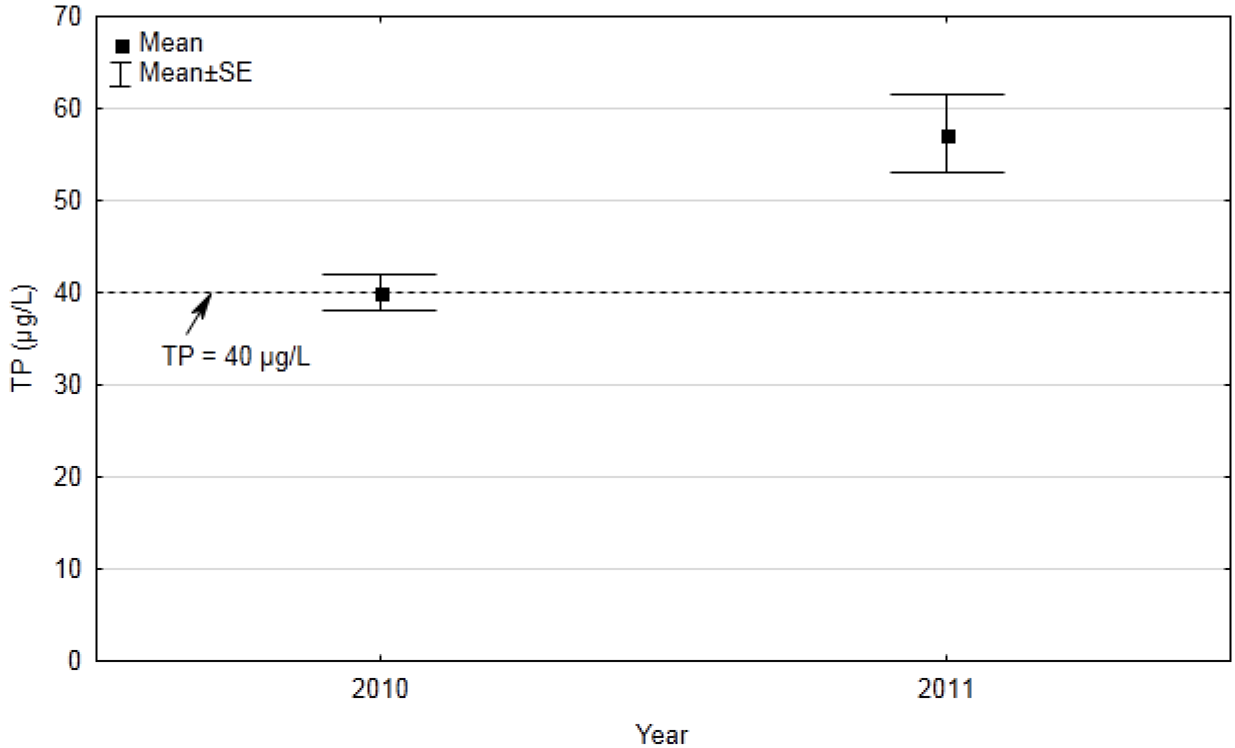


Figure 18. Echo Lake Bathymetry (DNR)

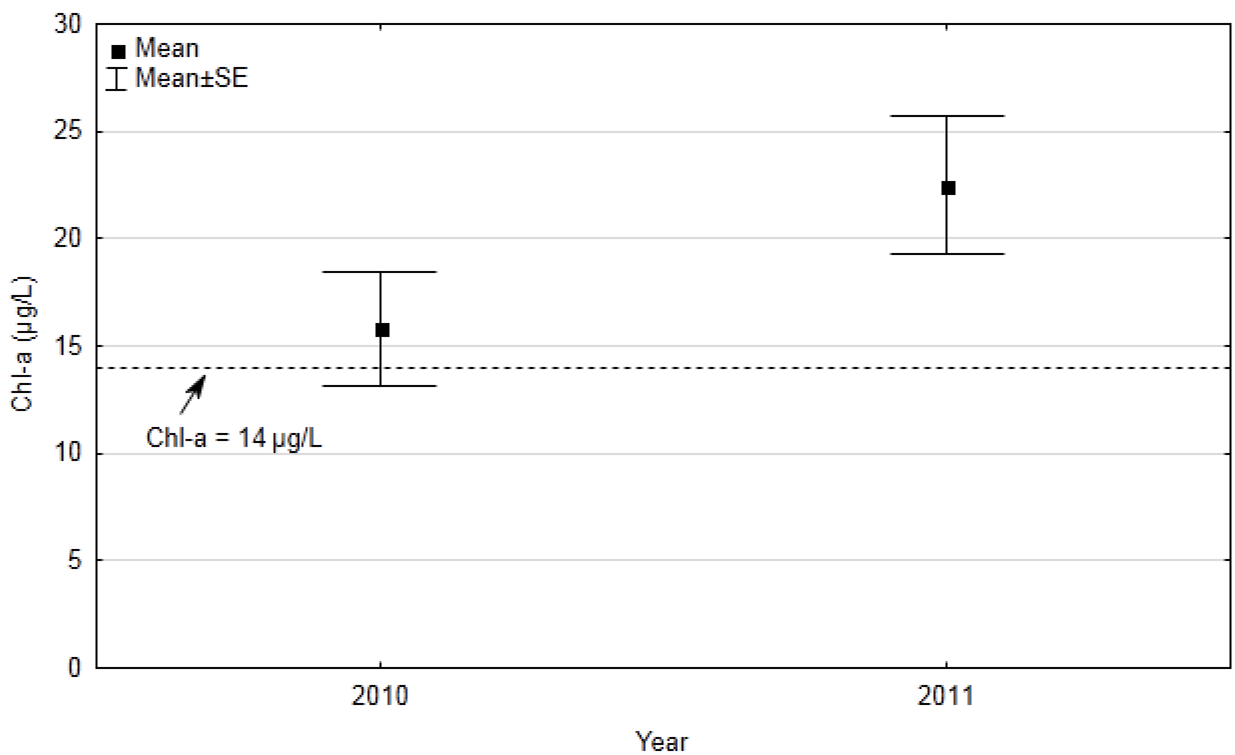
Figure 19. Aerial photograph of Echo Lake (Google Earth, May 2013)

A.2.1 Water Quality Trends



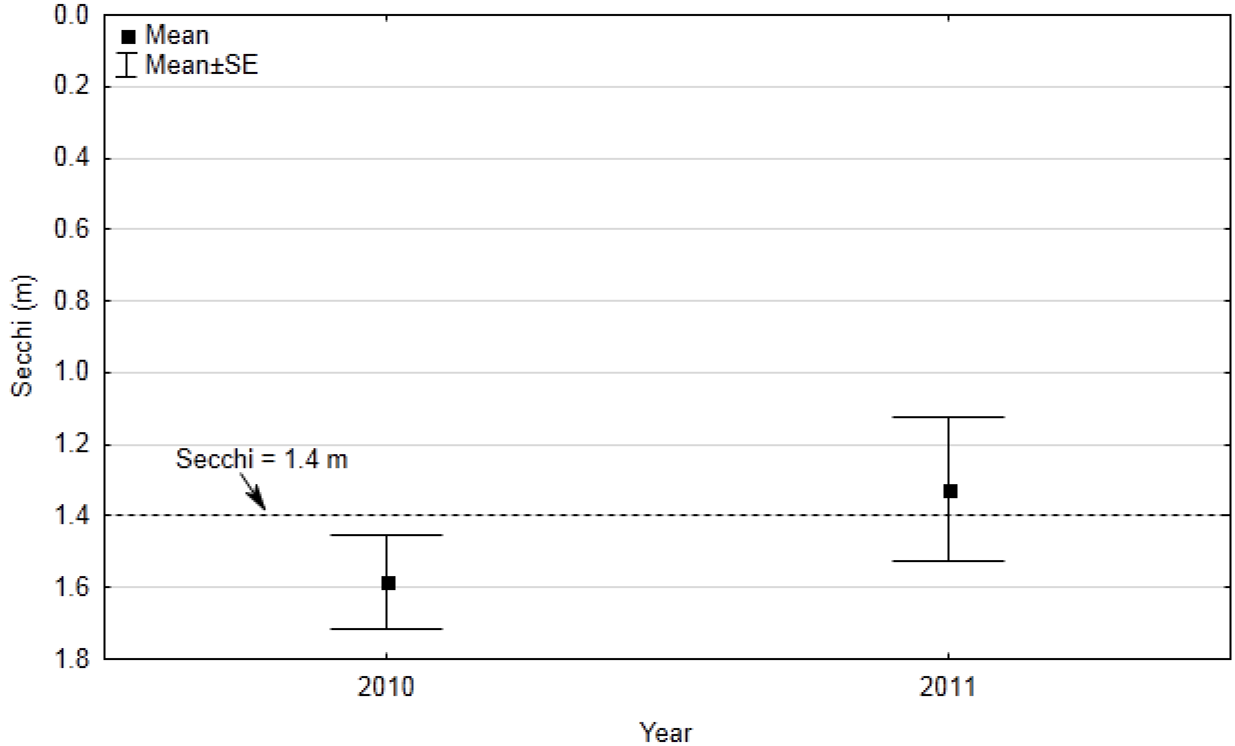
* The dashed line represents the water quality standard for TP (40 µg/L).

Figure 20. Growing Season Means ± SE of Total Phosphorus for Echo Lake by Year.



* The dashed line represents the water quality standard for Chl-*a* (14 µg/L).

Figure 21. Growing Season Means ± SE of Chl-*a* for Echo Lake by Year.



* The dashed line represents the lake water quality standard for transparency (1.4 m).

Figure 22. Growing Season Means ± SE of Secchi transparency for Echo Lake by Year

A.2.2 Aquatic Plants

No recent macrophyte survey has been conducted for Echo Lake.

A.2.3 Fish

The most recent DNR fish survey was conducted in 1966. The most abundant fish caught using a trap net was black bullhead followed by common carp. Northern pike, largemouth bass, black crappie, and yellow perch were among some of the other species caught in the survey. However, this survey is out of the time period of interest for this TMDL (2004-2013).

A.3 Fish Lake

Fish Lake (DNR Lake ID 56-0066-00) and its entire watershed are located in Otter Tail County. The watershed is located in the northwest portion of the Long Prairie River Watershed. Figure 23 illustrates the available bathymetry and Figure 24 shows the 2013 aerial photograph.

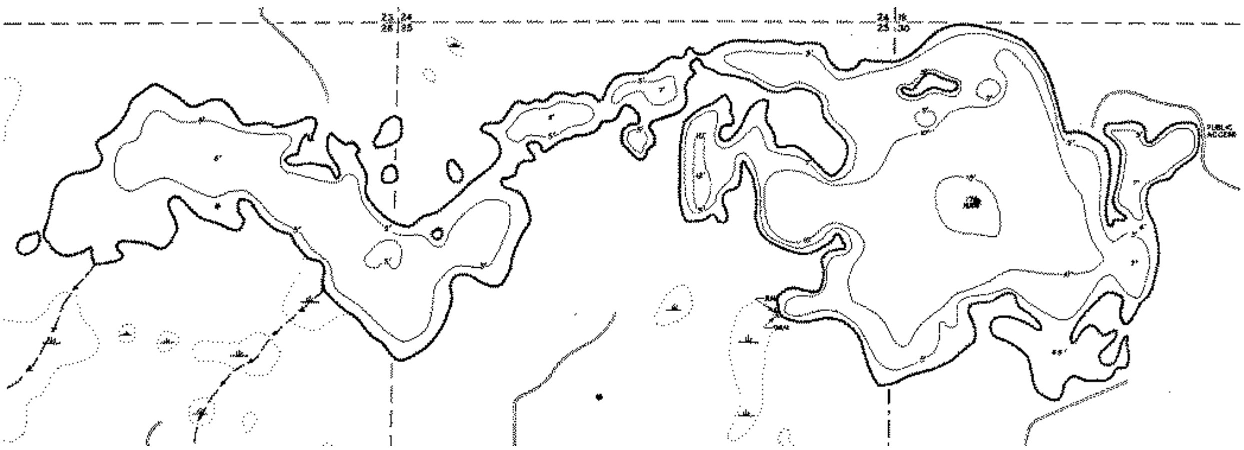
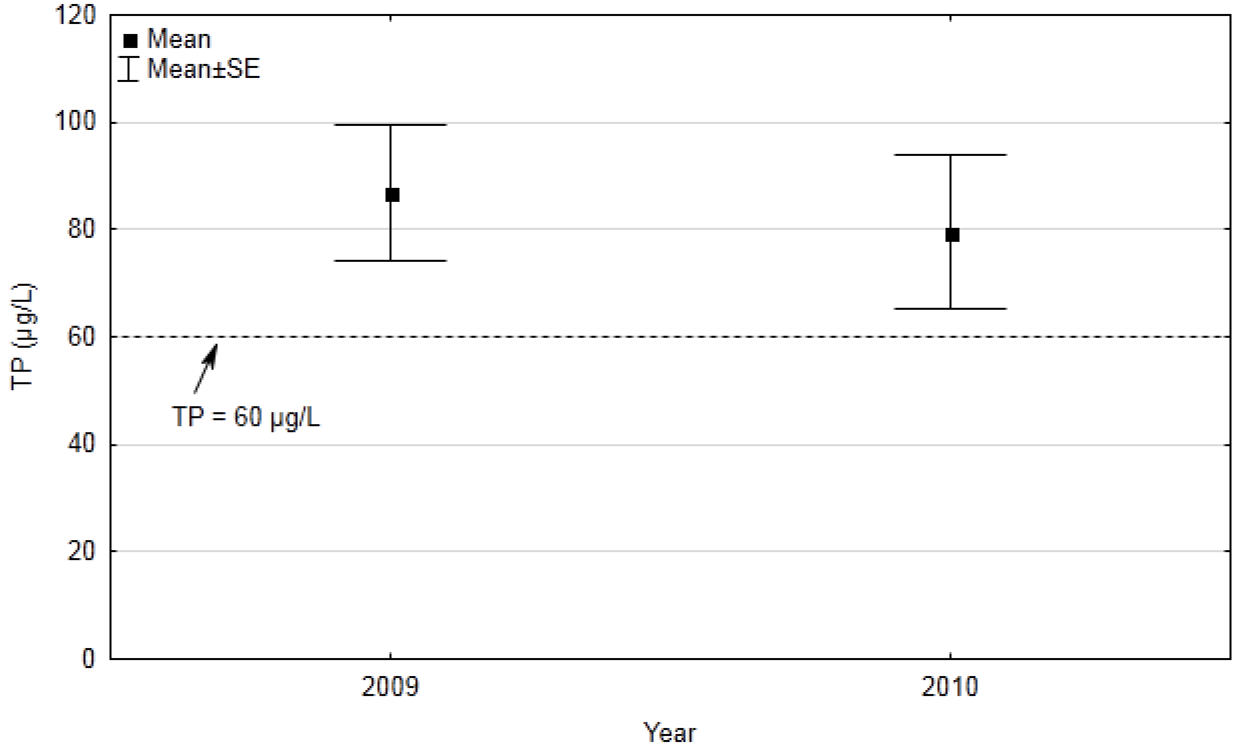


Figure 23. Fish Lake Bathymetry (DNR)

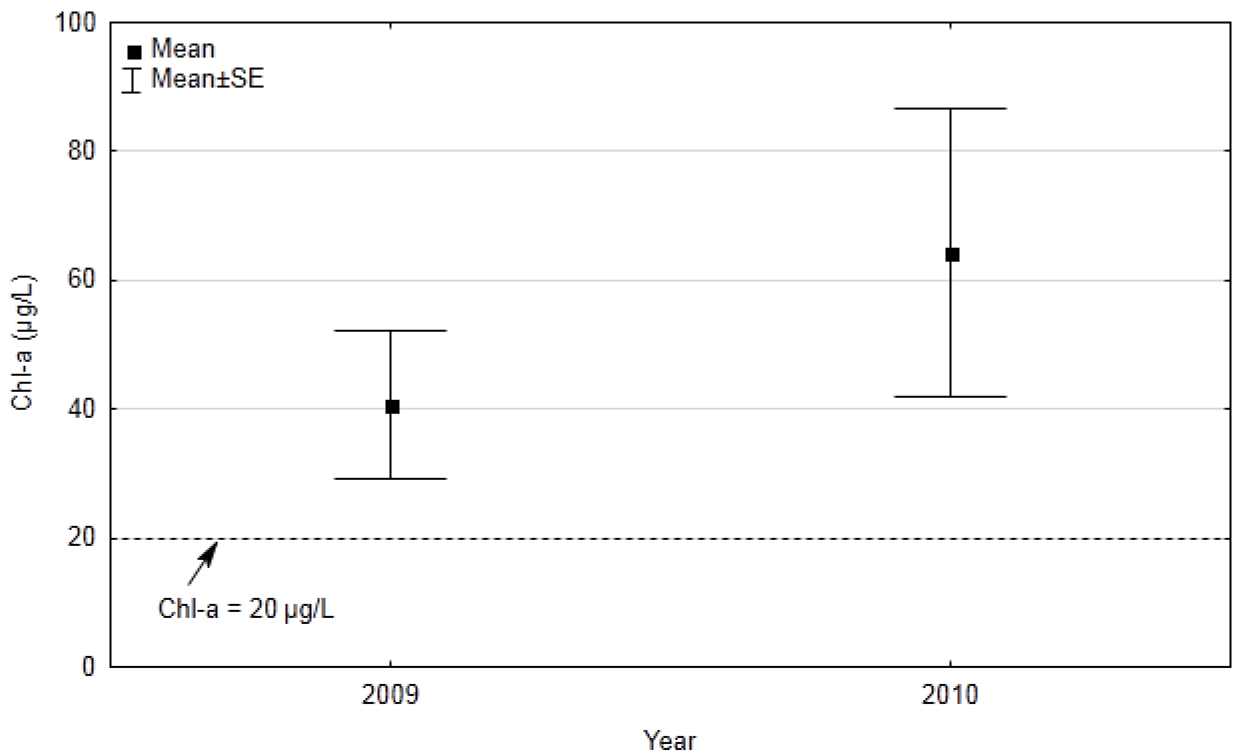
Figure 24. Aerial photograph of Fish Lake (Google Earth, May 2013)

A.3.1 Water Quality Trends



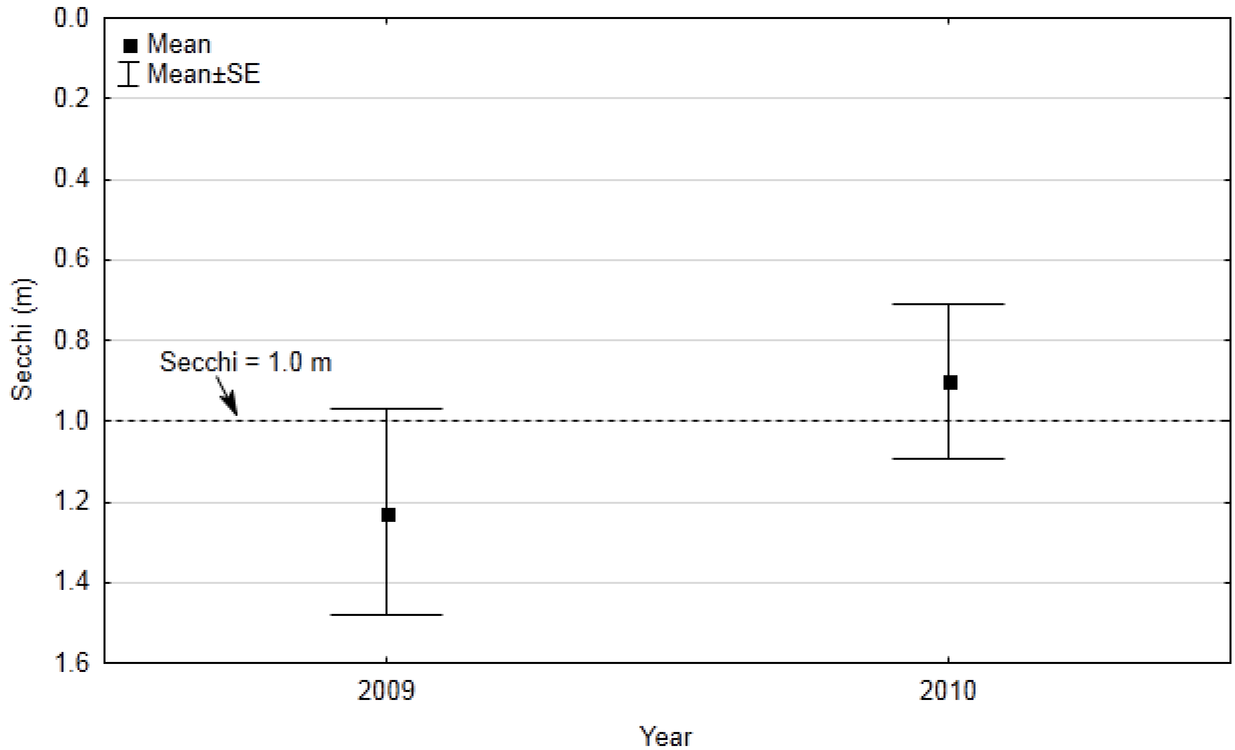
* The dashed line represents the water quality standard for TP (60 µg/L).

Figure 25. Growing Season Means ± SE of Total Phosphorus for Fish Lake by Year.



* The dashed line represents the water quality standard for Chl-*a* (20 µg/L).

Figure 26. Growing Season Means ± SE of Chl-*a* for Fish Lake by Year.



* The dashed line represents the lake water quality standard for transparency (1.0 m).

Figure 27. Growing Season Means ± SE of Secchi transparency for Fish Lake by Year

A.3.2 Aquatic Plants

Fish Lake is a shallow lake with a maximum depth of 17 feet and a littoral zone that encompasses 98% of the surface area. The shallow waters provide an excellent environment for aquatic plants to thrive. Hardstem bulrush, common cattail, and wild rice are found throughout the lake. The plant communities provide spawning areas for game fish and are critical for maintaining good water quality.

A.3.3 Fish

The most recent fish survey was conducted in June 2012. The lake is classified as a bass-panfish type of lake reflective of its fish community. Northern pike, largemouth bass, black crappie, and bluegill are the most dominant fish types. The lake is prone to periodic winter fish kills with the most recent partial fish kill occurring in the winter of 1996-1997. Walleye are commonly stocked by adding fry or fingerlings on alternating years. The fish population fluctuates depending on the intensity of frequency of such events. Emergent plants in the lake provide excellent spawning habitat for game fish and anglers are encouraged to release medium to large size fish to ensure a healthy spawning age fish population.

A.4 Jessie Lake

Jessie Lake (DNR Lake ID 21-0055-00) and its watershed are located in Douglas County. Jessie Lake discharges to Lake Victoria, east of the City of Alexandria. Figure 28 illustrates the available bathymetry and Figure 29 shows the 2013 aerial photograph.

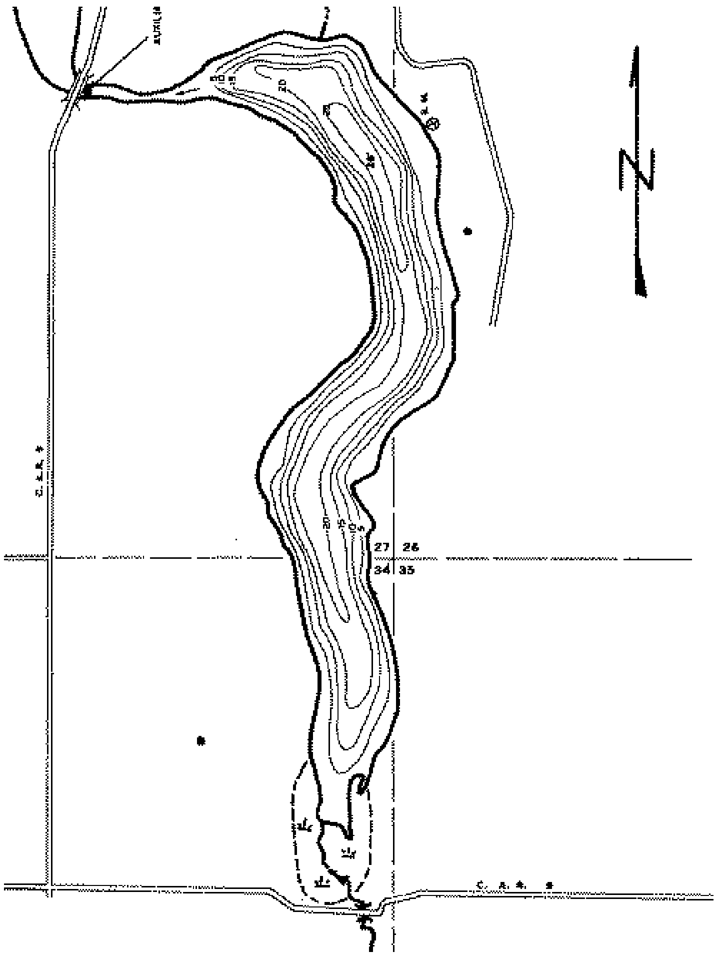
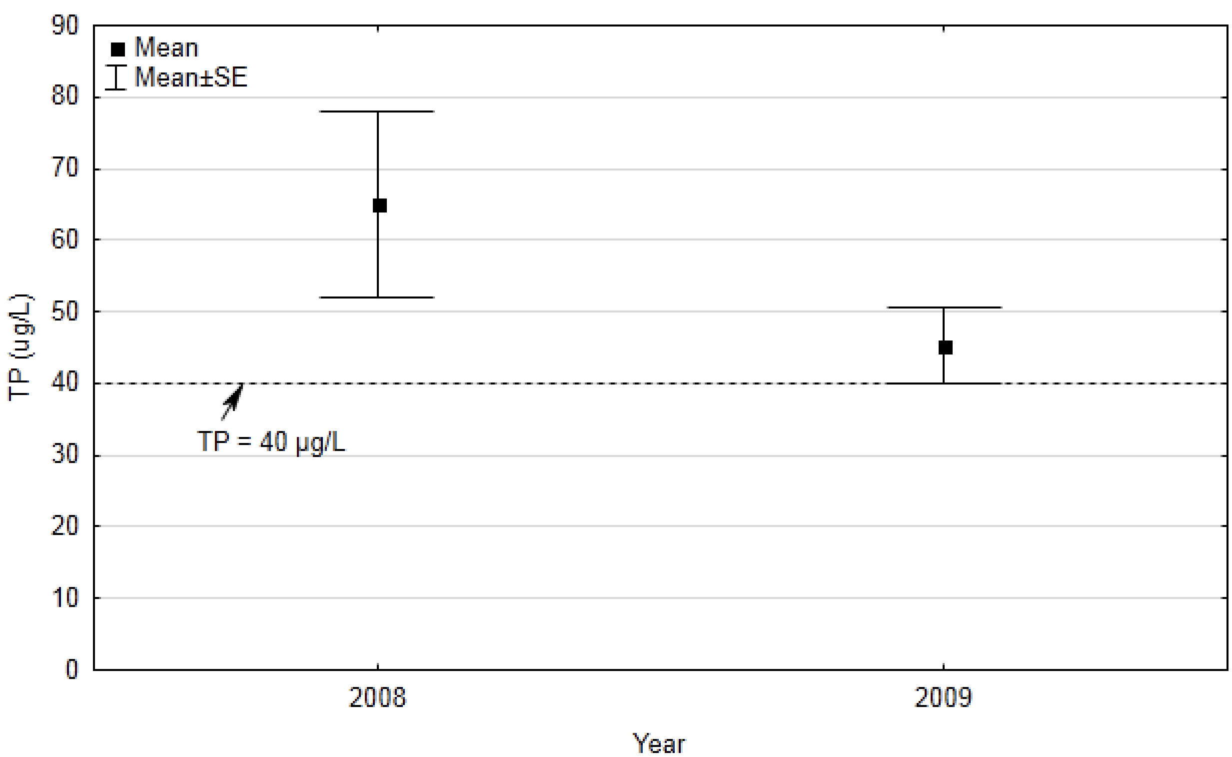


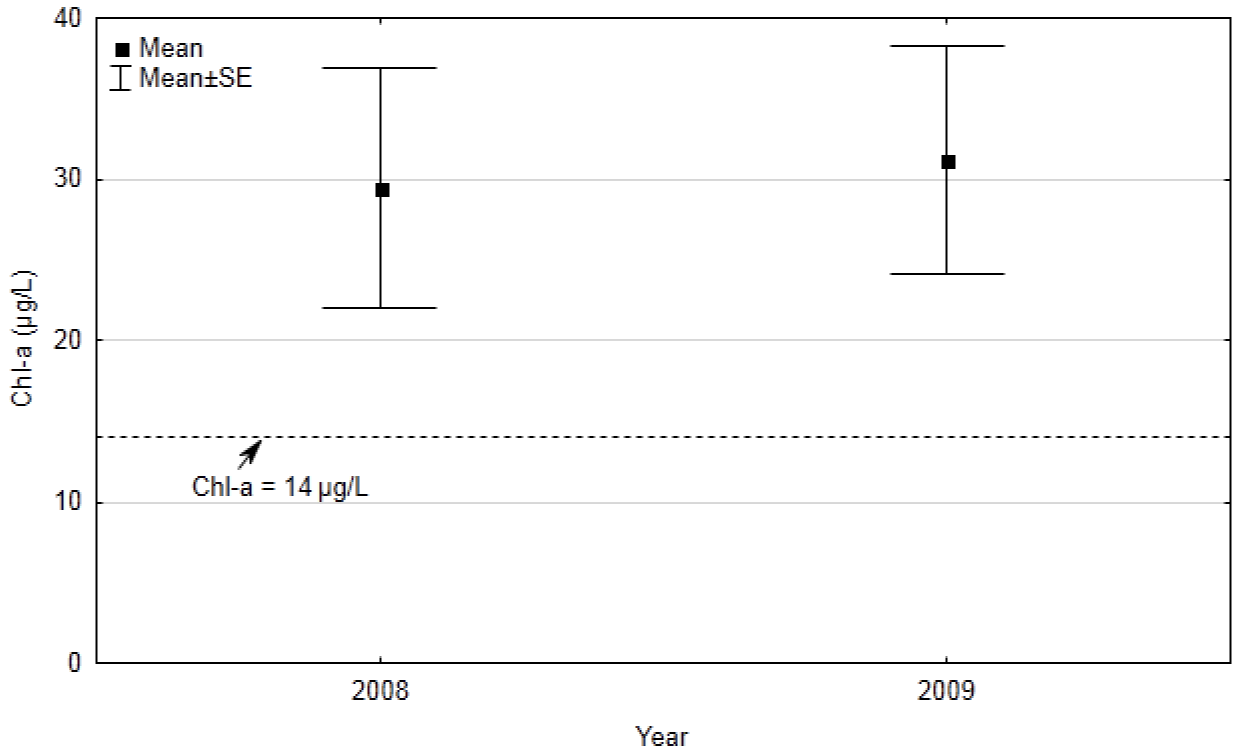
Figure 28. Jessie Lake Bathymetry (DNR)

Figure 29. Aerial photograph of Jessie Lake (Google Earth, May 2013)

A.4.1 Water Quality Trends

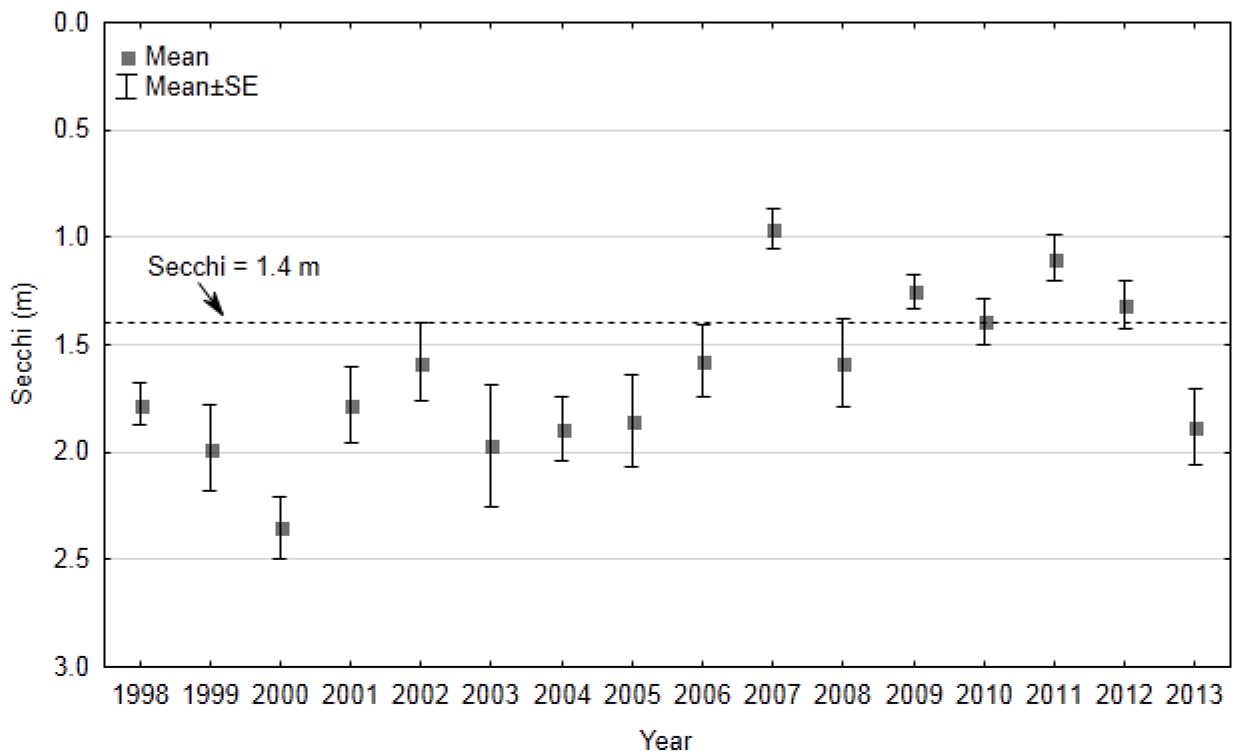


* The dashed line represents the water quality standard for TP (40 µg/L).
Figure 30. Growing Season Means ± SE of Total Phosphorus for Jessie Lake by Year.



* The dashed line represents the water quality standard for Chl-*a* (14 µg/L).

Figure 31. Growing Season Means ± SE of Chl-*a* for Jessie Lake by Year.



* The dashed line represents the lake water quality standard for transparency (1.4 m).

Figure 32. Growing Season Means ± SE of Secchi transparency for Jessie Lake by Year

A.4.2 Aquatic Plants

Aquatic vegetation is dense throughout shallow areas of the lake. There are large beds of water lily on the surface during summer months. Aquatic vegetation provides critical aquatic habitat for many fish species and help to maintain good water quality and clarity.

A.4.3 Fish

A Lake Survey Report was prepared in 2008. According to this report:

- The fish community in Lake Jessie is typical of small, densely vegetated lakes in west-central Minnesota.
- Largemouth bass, northern pike, bluegill, and black crappies are abundant and support most angling opportunities.
- State stocking is constrained due to lack of public access.

A.5 Latimer Lake

Latimer Lake (DNR Lake ID 77-0105-00) and its entire watershed are located in Todd County. The watershed is located in the southeast portion of the Long Prairie River Watershed. Figure 33 illustrates the available bathymetry and Figure 34 shows the 2013 aerial photograph.

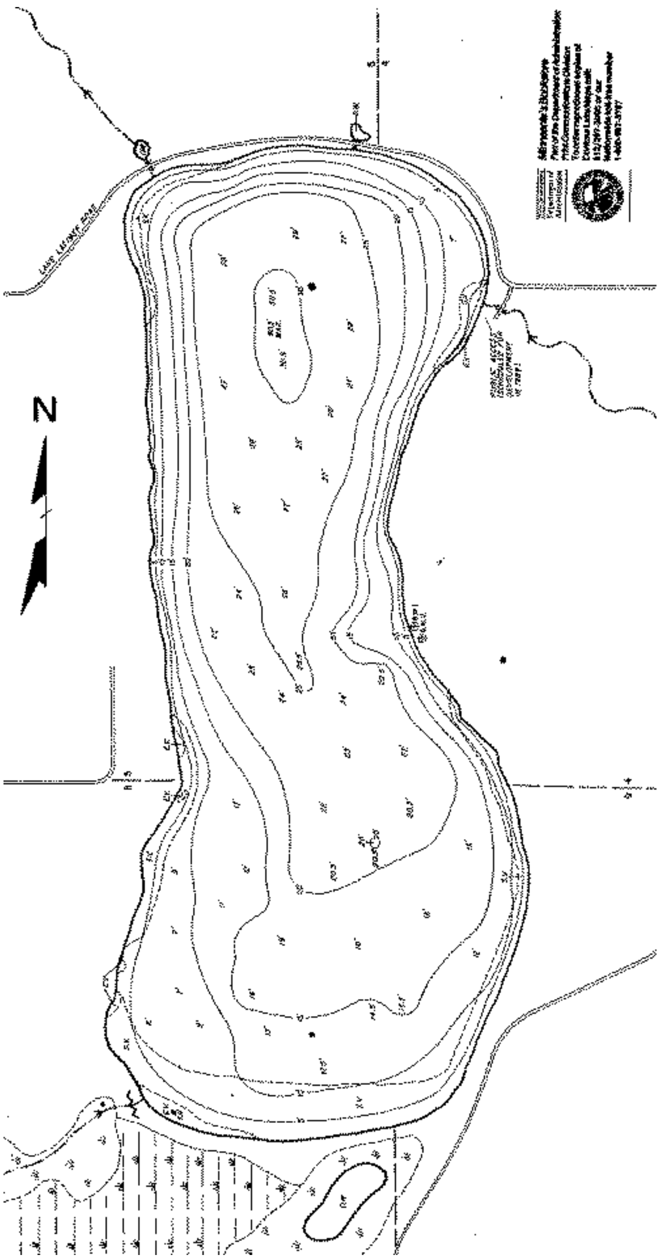
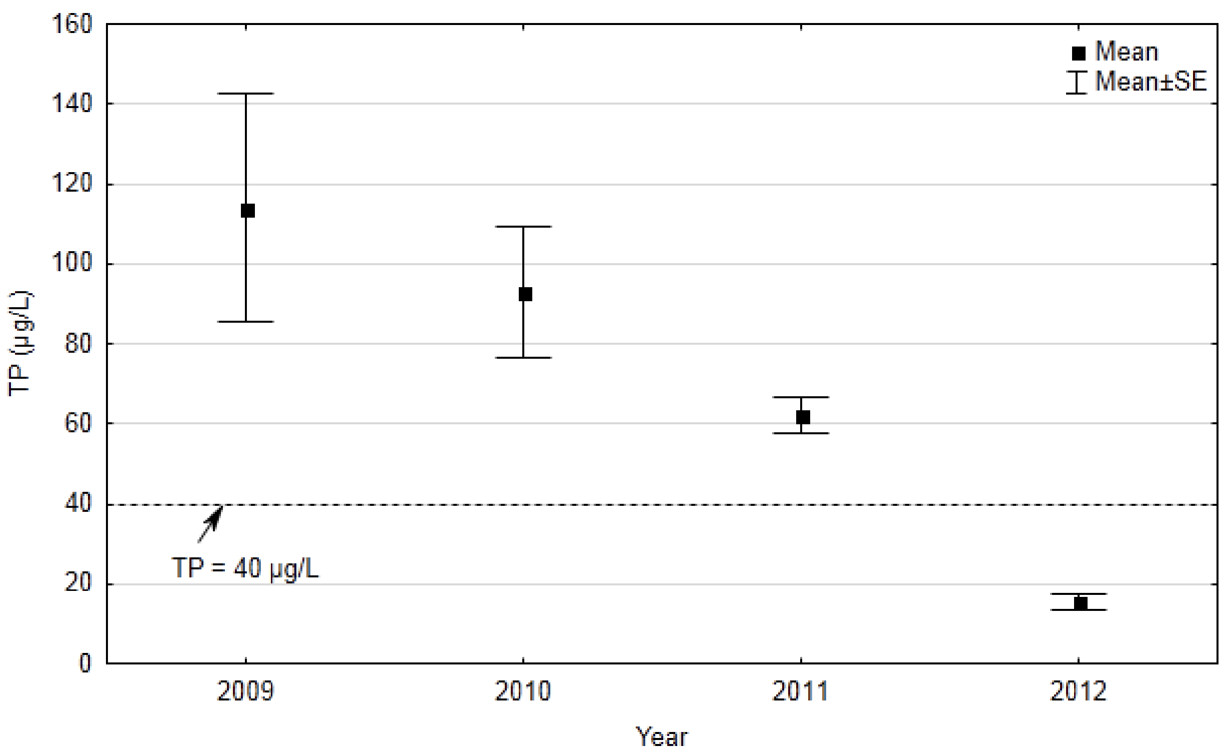


Figure 33. Latimer Lake Bathymetry (DNR)

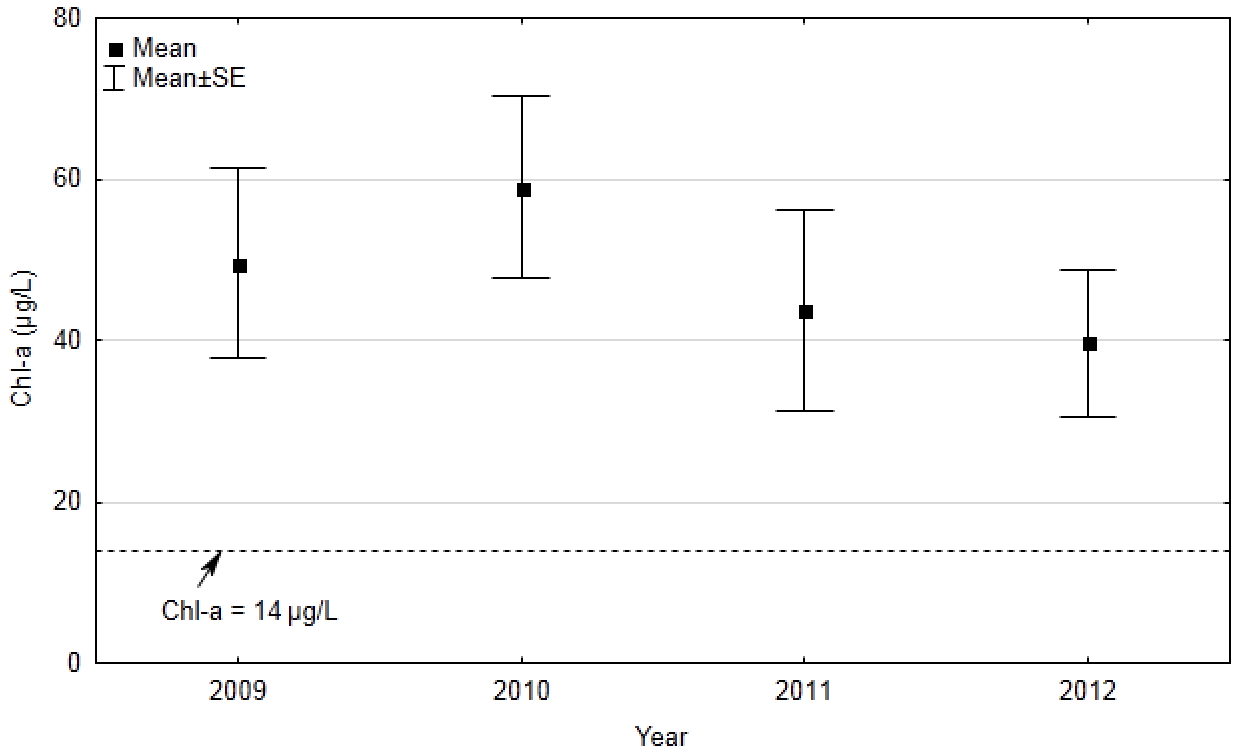
Figure 34. Aerial photograph of Latimer Lake (Google Earth, May 2013)

A.5.1 Water Quality Trends



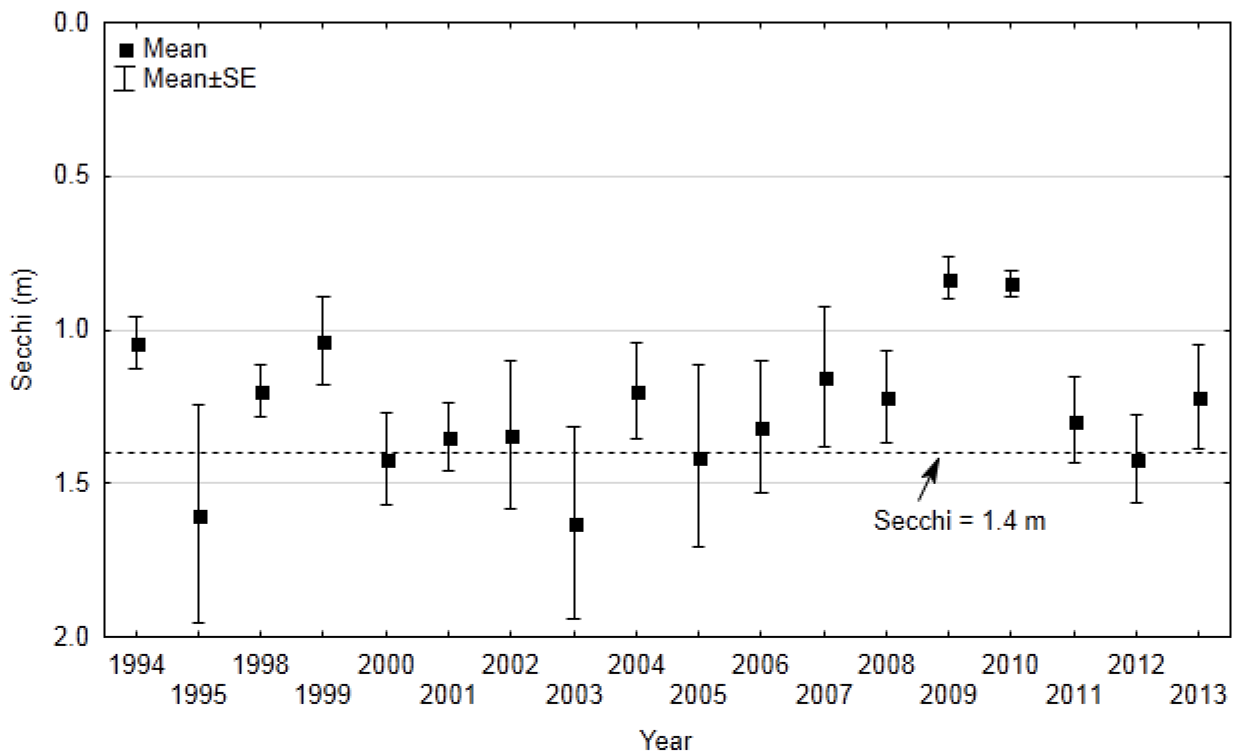
* The dashed line represents the water quality standard for TP (40 µg/L).

Figure 35. Growing Season Means ± SE of Total Phosphorus for Latimer Lake by Year.



* The dashed line represents the water quality standard for Chl-*a* (14 µg/L).

Figure 36. Growing Season Means ± SE of Chl-*a* for Latimer Lake by Year.



* The dashed line represents the lake water quality standard for transparency (1.4 m).

Figure 37. Growing Season Means ± SE of Secchi transparency for Latimer Lake by Year

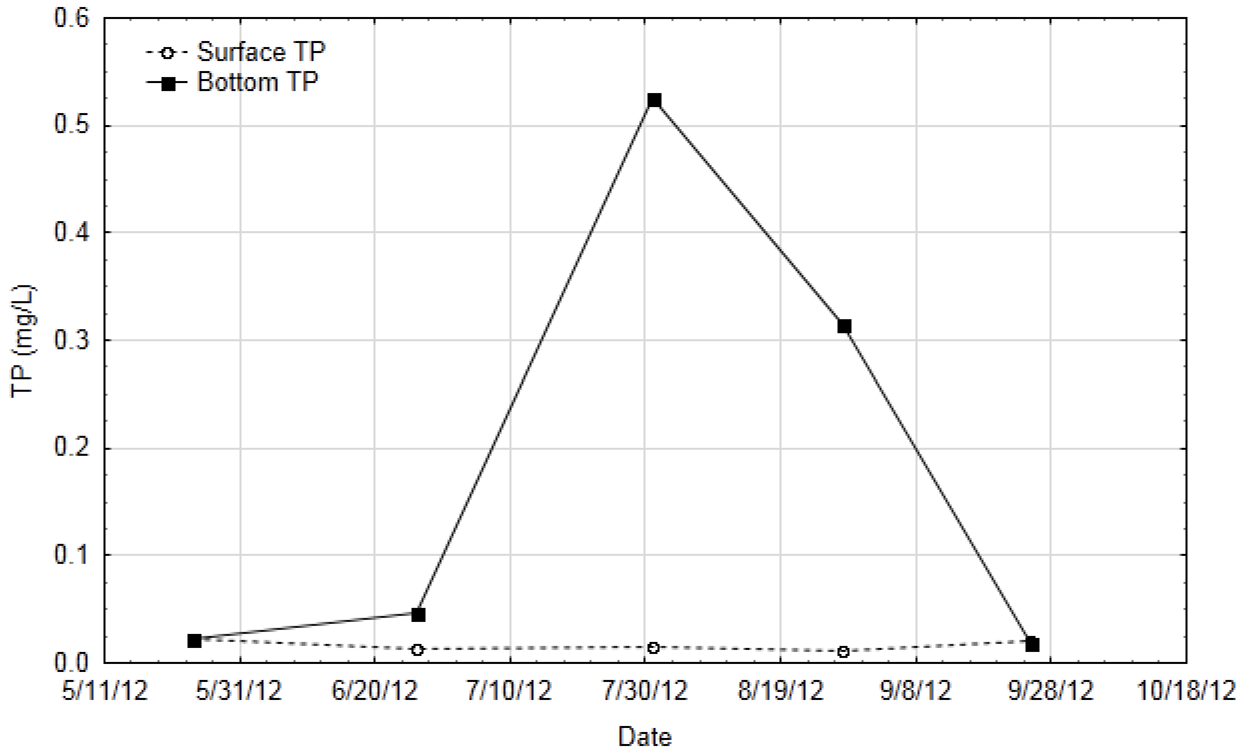


Figure 38. Bottom and surface TP concentrations, Latimer Lake, 2012

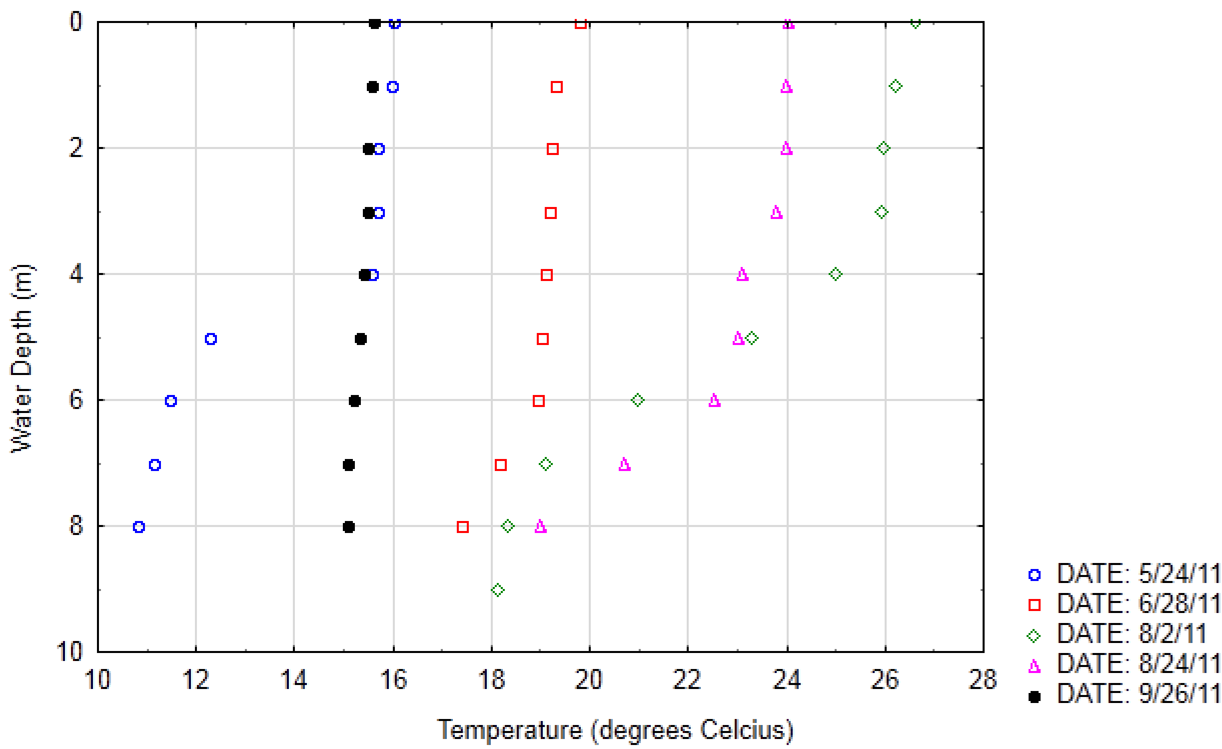


Figure 39. Temperature depth profiles, Latimer Lake, 2011

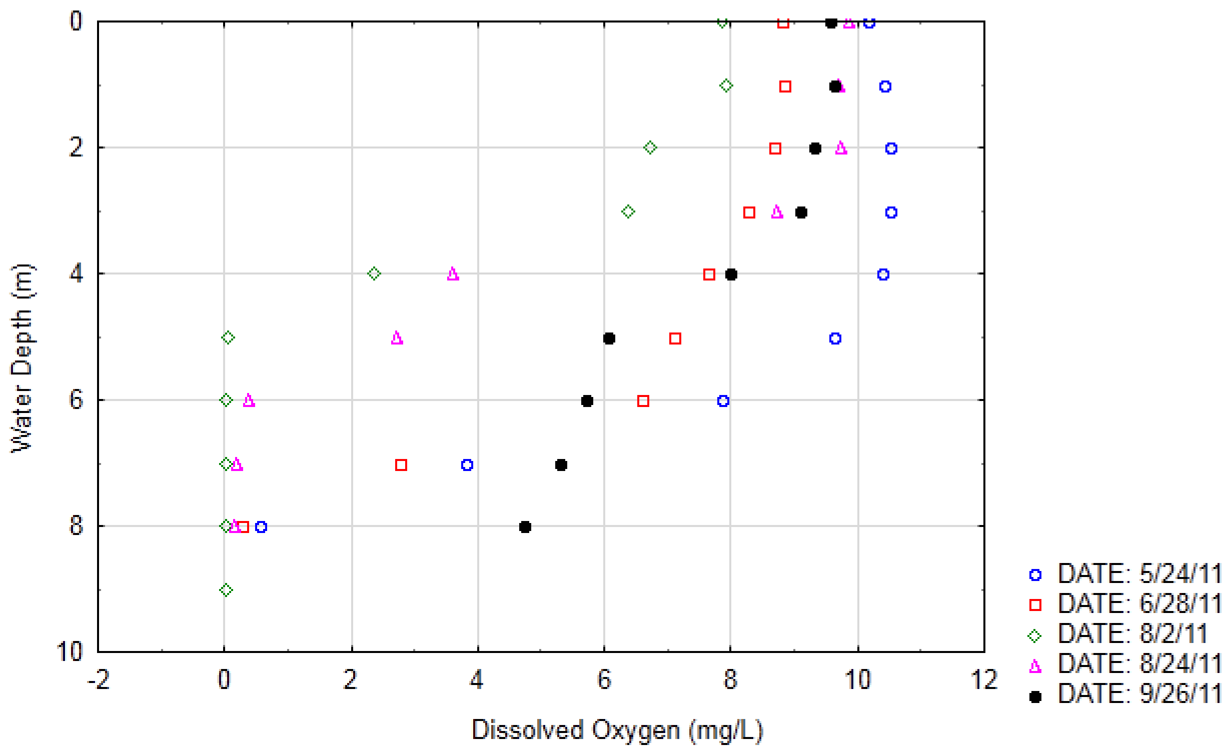


Figure 40. Dissolved oxygen depth profiles, Latimer Lake, 2011

A.5.2 Aquatic Plants

No aquatic plant survey has been conducted for this lake to date.

A.5.3 Fish

The most recent DNR fish survey was conducted in 2007 (DNR Lake Finder). According to this report:

- The fish population is dominated by black bullhead and black crappie.
- Game fish species such as northern pike, largemouth bass, walleye and bluegills are not supported.
- Walleye fingerlings are typically stocked in odd-numbered years.
- Northern pike numbers increased since the last survey and may have had a negative impact on walleye and yellow perch populations.

A.6 Nelson Lake

Nelson Lake (DNR Lake ID 56-0065-00) and its entire watershed are located in Otter Tail County. The watershed is located in the northwest portion of the Long Prairie River Watershed. Figure 41 shows the 2013 aerial photograph. No illustration of bathymetry is available.

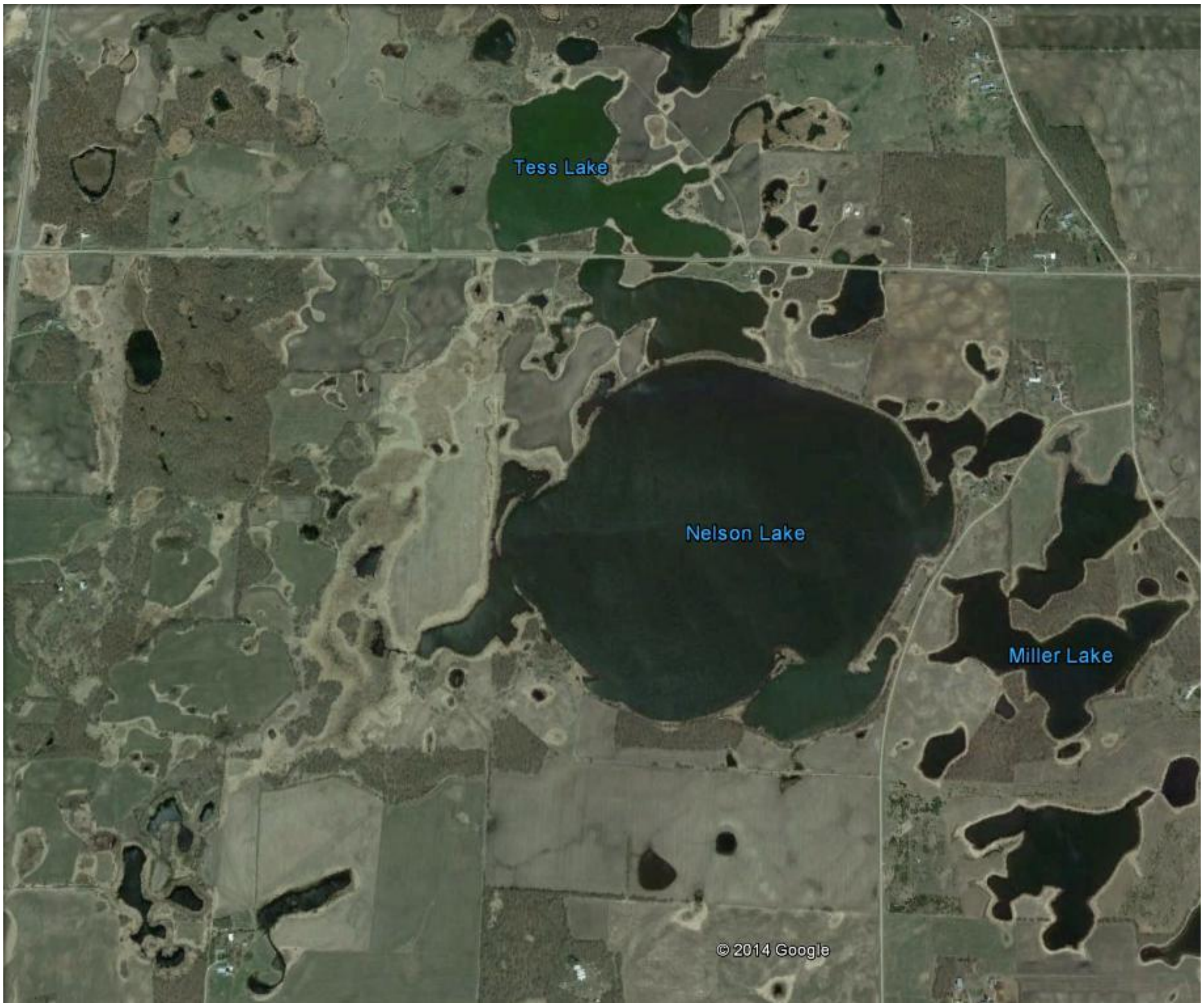
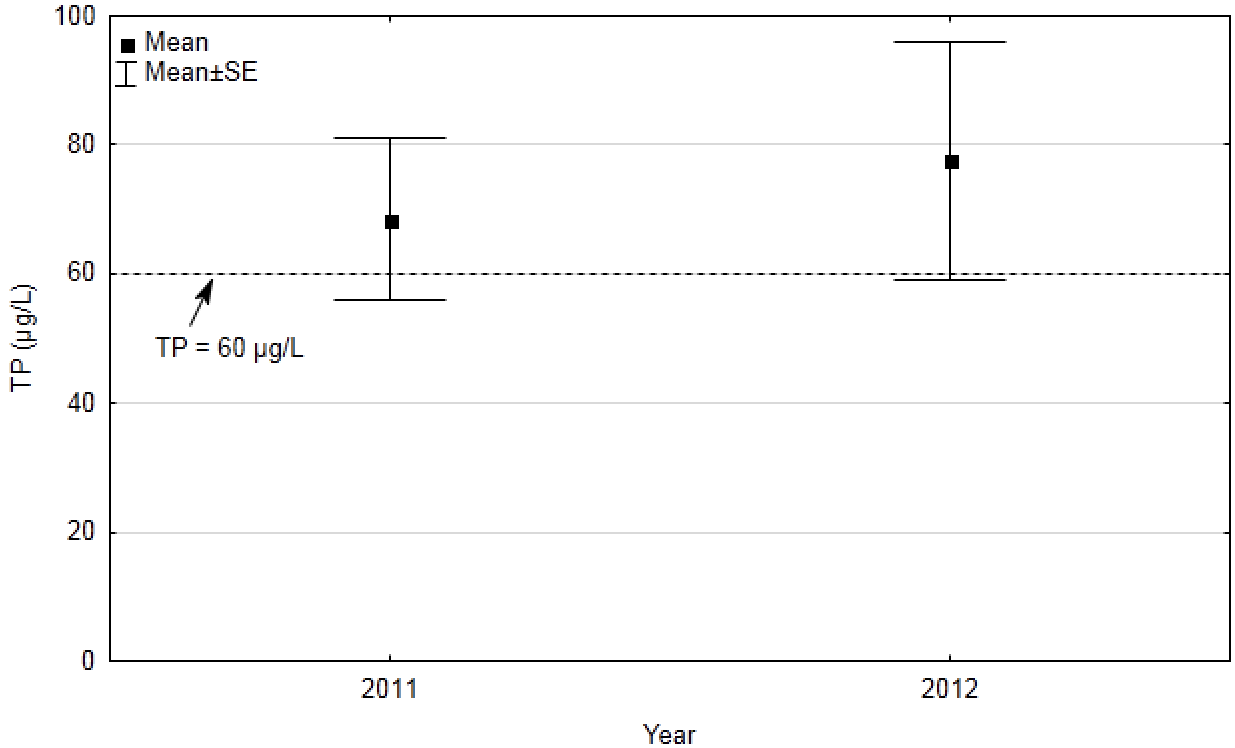


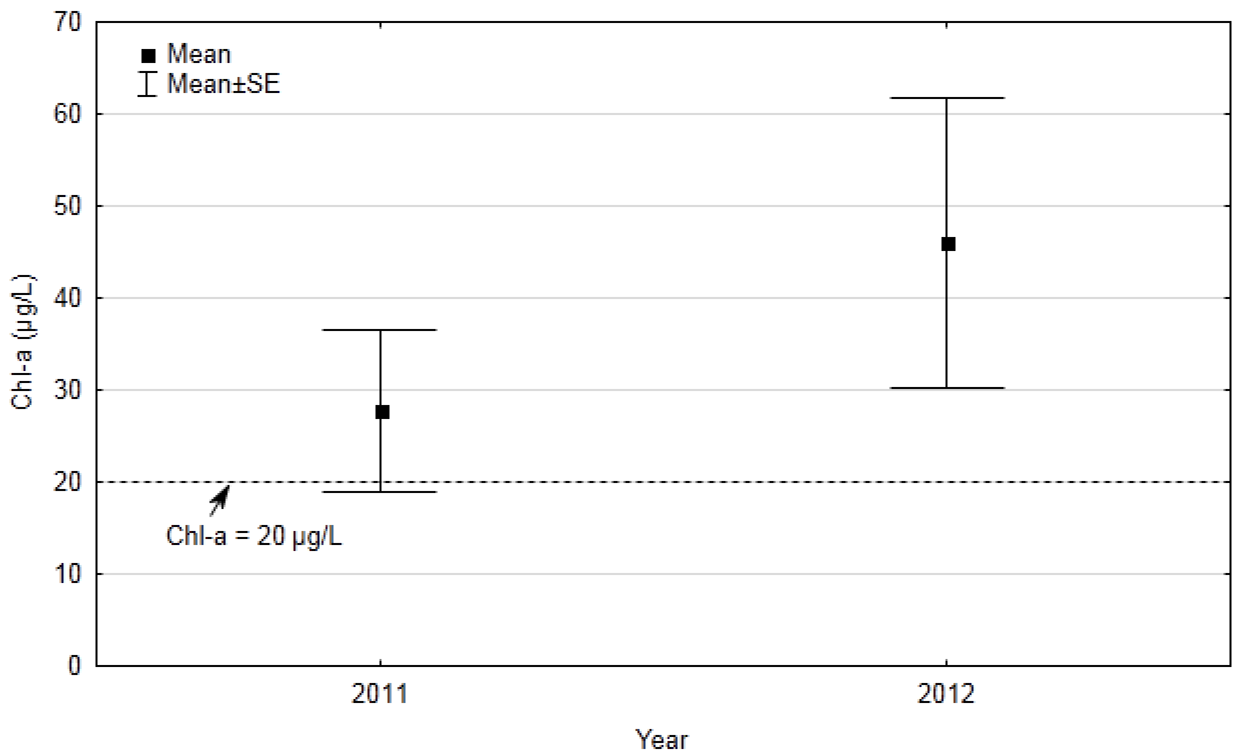
Figure 41. Aerial photograph of Nelson Lake (Google Earth, May 2013)

A.6.1 Water Quality Trends



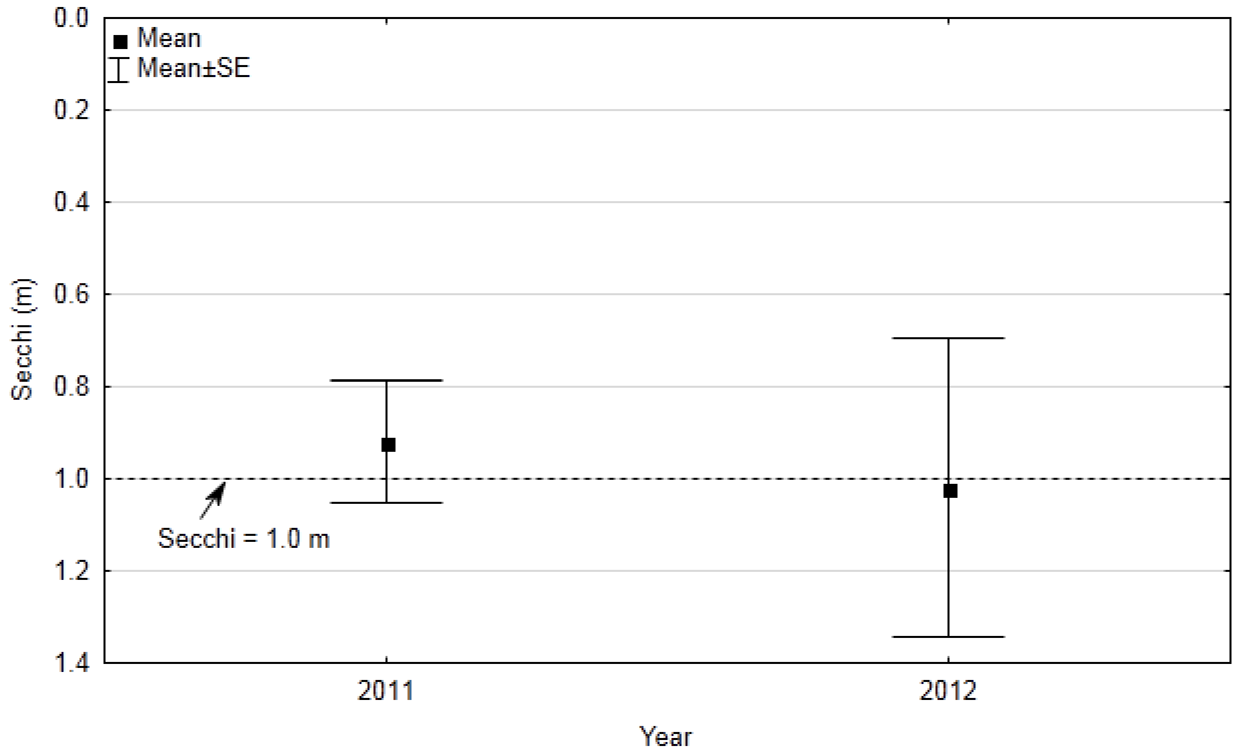
* The dashed line represents the water quality standard for TP (60 µg/L).

Figure 42. Growing Season Means ± SE of Total Phosphorus for Nelson Lake by Year.



* The dashed line represents the water quality standard for Chl-*a* (20 µg/L).

Figure 43. Growing Season Means ± SE of Chl-*a* for Nelson Lake by Year.



* The dashed line represents the lake water quality standard for transparency (1.0 m).

Figure 44. Growing Season Means ± SE of Secchi transparency for Nelson Lake by Year

A.6.2 Aquatic Plants

No aquatic plant survey has been conducted for this lake to date.

A.6.3 Fish

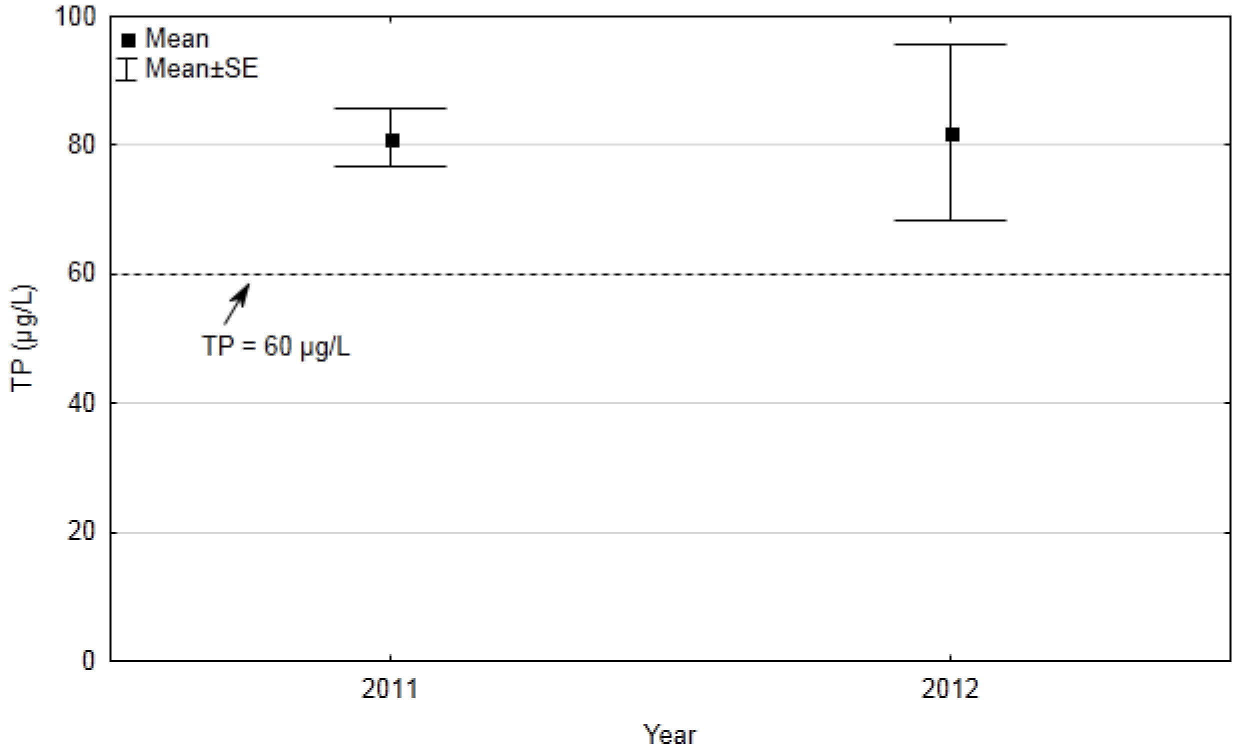
No fish survey has been conducted for this lake to date.

A.7 Twin Lake

Twin Lake (DNR Lake ID 56-0067-00) and its entire watershed are located in Otter Tail County. The watershed is located in the northwest portion of the Long Prairie River Watershed. Figure 45 shows the 2013 aerial photograph. No illustration of bathymetry is available for this lake.

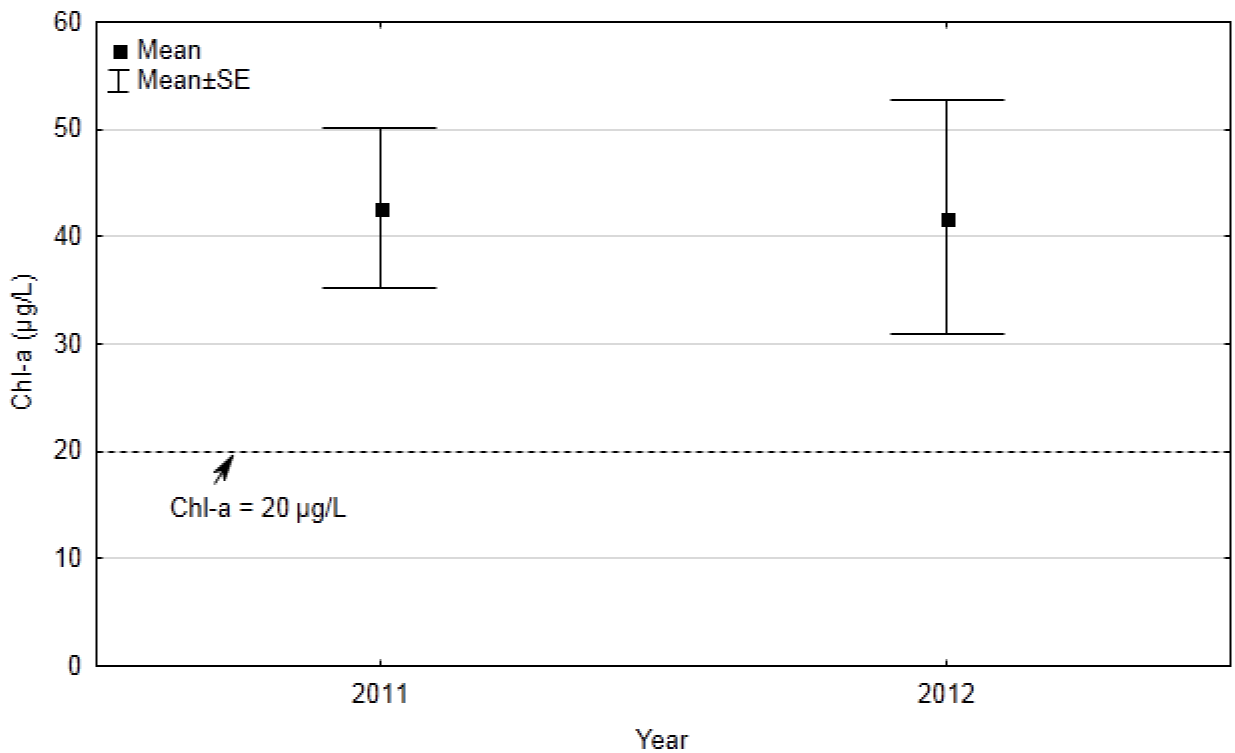
Figure 45. Aerial photograph of Twin Lake (Google Earth, May 2013)

A.7.1 Water Quality Trends



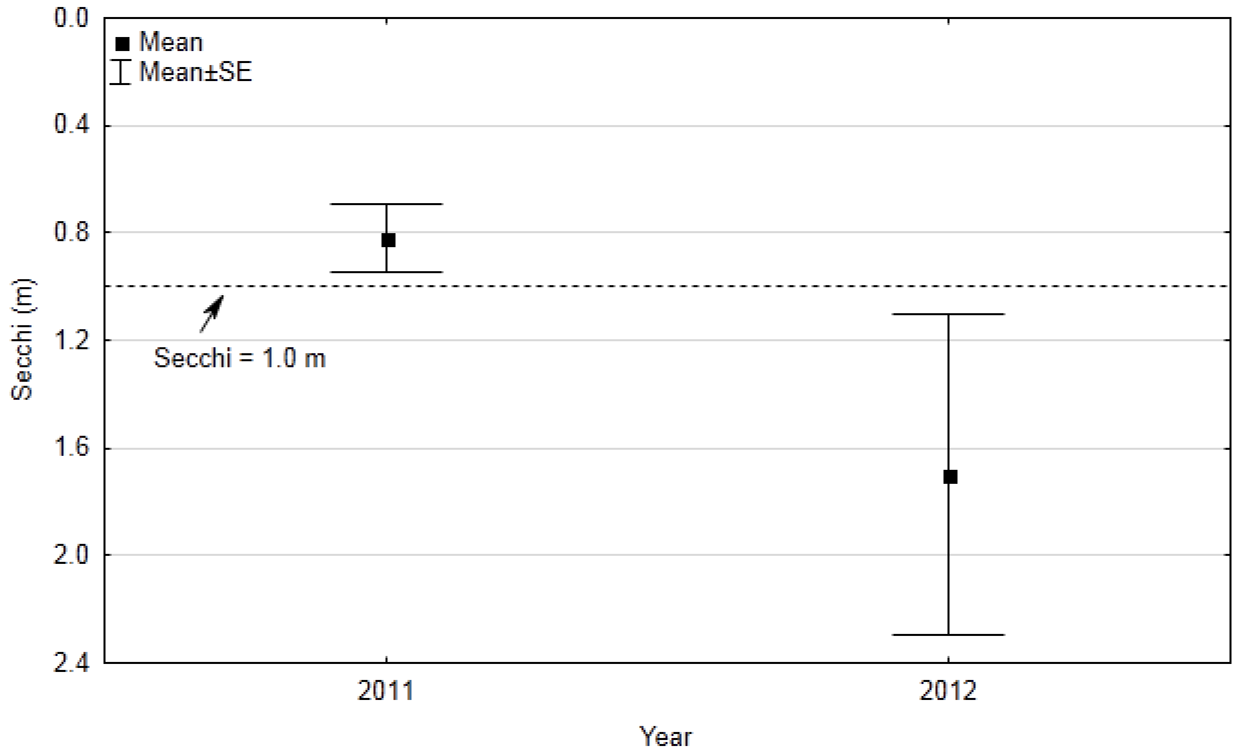
* The dashed line represents the water quality standard for TP (60 µg/L).

Figure 46. Growing Season Means ± SE of Total Phosphorus for Twin Lake by Year.



* The dashed line represents the water quality standard for Chl-*a* (20 µg/L).

Figure 47. Growing Season Means ± SE of Chl-*a* for Twin Lake by Year.



* The dashed line represents the lake water quality standard for transparency (1.0 m).

Figure 48. Growing Season Means ± SE of Secchi transparency for Twin Lake by Year

A.7.2 Aquatic Plants

No aquatic plant survey has been conducted for this lake to date.

A.7.3 Fish

No fish survey has been conducted for this lake to date.

Appendix B: BATHTUB Model Outputs

Table 43. Crooked East Lake Calibrated Model Predicted & Observed Phosphorus

Predicted & Observed Values Ranked Against CE Model Development Dataset								
Segment:		**1**	**Crooked East**					
		Predicted Values--->			**Observed Values--->**			
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**	
TOTAL P	MG/M3	43.3	0.38	45.5%	43.3	0.09	45.5%	

Table 44. Crooked East Lake Calibrated Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance					Averaging Period =		1.00	years
				Area	Flow	Variance	CV	Runoff
Trb	**Type**	**Seg**	**Name**	**km^2**	**hm^3/yr**	**$(hm3/yr)^2$**	**-**	**m/yr**
1	1	1	Direct Drainage	3.8	0.5	0.00E+00	0.00	0.12
PRECIPITATION				0.4	0.3	0.00E+00	0.00	0.62
TRIBUTARY INFLOW				3.8	0.5	0.00E+00	0.00	0.12
***TOTAL INFLOW				4.3	0.7	0.00E+00	0.00	0.17
ADVECTIVE OUTFLOW				4.3	0.3	0.00E+00	0.00	0.08
***TOTAL OUTFLOW				4.3	0.3	0.00E+00	0.00	0.08
***EVAPORATION					0.4	0.00E+00	0.00	

Overall Mass Balance Based Upon				Predicted		Outflow & Reservoir Concentrations				
Component:				TOTAL P						
				Load		Load Variance			Conc	Export
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**$(kg/yr)^2$**	**%Total**	**CV**	**mg/m^3**	**$kg/km^2/yr$**
1	1	1	Direct Drainage	68.2	86.1%	2.91E+02	90.5%	0.25	150.4	17.7
PRECIPITATION				11.0	13.9%	3.04E+01	9.5%	0.50	43.2	26.8
TRIBUTARY INFLOW				68.2	86.1%	2.91E+02	90.5%	0.25	150.4	17.7
***TOTAL INFLOW				79.2	100.0%	3.21E+02	100.0%	0.23	111.8	18.6
ADVECTIVE OUTFLOW				14.8	18.7%	3.24E+01		0.38	43.3	3.5
***TOTAL OUTFLOW				14.8	18.7%	3.24E+01		0.38	43.3	3.5
***RETENTION				64.4	81.3%	2.78E+02		0.26		

Overflow Rate (m/yr)	0.8	Nutrient Resid. Time (yrs)	0.6298
Hydraulic Resid. Time (yrs)	3.3682	Turnover Ratio	1.6
Reservoir Conc (mg/m3)	43	Retention Coef.	0.813

Table 45. Crooked East Lake TMDL Goal Scenario Model Predicted & Observed Phosphorus

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		**1**	**Crooked East**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	40.0	0.36	42.1%	43.3	0.09	45.5%

Table 46. Crooked East Lake TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance					**Averaging Period =**		**1.00**	**years**
				Area	**Flow**	**Variance**	**CV**	**Runoff**
Trb	**Type**	**Seg**	**Name**	**km^2**	**hm^3/yr**	**$(hm3/yr)^2$**	**-**	**m/yr**
1	1	1	Direct Drainage	3.8	0.5	0.00E+00	0.00	0.12
PRECIPITATION				0.4	0.3	0.00E+00	0.00	0.62
TRIBUTARY INFLOW				3.8	0.5	0.00E+00	0.00	0.12
***TOTAL INFLOW				4.3	0.7	0.00E+00	0.00	0.17
ADVECTIVE OUTFLOW				4.3	0.3	0.00E+00	0.00	0.08
***TOTAL OUTFLOW				4.3	0.3	0.00E+00	0.00	0.08
***EVAPORATION					0.4	0.00E+00	0.00	

Overall Mass Balance Based Upon Component:				**Predicted TOTAL P**	**Outflow & Reservoir Concentrations**					
				Load		**Load Variance**			**Conc**	**Export**
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**$(kg/yr)^2$**	**%Total**	**CV**	**mg/m^3**	**$kg/km^2/yr$**
1	1	1	Direct Drainage	58.9	84.2%	0.00E+00		0.00	130.0	15.3
PRECIPITATION				11.0	15.8%	3.04E+01	100.0%	0.50	43.2	26.8
TRIBUTARY INFLOW				58.9	84.2%	0.00E+00		0.00	130.0	15.3
***TOTAL INFLOW				70.0	100.0%	3.04E+01	100.0%	0.08	98.7	16.4
ADVECTIVE OUTFLOW				13.7	19.6%	2.39E+01		0.36	40.0	3.2
***TOTAL OUTFLOW				13.7	19.6%	2.39E+01		0.36	40.0	3.2
***RETENTION				56.3	80.4%	4.68E+01		0.12		

Overflow Rate (m/yr)	0.8		Nutrient Resid. Time (yrs)	0.6595
Hydraulic Resid. Time (yrs)	3.3682		Turnover Ratio	1.5
Reservoir Conc (mg/m3)	40		Retention Coef.	0.804

Table 47. Echo Lake Calibrated Model Predicted & Observed Phosphorus

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		**1**	**Echo**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	47.7	0.34	49.8%	47.7	0.08	49.8%

Table 48. Echo Lake Calibrated Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Direct Drainage	7.2	1.6	0.00E+00	0.00	0.23
PRECIPITATION				0.5	0.3	0.00E+00	0.00	0.62
TRIBUTARY INFLOW				7.2	1.6	0.00E+00	0.00	0.23
***TOTAL INFLOW				7.7	1.9	0.00E+00	0.00	0.25
ADVECTIVE OUTFLOW				7.7	1.5	0.00E+00	0.00	0.19
***TOTAL OUTFLOW				7.7	1.5	0.00E+00	0.00	0.19
***EVAPORATION					0.5	0.00E+00	0.00	

Overall Mass Balance Based Upon Component: **Predicted TOTAL P** — **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Direct Drainage	211.3	93.9%	2.79E+03	98.3%	0.25	130.0	29.5
PRECIPITATION				13.7	6.1%	4.69E+01	1.7%	0.50	43.2	26.8
TRIBUTARY INFLOW				211.3	93.9%	2.79E+03	98.3%	0.25	130.0	29.5
***TOTAL INFLOW				225.0	100.0%	2.84E+03	100.0%	0.24	115.8	29.3
ADVECTIVE OUTFLOW				71.0	31.5%	5.91E+02		0.34	47.7	9.2
***TOTAL OUTFLOW				71.0	31.5%	5.91E+02		0.34	47.7	9.2
***RETENTION				154.0	68.5%	2.21E+03		0.30		

Overflow Rate (m/yr)	2.9	Nutrient Resid. Time (yrs)	0.3718
Hydraulic Resid. Time (yrs)	1.1785	Turnover Ratio	2.7
Reservoir Conc (mg/m3)	48	Retention Coef.	0.685

Table 49. Echo Lake TMDL Goal Scenario Model Predicted & Observed Phosphorus

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		**1**	**Echo**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	40.0	0.33	42.1%	47.7	0.08	49.8%

Table 50. Echo Lake TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Direct Drainage	7.2	1.6	0.00E+00	0.00	0.23
PRECIPITATION				0.5	0.3	0.00E+00	0.00	0.62
TRIBUTARY INFLOW				7.2	1.6	0.00E+00	0.00	0.23
***TOTAL INFLOW				7.7	1.9	0.00E+00	0.00	0.25
ADVECTIVE OUTFLOW				7.7	1.5	0.00E+00	0.00	0.19
***TOTAL OUTFLOW				7.7	1.5	0.00E+00	0.00	0.19
***EVAPORATION					0.5	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted TOTAL P — **Outflow & Reservoir Concentrations**

Component:

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Direct Drainage	160.6	92.1%	1.61E+03	97.2%	0.25	98.8	22.4
PRECIPITATION				13.7	7.9%	4.69E+01	2.8%	0.50	43.2	26.8
TRIBUTARY INFLOW				160.6	92.1%	1.61E+03	97.2%	0.25	98.8	22.4
***TOTAL INFLOW				174.3	100.0%	1.66E+03	100.0%	0.23	89.7	22.7
ADVECTIVE OUTFLOW				59.5	34.1%	3.92E+02		0.33	40.0	7.7
***TOTAL OUTFLOW				59.5	34.1%	3.92E+02		0.33	40.0	7.7
***RETENTION				114.8	65.9%	1.26E+03		0.31		

Overflow Rate (m/yr)	2.9	Nutrient Resid. Time (yrs)	0.4022
Hydraulic Resid. Time (yrs)	1.1785	Turnover Ratio	2.5
Reservoir Conc (mg/m3)	40	Retention Coef.	0.659

Table 51. Fish Lake Calibrated Model Predicted & Observed Phosphorus

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		**1**	**Fish**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	83.1	0.27	73.0%	83.1	0.11	73.0%

Table 52. Fish Lake Calibrated Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km²	Flow hm³/yr	Variance (hm3/yr)²	CV -	Runoff m/yr
1	1	1	Direct Drainage	24.3	4.2	0.00E+00	0.00	0.17
2	1	1	Nelson Lake	17.9	2.5	0.00E+00	0.00	0.14
PRECIPITATION				2.0	1.2	0.00E+00	0.00	0.62
TRIBUTARY INFLOW				42.2	6.7	0.00E+00	0.00	0.16
***TOTAL INFLOW				44.2	7.9	0.00E+00	0.00	0.18
ADVECTIVE OUTFLOW				44.2	6.2	0.00E+00	0.00	0.14
***TOTAL OUTFLOW				44.2	6.2	0.00E+00	0.00	0.14
***EVAPORATION					1.8	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations
Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)²	%Total	CV	Conc mg/m³	Export kg/km²/yr
1	1	1	Direct Drainage	441.2	34.8%	1.22E+04	89.1%	0.25	106.0	18.2
2	1	1	Nelson Lake	186.0	14.7%	7.78E+02	5.7%	0.15	73.0	10.4
PRECIPITATION				53.1	4.2%	7.04E+02	5.2%	0.50	43.2	26.8
INTERNAL LOAD				587.3	46.3%	0.00E+00		0.00		
TRIBUTARY INFLOW				627.1	49.5%	1.29E+04	94.8%	0.18	93.5	14.9
***TOTAL INFLOW				1267.5	100.0%	1.36E+04	100.0%	0.09	159.7	28.7
ADVECTIVE OUTFLOW				513.0	40.5%	1.94E+04		0.27	83.1	11.6
***TOTAL OUTFLOW				513.0	40.5%	1.94E+04		0.27	83.1	11.6
***RETENTION				754.5	59.5%	2.50E+04		0.21		

Overflow Rate (m/yr)	3.1	Nutrient Resid. Time (yrs)	0.2635
Hydraulic Resid. Time (yrs)	0.6511	Turnover Ratio	3.8
Reservoir Conc (mg/m3)	83	Retention Coef.	0.595

Table 53. Fish Lake TMDL Goal Scenario Model Predicted & Observed Phosphorus

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		**1**	**Fish**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	60.0	0.24	59.9%	83.1	0.11	73.0%

Table 54. Fish Lake TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km²	Flow hm³/yr	Variance (hm3/yr)²	CV -	Runoff m/yr
1	1	1	Direct Drainage	24.3	4.2	0.00E+00	0.00	0.17
2	1	1	Nelson Lake	17.9	2.5	0.00E+00	0.00	0.14
PRECIPITATION				2.0	1.2	0.00E+00	0.00	0.62
TRIBUTARY INFLOW				42.2	6.7	0.00E+00	0.00	0.16
***TOTAL INFLOW				44.2	7.9	0.00E+00	0.00	0.18
ADVECTIVE OUTFLOW				44.2	6.2	0.00E+00	0.00	0.14
***TOTAL OUTFLOW				44.2	6.2	0.00E+00	0.00	0.14
***EVAPORATION					1.8	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted TOTAL P
Component:
Outflow & Reservoir Concentrations

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)²	%Total	CV	Conc mg/m³	Export kg/km²/yr
1	1	1	Direct Drainage	416.2	51.1%	0.00E+00		0.00	100.0	17.1
2	1	1	Nelson Lake	152.8	18.7%	0.00E+00		0.00	60.0	8.5
PRECIPITATION				53.1	6.5%	7.04E+02	100.0%	0.50	43.2	26.8
INTERNAL LOAD				193.1	23.7%	0.00E+00		0.00		
TRIBUTARY INFLOW				569.0	69.8%	0.00E+00		0.00	84.8	13.5
***TOTAL INFLOW				815.2	100.0%	7.04E+02	100.0%	0.03	102.7	18.4
ADVECTIVE OUTFLOW				370.3	45.4%	8.09E+03		0.24	60.0	8.4
***TOTAL OUTFLOW				370.3	45.4%	8.09E+03		0.24	60.0	8.4
***RETENTION				444.9	54.6%	8.31E+03		0.20		

Overflow Rate (m/yr)	3.1	Nutrient Resid. Time (yrs)	0.2957
Hydraulic Resid. Time (yrs)	0.6511	Turnover Ratio	3.4
Reservoir Conc (mg/m3)	60	Retention Coef.	0.546

Table 55. Jessie Lake Calibrated Model Predicted & Observed Phosphorus

Predicted & Observed Values Ranked Against CE Model Development Dataset						
Segment:	1 Jessie					
	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	55.2	0.34	56.2%	55.2	0.13	56.3%

Table 56. Jessie Lake Calibrated Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Direct Drainage	35.7	4.7	0.00E+00	0.00	0.13
PRECIPITATION				0.4	0.3	0.00E+00	0.00	0.62
TRIBUTARY INFLOW				35.7	4.7	0.00E+00	0.00	0.13
***TOTAL INFLOW				36.1	4.9	0.00E+00	0.00	0.14
ADVECTIVE OUTFLOW				36.1	4.5	0.00E+00	0.00	0.13
***TOTAL OUTFLOW				36.1	4.5	0.00E+00	0.00	0.13
***EVAPORATION					0.4	0.00E+00	0.00	

Overall Mass Balance Based Upon Component: Predicted TOTAL P — Outflow & Reservoir Concentrations

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Direct Drainage	711.9	98.3%	3.17E+04	99.9%	0.25	152.8	20.0
PRECIPITATION				12.0	1.7%	3.57E+01	0.1%	0.50	43.2	26.8
TRIBUTARY INFLOW				711.9	98.3%	3.17E+04	99.9%	0.25	152.8	20.0
***TOTAL INFLOW				723.9	100.0%	3.17E+04	100.0%	0.25	146.7	20.0
ADVECTIVE OUTFLOW				250.5	34.6%	7.07E+03		0.34	55.2	6.9
***TOTAL OUTFLOW				250.5	34.6%	7.07E+03		0.34	55.2	6.9
***RETENTION				473.4	65.4%	2.35E+04		0.32		

Overflow Rate (m/yr)	10.2	Nutrient Resid. Time (yrs)	0.1180
Hydraulic Resid. Time (yrs)	0.3411	Turnover Ratio	8.5
Reservoir Conc (mg/m3)	55	Retention Coef.	0.654

Table 57. Jessie Lake TMDL Goal Scenario Model Predicted & Observed Phosphorus

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		**1**	**Jessie**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	41.1	0.27	43.2%	55.2	0.13	56.3%

Table 58. Jessie Lake TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Direct Drainage	35.7	4.7	0.00E+00	0.00	0.13
PRECIPITATION				0.4	0.3	0.00E+00	0.00	0.62
TRIBUTARY INFLOW				35.7	4.7	0.00E+00	0.00	0.13
***TOTAL INFLOW				36.1	4.9	0.00E+00	0.00	0.14
ADVECTIVE OUTFLOW				36.1	4.5	0.00E+00	0.00	0.13
***TOTAL OUTFLOW				36.1	4.5	0.00E+00	0.00	0.13
***EVAPORATION					0.4	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Component: TOTAL P — **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Direct Drainage	465.9	97.5%	0.00E+00		0.00	100.0	13.1
PRECIPITATION				12.0	2.5%	3.57E+01	100.0%	0.50	43.2	26.8
TRIBUTARY INFLOW				465.9	97.5%	0.00E+00		0.00	100.0	13.1
***TOTAL INFLOW				477.9	100.0%	3.57E+01	100.0%	0.01	96.8	13.2
ADVECTIVE OUTFLOW				186.5	39.0%	2.53E+03		0.27	41.1	5.2
***TOTAL OUTFLOW				186.5	39.0%	2.53E+03		0.27	41.1	5.2
***RETENTION				291.4	61.0%	2.54E+03		0.17		

Overflow Rate (m/yr)	10.2	Nutrient Resid. Time (yrs)	0.1331
Hydraulic Resid. Time (yrs)	0.3411	Turnover Ratio	7.5
Reservoir Conc (mg/m3)	41	Retention Coef.	0.610

Table 59. Latimer Lake Calibrated Model Predicted & Observed Phosphorus

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		1	Latimer				
		Predicted Values--->			Observed Values--->		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	71.1	0.36	67.0%	71.1	0.17	67.0%

Table 60. Latimer Lake Calibrated Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Direct Drainage	7.2	1.7	0.00E+00	0.00	0.23
TRIBUTARY INFLOW				7.2	1.7	0.00E+00	0.00	0.23
***TOTAL INFLOW				8.1	1.7	0.00E+00	0.00	0.21
ADVECTIVE OUTFLOW				8.1	1.7	0.00E+00	0.00	0.21
***TOTAL OUTFLOW				8.1	1.7	0.00E+00	0.00	0.21

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations
Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Direct Drainage	280.0	48.4%	4.90E+03	97.6%	0.25	167.3	38.7
PRECIPITATION				21.9	3.8%	1.19E+02	2.4%	0.50		26.8
INTERNAL LOAD				277.0	47.8%	0.00E+00		0.00		
TRIBUTARY INFLOW				280.0	48.4%	4.90E+03	97.6%	0.25	167.3	38.7
***TOTAL INFLOW				578.9	100.0%	5.02E+03	100.0%	0.12	345.8	71.8
ADVECTIVE OUTFLOW				119.0	20.6%	1.81E+03		0.36	71.1	14.8
***TOTAL OUTFLOW				119.0	20.6%	1.81E+03		0.36	71.1	14.8
***RETENTION				459.8	79.4%	5.52E+03		0.16		

Overflow Rate (m/yr)	2.1	Nutrient Resid. Time (yrs)	0.5118
Hydraulic Resid. Time (yrs)	2.4892	Turnover Ratio	2.0
Reservoir Conc (mg/m3)	71	Retention Coef.	0.794

Table 61. Latimer Lake TMDL Goal Scenario Model Predicted & Observed Phosphorus

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 Latimer

Variable		Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P	MG/M3	40.0	0.34	42.0%	71.1	0.17	67.0%

Table 62. Latimer Lake TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Direct Drainage	7.2	1.7	0.00E+00	0.00	0.23
TRIBUTARY INFLOW				7.2	1.7	0.00E+00	0.00	0.23
***TOTAL INFLOW				8.1	1.7	0.00E+00	0.00	0.21
ADVECTIVE OUTFLOW				8.1	1.7	0.00E+00	0.00	0.21
***TOTAL OUTFLOW				8.1	1.7	0.00E+00	0.00	0.21

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations
Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Direct Drainage	167.4	70.0%	1.75E+03	93.6%	0.25	100.0	23.1
PRECIPITATION				21.9	9.1%	1.19E+02	6.4%	0.50		26.8
INTERNAL LOAD				50.0	20.9%	0.00E+00		0.00		
TRIBUTARY INFLOW				167.4	70.0%	1.75E+03	93.6%	0.25	100.0	23.1
***TOTAL INFLOW				239.3	100.0%	1.87E+03	100.0%	0.18	142.9	29.7
ADVECTIVE OUTFLOW				66.9	28.0%	5.16E+02		0.34	40.0	8.3
***TOTAL OUTFLOW				66.9	28.0%	5.16E+02		0.34	40.0	8.3
***RETENTION				172.4	72.0%	1.69E+03		0.24		

Overflow Rate (m/yr)	2.1	Nutrient Resid. Time (yrs)	0.6957
Hydraulic Resid. Time (yrs)	2.4892	Turnover Ratio	1.4
Reservoir Conc (mg/m3)	40	Retention Coef.	0.720

Table 63. Nelson Lake Calibrated Model Predicted & Observed Phosphorus

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		1	Nelson				
		Predicted Values--->			Observed Values--->		
Variable		Mean	CV	Rank	Mean	CV	Rank
TOTAL P	MG/M3	73.0	0.29	68.0%	73.0	0.15	68.0%

Table 64. Nelson Lake Calibrated Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Direct Drainage	16.8	2.8	0.00E+00	0.00	0.17
PRECIPITATION				1.1	0.7	0.00E+00	0.00	0.62
TRIBUTARY INFLOW				16.8	2.8	0.00E+00	0.00	0.17
***TOTAL INFLOW				17.9	3.5	0.00E+00	0.00	0.20
ADVECTIVE OUTFLOW				17.9	2.5	0.00E+00	0.00	0.14
***TOTAL OUTFLOW				17.9	2.5	0.00E+00	0.00	0.14
***EVAPORATION					1.0	0.00E+00	0.00	

Overall Mass Balance Based Upon Component: Predicted TOTAL P — **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Direct Drainage	317.4	72.1%	6.30E+03	96.7%	0.25	111.6	18.9
PRECIPITATION				29.5	6.7%	2.18E+02	3.3%	0.50	43.2	26.8
INTERNAL LOAD				93.3	21.2%	0.00E+00		0.00		
TRIBUTARY INFLOW				317.4	72.1%	6.30E+03	96.7%	0.25	111.6	18.9
***TOTAL INFLOW				440.2	100.0%	6.52E+03	100.0%	0.18	124.8	24.5
ADVECTIVE OUTFLOW				185.9	42.2%	2.88E+03		0.29	73.0	10.4
***TOTAL OUTFLOW				185.9	42.2%	2.88E+03		0.29	73.0	10.4
***RETENTION				254.3	57.8%	5.36E+03		0.29		

Overflow Rate (m/yr)	2.3	Nutrient Resid. Time (yrs)	0.2781
Hydraulic Resid. Time (yrs)	0.6585	Turnover Ratio	3.6
Reservoir Conc (mg/m3)	73	Retention Coef.	0.578

Table 65. Nelson Lake TMDL Goal Scenario Model Predicted & Observed Phosphorus

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 Nelson

Variable		Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P	MG/M3	60.0	0.29	59.9%	73.0	0.15	68.0%

Table 66. Nelson Lake TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Direct Drainage	16.8	2.8	0.00E+00	0.00	0.17
PRECIPITATION				1.1	0.7	0.00E+00	0.00	0.62
TRIBUTARY INFLOW				16.8	2.8	0.00E+00	0.00	0.17
***TOTAL INFLOW				17.9	3.5	0.00E+00	0.00	0.20
ADVECTIVE OUTFLOW				17.9	2.5	0.00E+00	0.00	0.14
***TOTAL OUTFLOW				17.9	2.5	0.00E+00	0.00	0.14
***EVAPORATION					1.0	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted TOTAL P

Component: — Outflow & Reservoir Concentrations

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Direct Drainage	284.5	84.1%	5.06E+03	95.9%	0.25	100.0	16.9
PRECIPITATION				29.5	8.7%	2.18E+02	4.1%	0.50	43.2	26.8
INTERNAL LOAD				24.1	7.1%	0.00E+00		0.00		
TRIBUTARY INFLOW				284.5	84.1%	5.06E+03	95.9%	0.25	100.0	16.9
***TOTAL INFLOW				338.1	100.0%	5.27E+03	100.0%	0.21	95.9	18.8
ADVECTIVE OUTFLOW				152.8	45.2%	1.97E+03		0.29	60.0	8.5
***TOTAL OUTFLOW				152.8	45.2%	1.97E+03		0.29	60.0	8.5
***RETENTION				185.2	54.8%	3.69E+03		0.33		

Overflow Rate (m/yr)	2.3	Nutrient Resid. Time (yrs)	0.2977
Hydraulic Resid. Time (yrs)	0.6585	Turnover Ratio	3.4
Reservoir Conc (mg/m3)	60	Retention Coef.	0.548

Table 67. Twin Lake Calibrated Model Predicted & Observed Phosphorus

Predicted & Observed Values Ranked Against CE Model Development Dataset						
Segment:	**1**	**Twin**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	81.6	0.16	72.3%	81.6	0.08	72.3%

Table 68. Twin Lake Calibrated Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance						**Averaging Period =**	**1.00**	**years**
				Area	**Flow**	**Variance**	**CV**	**Runoff**
Trb	**Type**	**Seg**	**Name**	**km^2**	**hm^3/yr**	**$(hm3/yr)^2$**	**-**	**m/yr**
1	1	1	Direct Drainage	3.9	0.7	0.00E+00	0.00	0.18
2	1	1	Fish Lake	44.2	6.2	0.00E+00	0.00	0.14
PRECIPITATION				0.5	0.3	0.00E+00	0.00	0.62
TRIBUTARY INFLOW				48.1	6.9	0.00E+00	0.00	0.14
***TOTAL INFLOW				48.6	7.2	0.00E+00	0.00	0.15
ADVECTIVE OUTFLOW				48.6	6.7	0.00E+00	0.00	0.14
***TOTAL OUTFLOW				48.6	6.7	0.00E+00	0.00	0.14
***EVAPORATION					0.5	0.00E+00	0.00	

Overall Mass Balance Based Upon				**Predicted**		**Outflow & Reservoir Concentrations**				
Component:				**TOTAL P**						
				Load		**Load Variance**			**Conc**	**Export**
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**$(kg/yr)^2$**	**%Total**	**CV**	**mg/m^3**	**$kg/km^2/yr$**
1	1	1	Direct Drainage	77.1	9.2%	3.71E+02	10.3%	0.25	109.5	19.8
2	1	1	Fish Lake	513.1	61.3%	3.19E+03	88.3%	0.11	83.1	11.6
PRECIPITATION				14.5	1.7%	5.28E+01	1.5%	0.50	43.2	26.8
INTERNAL LOAD				231.7	27.7%	0.00E+00		0.00		
TRIBUTARY INFLOW				590.2	70.6%	3.56E+03	98.5%	0.10	85.8	12.3
***TOTAL INFLOW				836.5	100.0%	3.61E+03	100.0%	0.07	115.9	17.2
ADVECTIVE OUTFLOW				549.5	65.7%	8.15E+03		0.16	81.6	11.3
***TOTAL OUTFLOW				549.5	65.7%	8.15E+03		0.16	81.6	11.3
***RETENTION				287.0	34.3%	7.77E+03		0.31		

Overflow Rate (m/yr)	12.4	Nutrient Resid. Time (yrs)	0.0968
Hydraulic Resid. Time (yrs)	0.1473	Turnover Ratio	10.3
Reservoir Conc (mg/m3)	82	Retention Coef.	0.343

Table 69. Twin Lake TMDL Goal Scenario Model Predicted & Observed Phosphorus

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		1	Twin				
		Predicted Values--->			Observed Values--->		
Variable		Mean	CV	Rank	Mean	CV	Rank
TOTAL P	MG/M3	60.0	0.15	59.8%	81.6	0.08	72.3%

Table 70. Twin Lake TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance					Averaging Period =		1.00	years
				Area	Flow	Variance	CV	Runoff
Trb	Type	Seg	Name	km^2	hm^3/yr	$(hm3/yr)^2$	-	m/yr
1	1	1	Direct Drainage	3.9	0.7	0.00E+00	0.00	0.18
2	1	1	Fish Lake	44.2	6.2	0.00E+00	0.00	0.14
PRECIPITATION				0.5	0.3	0.00E+00	0.00	0.62
TRIBUTARY INFLOW				48.1	6.9	0.00E+00	0.00	0.14
***TOTAL INFLOW				48.6	7.2	0.00E+00	0.00	0.15
ADVECTIVE OUTFLOW				48.6	6.7	0.00E+00	0.00	0.14
***TOTAL OUTFLOW				48.6	6.7	0.00E+00	0.00	0.14
***EVAPORATION					0.5	0.00E+00	0.00	

Overall Mass Balance Based Upon				Predicted		Outflow & Reservoir Concentrations				
Component:				TOTAL P						
				Load		Load Variance			Conc	Export
Trb	Type	Seg	Name	kg/yr	%Total	$(kg/yr)^2$	%Total	CV	mg/m^3	$kg/km^2/yr$
1	1	1	Direct Drainage	70.4	12.1%	3.10E+02	15.3%	0.25	100.0	18.1
2	1	1	Fish Lake	370.5	63.6%	1.66E+03	82.1%	0.11	60.0	8.4
PRECIPITATION				14.5	2.5%	5.28E+01	2.6%	0.50	43.2	26.8
INTERNAL LOAD				126.8	21.8%	0.00E+00		0.00		
TRIBUTARY INFLOW				440.9	75.7%	1.97E+03	97.4%	0.10	64.1	9.2
***TOTAL INFLOW				582.2	100.0%	2.02E+03	100.0%	0.08	80.7	12.0
ADVECTIVE OUTFLOW				403.6	69.3%	3.76E+03		0.15	60.0	8.3
***TOTAL OUTFLOW				403.6	69.3%	3.76E+03		0.15	60.0	8.3
***RETENTION				178.6	30.7%	3.38E+03		0.33		

Overflow Rate (m/yr)	12.4	Nutrient Resid. Time (yrs)	0.1021
Hydraulic Resid. Time (yrs)	0.1473	Turnover Ratio	9.8
Reservoir Conc (mg/m3)	60	Retention Coef.	0.307

Appendix C: LDC Supporting Information

Gaged flows in the Long Prairie River Watershed:

- USGS 05245100, Long Prairie River nr Long Prairie at CSAH 11 (MN 14051001), 1971-2014. Located in HSPF basin 327 at Cty Rd 11. Drainage at basin 327 outlet = 430 mi^2, drainage at gage on Cty 11 = 418 mi^2.
- DNR gage 140340001, Long Prairie River nr Philbrook, 2004-2014. Drainage at basin 347 outlet (also confluence with Crow Wing River) = 885 mi^2, drainage at gage = 866 mi^2.

Table 71. *E. coli* LDC data sources

<table>
<tr><th rowspan="2">Impaired Reach Name/AUID</th><th colspan="2">Standard Load</th><th colspan="4">Existing Load</th><th rowspan="2">Comments</th></tr>
<tr><th>Flow Data Source</th><th>Flow Data Range</th><th colspan="2">Flow Data Source and Data Range</th><th>Water Quality Station</th><th>Water Quality Data Range</th></tr>
<tr><td>Eagle Creek 07010108-507</td><td>HSPF subbasin 332
Area-weighted to WQ station S000-723</td><td rowspan="3">2000-2009</td><td colspan="2">MPCA gage H14047001, March 2011 – November 2013</td><td>S000-723</td><td>2011-2012</td><td>HSPF subbasin 332 total drainage = 70.75 mi^2
Drainage at S000-723 = 58.1 mi^2</td></tr>
<tr><td>Moran Creek 07010108-511</td><td>HSPF subbasin 339
Area-weighted to WQ station S002-903</td><td colspan="2">MPCA gage H14047001, March 2011 – November 2013</td><td>S002-903</td><td>2011-2012</td><td>HSPF subbasin 339 total drainage = 74.1mi^2
Drainage at S002-903 = 69.6 mi^2</td></tr>
<tr><td>Unnamed Creek 07010108-552</td><td>HSPF basin 307</td><td>USGS Gage 05245100
Long Prairie River at CSAH 11 (2010-2014)</td><td>flow = 0.0751 x $(gage)^{0.9523}$
R^2=0.54</td><td>S001-780</td><td>2011-2012</td><td>WQ station S001-780 located near HSPF basin 307 outlet.</td></tr>
</table>

*Flow records for this ungaged stream reaches were estimated from gage records for USGS gage 05245100 for the period 2010-2014 using regressions analysis. Regression equations are based on comparison of mean daily flows predicted by the HSPF modeled for each impaired reach and flow records USGS gage for the period 2000-2009.

Flow Extrapolation Error Analysis

HSPF modeled flow data were available for the years 2000-2009 for the Long Prairie River Watershed while water quality monitoring data were available for the period 2011-2013 (all or a portion thereof for individual streams). In subwatersheds for which flow records for the period 2011-2013 could not be reasonably estimated based on nearby gage station, regressions were developed to estimate HSPF flows based on flow records from USGS gage #05245100 (Long Prairie River near Long Prairie, Minnesota) for the years 2000-2009 (the period of record overlap). As an example, Figure 49 shows the regression for Moran Creek HSPF flows on the USGS gage. Ninety-five percent confidence intervals for the regression are shown in grey. Standard deviations in observed flows and prediction intervals are greatest for flows in the low and mid-range flow regimes. This pattern and the relative magnitude of the 95% confidence interval are typical of all regressions developed to estimate missing flow records. See Table 71 for a list of flow estimation methods used in the development of LDCs.

Since the existing loads written in each of the stream TMDLs are based on flows extrapolated from regression equations, there is a corresponding uncertainty in the estimates of these existing loads. Additional sources of error in flow (and therefore load) estimates include:

- Uncertainty inherent in HSPF modeled flow data
- Uncertainty in gaged flow records
- Uncertainty introduced by area-weighting flows where this was required
- Uncertainty in reported monitoring data

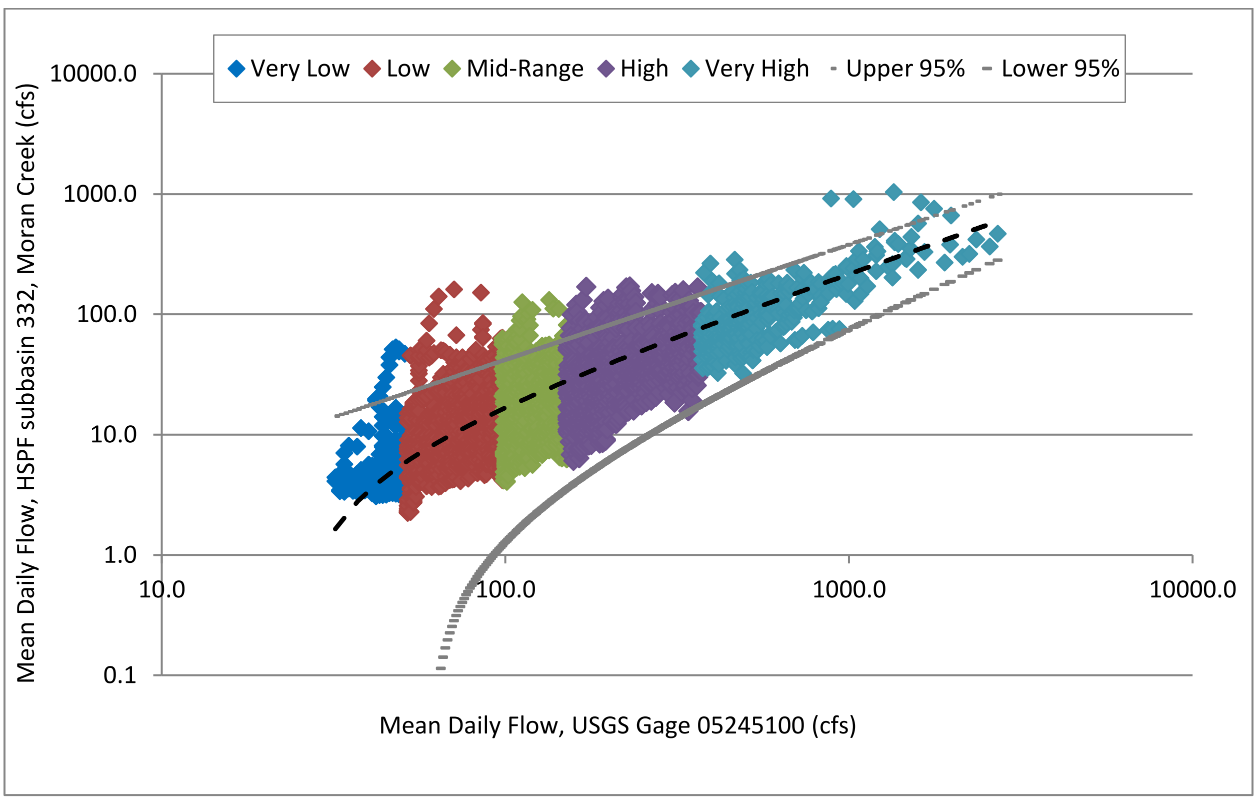


Figure 49. Moran Creek HSPF flows vs. USGS gaged flow for the Long Prairie River near Long Prairie at CSAH 11, 2000 to 2009. Note that flows are plotted on a log-log scale.