Mississippi River-Brainerd Area Watershed Total Maximum Daily Load Report

MINNESOTA POLLUTION CONTROL AGENCY

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Acronyms

AUID	Assessment Unit Identification
BMP	best management practices
BOD	biochemical oxygen demand
BWSR	Board of Water and Soil Resources
CAFO	concentrated animal feeding operation
CBOD	carbonaceous biochemical oxygen demand
Chl-*a*	chlorophyll-*a*
CPUE	catch per unit effort
CWA	Clean Water Act
DMR	discharge monitoring report
DNR	Minnesota Department of Natural Resources
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
ft	feet
GR	geometry ratio
HSG	hydrologic soil group
HSPF	Hydrological Simulation Program–FORTRAN
HUC	Hydrologic Unit Code
LA	load allocation
LDC	load duration curve
LGU	local government unit
LID	low-impact development
m	meter
µg/L	micrograms per liter
MIDS	Minimal Impact Design Standards
MINLEAP	Minnesota Lake Eutrophication Analysis Procedure
MOS	margin of safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer System
NCHF	North Central Hardwood Forest
NHD	National Hydrology Dataset
NLF	Northern Lakes and Forests
NOAA	National Oceanic and Atmospheric Administration
NOD	nitrogenous oxygen demand
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
P	Phosphorus
SDD	Secchi disc depth

SDS	State Disposal System
SOD	sediment oxygen demand
SSTS	subsurface sewage treatment systems
SWCD	soil and water conservation district
SWPPP	storm water pollution prevention plan
TMDL	Total Maximum Daily Load
TP	total phosphorus
TSI	Trophic State Index
TSS	total suspended sediment
USGS	US Geological Survey
WLA	wasteload allocation
WRAPS	Watershed Restoration and Protection Strategy
WWTF	wastewater treatment facility

Executive Summary

This Total Maximum Daily Load (TMDL) study was completed for impaired waterbodies of the Mississippi-Brainerd Area Watershed (Hydrologic Unit Code [HUC] 07010104), which is part of the Upper Mississippi River Basin. The study addresses 8 river/stream reach bacteria impairments, 2 river/stream reach biology impairments of macroinvertebrates, and 11 lake nutrient impairments. The goal of this TMDL study is to quantify the pollutant reductions needed to meet the state water quality standards for bacteria (*E. coli*), macroinvertebrates, and nutrients (phosphorus [P]) for impaired streams and lakes located in the Mississippi-Brainerd Area Watershed. *E. coli* bacteria is an indicator of health risk from water contact in recreational waters. Biology impairments (benthic macroinvertebrates) are small aquatic animals and the aquatic larval stages of insects which are commonly used as indicators of the biological condition of waterways. The presence of only pollution-tolerant species or very little diversity indicate a less healthy waterway. Excess nutrients in lakes can not only cause an increased algal presence, but can also lead to blue-green algae that can produce toxins that are harmful to human and animal health.

TMDLs described herein were primarily derived from output of the Hydrological Simulation Program–FORTRAN (HSPF) model developed for the entire Mississippi-Brainerd Area Watershed. This model incorporated available flows (1996 through 2015), monitored water quality, and the latest land cover data of 2013. HSPF-estimated runoff and pollutant characterizations were employed to assess TMDLs for stream bacteria (*E. coli*), total suspended solids (TSS), and lake nutrient loads. HSPF-generated flows and outputs were used to establish load duration curves (LDCs) for eight stream reach bacteria impairments with wasteload allocations (WLAs) and load allocations (LAs) established for five flow duration curve categories: very high, high, mid, low, and very low flow conditions. Reductions required to achieve state bacteria standards range from 0% to 93% by TMDL duration curve category.

Lake average annual income-outgo P budgets were developed from HSPF-modeled flows and P loadings and corresponding in-lake monitoring data incorporated into the widely used lake response model BATHTUB. Internal release of P was evaluated and explicitly incorporated as determined by a collective weight-of-evidence approach on a lake-by-lake basis. Lake assimilative capacity is strongly influenced by lake depth, with three of the lakes being evaluated as shallow and 8 lakes assessed as deep lakes. P reduction required to achieve the shallow lake standard for Trace Lake was 46% while the other two shallow lakes, Fleming and Fawn, are located in the Northern Lakes and Forests (NLF) Ecoregion and do not have a separate shallow lakes standard. Fleming and Fawn P reductions are 64% and 66% respectively. P reductions required for deep lakes ranged from 15% to 56%.

Lake rehabilitation should focus on reducing P from agricultural sources, septic systems, and urban stormwater. Based on HSPF modeling, elevated dissolved P loadings should receive high priority for phased implementation actions to directly reduce algal generation and internal loading potentials. As wetlands have generally lower P assimilative capacities than lakes, upgradient wetland complexes should be evaluated for growing season internal P loading and release to downstream water bodies. Offsetting effects of legacy loading and historical channelization to wetlands will require examining rehabilitation options. Subsequent to substantial reductions of lake watershed P sources, lakes with internal loading allocations should be reevaluated for lake sediment treatments, such as adding aluminum sulfate (alum)/ferric chloride and/or oxygenating bottom waters. Winter aeration to reduce winter fish kills should be considered, as guided by Minnesota Department of Natural Resources (DNR) fisheries managers.

Restoring water quality will continue to be aided by the interdependent and cooperative efforts of the local communities, counties, state, and federal partners via leveraged management actions phased over budgetary cycles in regard to the largest pollutant sources. Phased approaches beginning in headwaters of impaired stream reach and lake areas (continuing downstream) may cause quicker detection of measurable changes. Improving upgradient lakes will help improve the quality of downstream lakes. Of the best management practices (BMPs), widespread buffers and streambank stabilization adoption should proceed as a high priority and will assist in reducing bacteria, organic matter linked to reduced dissolved oxygen (DO), TSS, and nutrients. Pollutant sources have been identified by impaired stream and by flow pattern that will help prioritize/guide implementation with agricultural producers and municipal separate storm sewer system (MS4) areas. Reducing general system oxygen demand from excess sediments and organic matter will occur via cumulative implementation, beginning with adopting buffers. Legacy sources may have impacted low assimilative capacity wetlands and will require further characterization assessments. Looking ahead, anticipated shifts in land uses to more intense urban development and agriculture with corresponding increases in artificial drainage practices may present additional runoff volume and quality challenges in the watershed.

Subtle east-west climate gradients were noted across the watershed, as defined by storm precipitation intensities and durations, annual precipitation, evaporation, and frost-free periods, with greater levels of tracking in the eastern part of the basin. Storm rainfall amounts for the typical 24-hour storm and multiday wet periods can be substantial, with potential wide-ranging negative impacts to communities and agricultural producers as well as the receiving streams, lakes, wetlands, and associated aquatic habitats. Collectively, this report's dry- and wet-cycle characterizations may aid in considering BMP design factors for wet periods and in augmenting storage/retention practices for dry periods to increase stream-base flows and reuse (irrigation).

The Mississippi-Brainerd Watershed is in Todd, Morrison, Crow Wing, and Aitkin Counties. Future implementation strategies to improve and protect local waters and those downstream will require the continued close cooperative efforts of all watershed counties and local units of government. The findings from this TMDL study were used to assist in selecting implementation and monitoring activities as part of the Watershed Restoration and Protection Strategy (WRAPS) process. The purpose of the WRAPS report is to support these local working groups and jointly develop scientifically supported restoration and protection strategies to be used for subsequent local watershed planning and implementation. Following completion, this TMDL report and the WRAPS report will be publicly available on the Minnesota Pollution Control Agency (MPCA) website.

1. Project Overview

1.1 Purpose

Section 303(d) of the Clean Water Act (CWA) and the U.S. Environmental Protection Agency (EPA) Water Quality Planning and Management Regulations (40 CFR 130) require states to develop TMDLs for waterbodies that do not meet applicable water quality standards or guidelines to protect their designated uses. TMDLs specify the maximum pollutant load that a waterbody can receive and still meet water quality standards. Based on a calculation of the total allowable load, TMDLs allocate pollutant loads to sources and incorporate a margin of safety (MOS). TMDL pollutant load reduction goals for significant sources provide a scientific basis for restoring surface water quality by linking the development and implementation of control actions to attaining and maintaining water quality standards and designated uses.

This TMDL study addresses 8 stream reach *Escherichia coli* bacteria (*E. coli*) impairments, 2 stream reach biology impairments of macroinvertebrates, and 11 lake nutrient (P) impairments of the Mississippi-Brainerd Watershed. The impaired waterbodies are located in Aitkin, Crow Wing, Morrison, and Todd Counties. The Mississippi-Brainerd Area Watershed is approximately 1,682 square miles.

Developing TMDLs for the Mississippi-Brainerd Area Watershed will provide a framework for the MPCA, other state and federal agencies, and county and tribal watershed managers on which to base management decisions. TMDLs will also provide reasonable assurance that impairments will be addressed by continued BMP implementation and that future impairments will be addressed with an in-place model and TMDL. Furthermore, outcomes from the TMDLs, such as increased implementation, will protect the designated uses assigned to these waterbodies.

1.2 Identifications of Waterbodies

The Mississippi-Brainerd Area Watershed is located in central Minnesota, as shown in Figure 1-1. This TMDL addresses 8 bacteria impaired streams, 2 biologic impaired streams, and 11 nutrient impairments (Table 1-1). Some of the impairments in the 2020 303(d) list of impaired waters are not addressed in this TMDL (Table 1-2) because of lack of sufficient data to adequately develop all TMDLs at this time. Impairments not addressed in this TMDL will still be addressed with BMPs identified in the WRAPS document and re-evaluated during the next assessment cycle. The Mississippi-Brainerd Area Watershed bacteria impaired stream reaches addressed are shown in Figure 1-2, the biology impaired reaches addressed are shown in Figure 1-3, and nutrient impaired lakes addressed are shown in Figure 1-4. None of the drainage areas of impaired waterbodies addressed in this document contain tribal lands. Tribal lands in nonimpaired subwatersheds are shown in Figure 1-1 and include Minnesota Chippewa Indian Land and the Mille Lacs Band Sandy Lake Reservation.

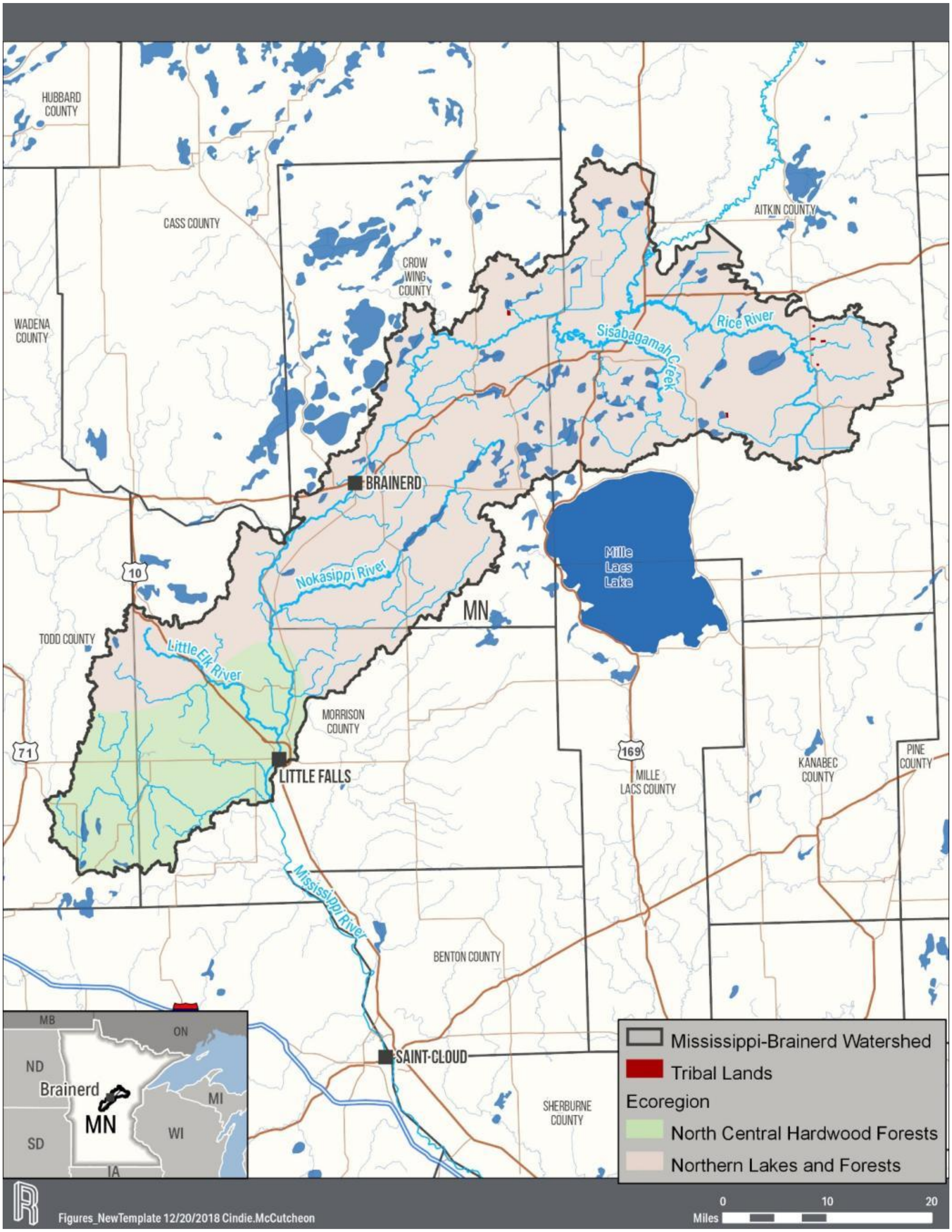


Figure 1-1. Project Area

The State of Minnesota classifies streams into categories, which are protected for specific designated uses. All impairments addressed in this TMDL are Class 2B, 2Bg, and/or Class 3C waters. The quality of Class 2B surface waters enable the propagation and maintenance of a healthy community of cool- or warm-water sport or commercial fish and associated aquatic life, as well as their habitats (Minn. R. ch. 7050.0222, subp. 4). These waters shall be suitable for all kinds of aquatic recreation, including bathing. This class of surface water is not protected as a source of drinking water. Class 2Bg, or "general cool and warm water aquatic life and habitat" is a beneficial use that means waters capable of supporting and maintaining a balanced, integrated, adaptive community of warm or cool water aquatic organisms having a species composition, diversity, and functional organization comparable to the median of biological condition gradient level 4 (Minn. R. ch. 7050.0222, subp. 4C). The quality of the state's Class 3C waters enable their use for industrial cooling and materials transport, without a high degree of treatment being necessary to avoid severe fouling, corrosion, scaling, or other unsatisfactory conditions (Minn. R. ch. 7050.0223, subp. 4). One impaired waterbody in the Mississippi-Brainerd Area Watershed is Class 1B, 2Ag, 3B. However, this waterbody is not addressed in this TMDL and therefore these designated uses are not defined in this TMDL.

Table 1-1. Water Quality Impairments Addressed.

Name	Lake/ Stream	ID	Proposed Use Subclass	Impairment	Year Listed
Sisabagamah Creek	Stream	07010104-659	2Bg, 3C	Macroinvertebrate Bioassessments	2020
Hay Creek	Stream	07010104-645	2Bg, 3C	*E. coli*	2020
Unnamed creek	Stream	07010104-679	2Bg, 3C	Macroinvertebrate Bioassessments	2020
Buffalo Creek (Little Buffalo Creek)	Stream	07010104-695	2Bg, 3C	*E. coli*	2020
Little Elk River	Stream	07010104-521	2Bg, 3C	*E. coli*	2020
Pike Creek	Stream	07010104-522	2Bg, 3C	*E. coli*	2020
Swan River	Stream	07010104-502	2Bg, 3C	*E. coli*	2020
Unnamed creek	Stream	07010104-626	2Bg, 3C	*E. coli*	2020
Schwanke Creek	Stream	07010104-627	2Bg, 3C	*E. coli*	2020
Unnamed creek	Stream	07010104-629	2Bg, 3C	*E. coli*	2020
Gun	Lake	01-0099-00	2B, 3C	Nutrients	2010
Fleming	Lake	01-0105-00	2B, 3C	Nutrients	2010
Elm Island	Lake	01-0123-00	2B, 3C	Nutrients	2010
Ripple	Lake	01-0146-00	2B, 3C	Nutrients	2020
Crow Wing	Lake	18-0155-00	2B, 3C	Nutrients	2010
Sebie	Lake	18-0161-00	2B, 3C	Nutrients	2020
Fawn	Lake	18-0240-00	2B, 3C	Nutrients	2020
Lower Mission	Lake	18-0243-00	2B, 3C	Nutrients	2020
Trace	Lake	77-0009-00	2B, 3C	Nutrients	2008
Big Swan	Lake	77-0023-00	2B, 3C	Nutrients	2010
Moose	Lake	77-0026-00	2B, 3C	Nutrients	2020

Table 1-2. Water Quality Impairments that Are Not Addressed in This TMDL Report.

Name	Lake/ Stream	ID	Proposed Use Subclass	Impairments	Year Listed
Swan River	Stream	07010104-502	2Bg, 3C	Dissolved Oxygen	2010
Rice River	Stream	07010104-505	2Bg, 3C	Fish Bioassessments, Dissolved Oxygen	2020
Little Swan River	Stream	07010104-570	2Bg, 3C	Fish Bioassessments	2020
Whiteley Creek	Stream	07010104-589	1B, 2Ag, 3B	Macroinvertebrate Bioassessments	2020
Buffalo Creek	Stream	07010104-610	2Bg, 3C	Macroinvertebrate Bioassessments	2020
Unnamed creek	Stream	07010104-632	2Bg, 3C	*E. coli*	2020
Rice River	Stream	07010104-649	2Bg, 3C	Fish IBI, Dissolved Oxygen, *E. coli*	2020
Mississippi River	Stream	07010104-655	2Bg, 3C	Turbidity	1998
Mississippi River	Stream	07010104-656	2Bg, 3C	Total Suspended Solids	2016
Sisabagamah Creek	Stream	07010104-677	2Bg, 3C	Fish Bioassessments	2020
Unnamed creek	Stream	07010104-681	2Bg, 3C	Fish Bioassessments	2020
Hay Creek	Stream	07010104-682	2Bg, 3C	Macroinvertebrate Bioassessments	2020
Unnamed creek	Stream	07010104-684	2Bg, 3C	Macroinvertebrate Bioassessments, Dissolved Oxygen	2020
Rabbit Creek	Stream	07010104-688	2Bg, 3C	Fish Bioassessments	2020
Unnamed ditch (Little Willow River Diversion)	Stream	07010104-691	2Bg, 3C	Macroinvertebrate Bioassessments	2020
Buffalo Creek (Little Buffalo Creek)	Stream	07010104-695	2Bg, 3C	Fish Bioassessments, Macroinvertebrate Bioassessments	2002
Little Willow River Old Channel	Stream	07010104-701	2Bg, 3C	Fish Bioassessments	2020
Portage	Lake	01-0069-00	2B, 3C	Nutrients	2020
Elm Island	Lake	01-0123-00	2B, 3C	Fish Bioassessments	2020
Waukenabo	Lake	01-0136-00	2B, 3C	Nutrients	2010
Esquagamah	Lake	01-0147-00	2B, 3C	Nutrients	2010
Blind	Lake	01-0188-00	2B, 3C	Nutrients	2010
Casey	Lake	18-0087-00	2B, 3C	Nutrients	2020
Grave	Lake	18-0110-00	2B, 3C	Nutrients	2020
Crow Wing	Lake	18-0155-00	2B, 3C	Fish Bioassessments	2020
Upper Dean	Lake	18-0170-00	2B, 3C	Nutrients	2020
Green Prairie Fish	Lake	49-0035-00	2B, 3C	Fish Bioassessments	2020
Moose	Lake	77-0026-00	2B, 3C	Fish Bioassessments	2020

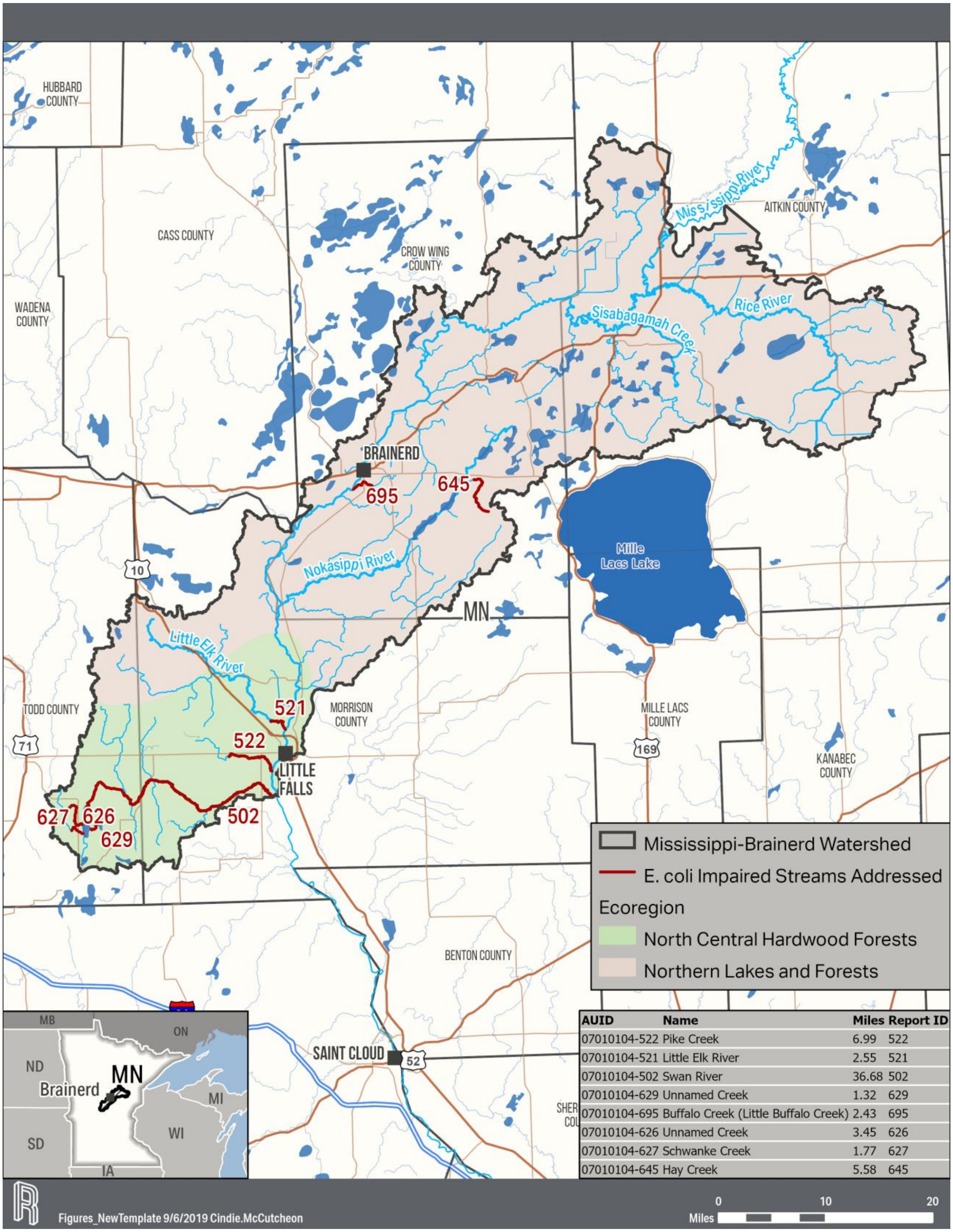
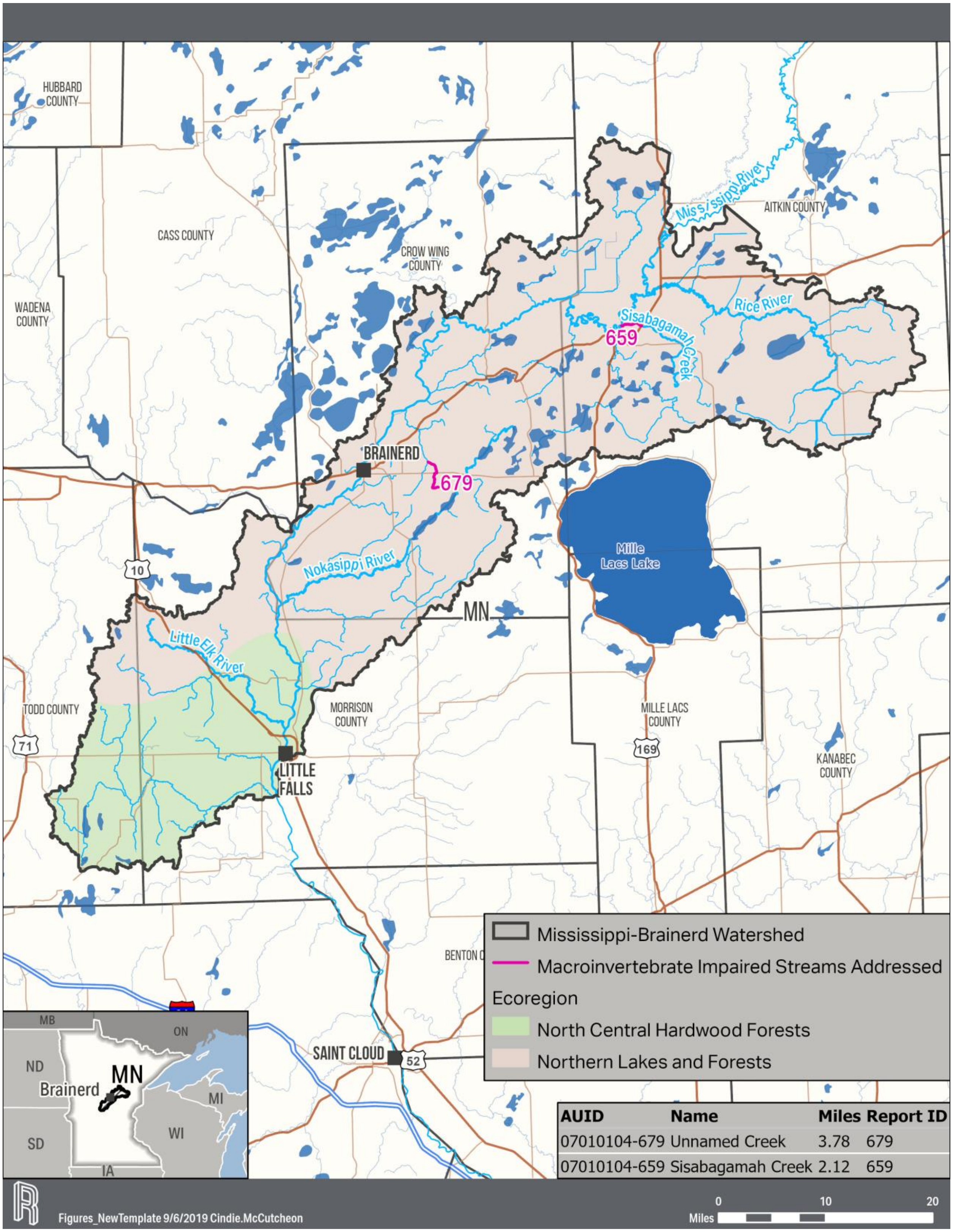
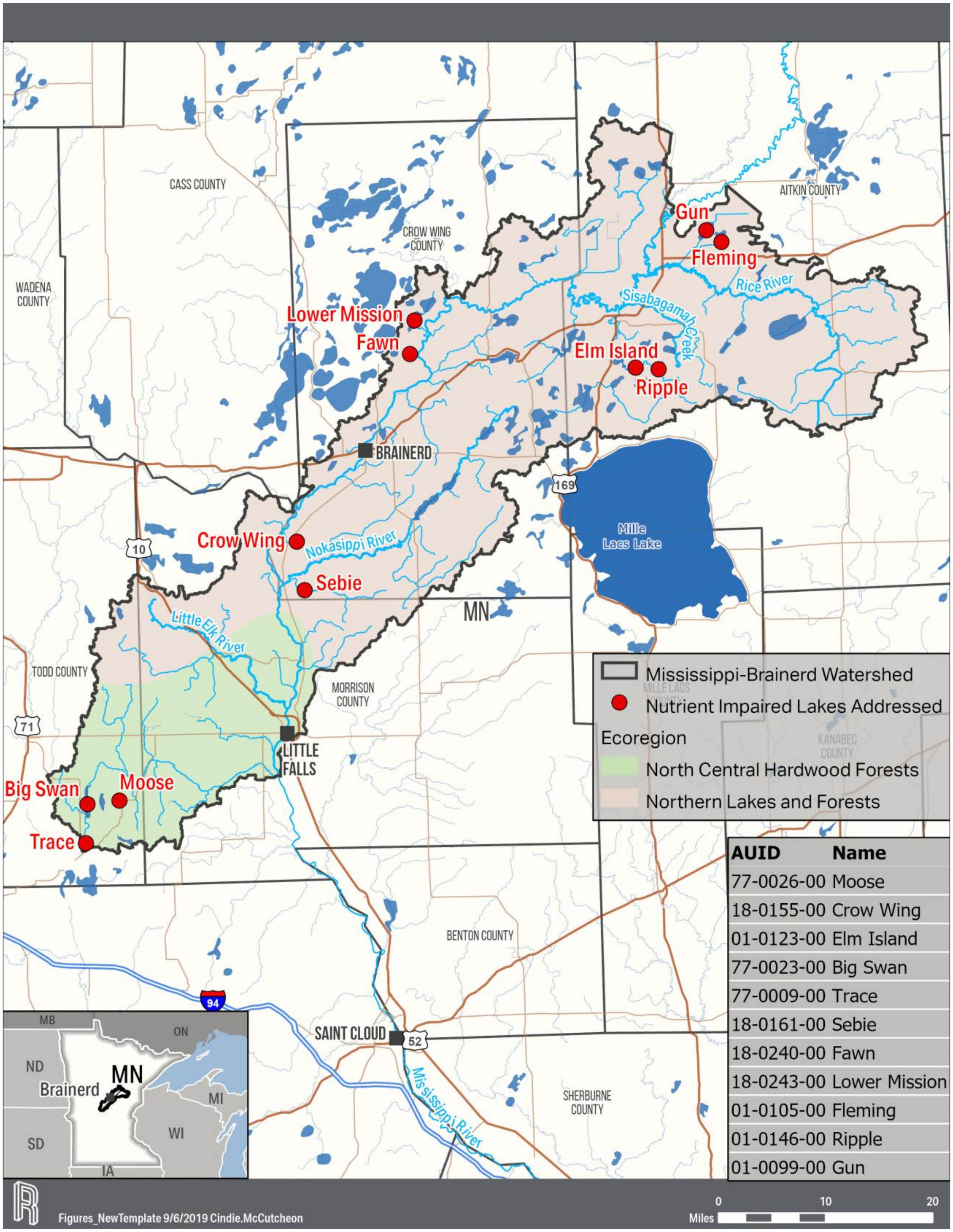


Figure 1-2. ***E. coli*** **Impaired Streams Addressed**



AUID	Name	Miles	Report ID
07010104-679	Unnamed Creek	3.78	679
07010104-659	Sisabagamah Creek	2.12	659

Figure 1-3. Biology Impaired Streams Addressed.



AUID	Name
77-0026-00	Moose
18-0155-00	Crow Wing
01-0123-00	Elm Island
77-0023-00	Big Swan
77-0009-00	Trace
18-0161-00	Sebie
18-0240-00	Fawn
18-0243-00	Lower Mission
01-0105-00	Fleming
01-0146-00	Ripple
01-0099-00	Gun

Figure 1-4. Nutrient Impaired Lakes Addressed

Nonpollutant stressors are not subject to load quantification and therefore do not require TMDLs. If a nonpollutant stressor is linked to a pollutant (e.g. habitat issues driven by TSS or low DO caused by excess P) a TMDL is required. However, in many cases habitat stressors are not linked to pollutants. Note that all aquatic life use impairments – not just those with associated TMDLs – are addressed in the WRAPS report.

Applicable standards for Class 2B and Class 2Bg waters from Minn. R. ch. 7050.0222 are summarized in Section 2. Class 3C-related water quality standards (chlorides, hardness, and pH) are not impaired and thus not addressed in this TMDL.

1.3 Priority Ranking

The MPCA's schedule for TMDL completions, as indicated on the 303(d) impaired waters list, reflects Minnesota's priority ranking of this TMDL. MPCA has aligned our TMDL priorities with the watershed approach and our WRAPS schedule. The MPCA developed a state plan to meet the needs of EPA's national measure (WQ-27) under the CWA Section 303(d) Program. As part of these efforts, the MPCA identified water-quality-impaired segments that will be addressed by TMDLs by 2022. The Mississippi-Brainerd Area Watershed waters addressed by this TMDL are part of that MPCA prioritization plan to meet EPA's national measure.

2. Applicable Water Quality Standards and Numeric Water Quality Targets

The Mississippi-Brainerd Area Watershed is located within the North Central Hardwood Forests (NCHF) ecoregion, which covers the southern one-third of the watershed, and the NLF ecoregion, which covers the northern two-thirds of the watershed. For the recently adopted river nutrient standards and TSS standards, the Mississippi-Brainerd Watershed is in the North and Central River Nutrient Regions.

2.1 *E. coli* Bacteria

The Minnesota water quality rules from Minn. R. ch. 7050.0222 state that *E. coli* bacteria is "not to exceed 126 organisms per 100 milliliters (mL) as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than 10% of all samples taken during any calendar month individually exceed 1,260 organisms per 100 mL. The standard applies only between April 1 and October 31."

2.2 Aquatic Macroinvertebrate Bioassessments

The Guidance Manual for Assessing the Quality of Minnesota Surface Waters [MPCA 2018b] states that "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 the aquatic community, or biological monitoring, is therefore a relatively direct way to assess aquatic life use-support. Interpreting aquatic community data is accomplished using an index of biological integrity or IBI. The IBI incorporates multiple attributes of the aquatic community, called "metrics," to evaluate a complex biological system." Once a waterbody is identified as having an impaired aquatic community, a stressor identification process is completed. For stressor identification, factors including temperature, DO, eutrophication, TSS, connectivity, specific conductance, pH, and pesticides are evaluated to determine the most probable cause of the impairment.

Minnesota's biological criteria are based on the prevention of "material alteration of the species composition, material degradation of the stream beds, and the prevention or hindrance of the propagation and migration of fish and other biota normally present" (Minn. R. 7050.0150, subp. 6). The Mississippi-Brainerd Stressor Identification Report [MPCA 2019] provides detailed information on the fish and macroinvertebrate communities. For the Mississippi-Brainerd Area Watershed, the fish IBI (FIBI) scores were evaluated using the Northern Streams Class (Class 5), the Northern Headwaters Class (Class 6), and the Low Gradient Class (Class 7). The macroinvertebrate IBI (MIBI) scores were evaluated using the Northern Forest Stream Riffle Run (RR) Class (Class 3), the Northern Forest Streams Glide Pool (GP) Class (Class 4), and the Southern Forest Streams GP Class (Class 6). The thresholds and confidence intervals for the FIBI and MIBI are in Table 2-1. When IBI scores fall below the threshold, the stream is not supporting aquatic life and an assessment is completed to determine the stressor(s) to the biotic communities.

Table 2-1. Thresholds and Confidence Intervals for the FIBI and MIBI.

Class	Class Name	IBI Threshold	Upper CL	Lower CL
Fish Class 5	Northern Streams	50	59	41
Fish Class 6	Northern Headwaters	40	56	24
Fish Class 7	Low Gradient	40	50	30
Macroinvertebrate Class 3	Northern Forest Streams RR	50.3	62.9	37.7
Macroinvertebrate Class 4	Northern Forest Streams GP	52.4	66.0	33.2
Macroinvertebrate Class 6	Southern Forest Streams GP	46.3	60.4	33.2

Two reaches with impaired aquatic communities are being addressed in this TMDL. Sisabagamah Creek Reach 659 was in Macroinvertebrate Class 4 and had MIBI scores greater than the lower confidence level and less than the threshold (37.9 and 42.0). Fish were not evaluated in Sisabagamah Creek Reach 659. Stressors determined for Sisabagamah Creek Reach 659 include a lack of habitat caused by the flow alteration and the amount of sediment coming into the stream from stream bank instability and nonvegetated ditch banks. TSS is also a stressor to the macroinvertebrates in Sisabagamah Creek. Therefore, for the purposes of this TMDL, the newly adopted TSS standard of 15 mg/L TSS for the North River Nutrient Region will be used as a surrogate for the Reach 659 MIBI impairment. The assessment season for the TSS standard is April through September. Also, the unnamed tributary to Sand Creek Reach 679 was in Macroinvertebrate Class 4 and had MIBI scores less than the lower confidence limit (17.3 and 19.9). Fish were evaluated to Fish Class 7 in the unnamed tributary to Sand Creek and the fish IBI score was above the upper confidence limit (69). Stressors determined for unnamed tributary to Sand Creek Reach 679 include elevated nutrients and low DO. Direct runoff from three cattle pastures located upstream are impacting the nutrient and DO concentrations, and the recently adopted regional stream-nutrient standards (listed in Table 2-2) will be used as a surrogate for the Reach 679 MIBI impairment. River nutrient regions were defined by the MPCA using ecoregions, and the unnamed tributary to Sand Creek Reach 679 watershed is in the North River Nutrient Region of Minnesota. Eutrophication standards for rivers and streams are compared to summer average data. Exceedance of the total phosphorus (TP) levels and Chl-*a* (seston), BOD_5, diel DO flux, or pH levels is required to indicate a polluted condition. For rivers and streams, the response variables (chlorophyll-a, diel DO, BOD5, and pH) will need to be met. Clear relationships between the TP and the response variables have been established, and it is expected that by meeting the P target, the response variables shown in Table 2-2 will also be met. When the TP standard and the response variables are met, it is expected that the aquatic macroinvertebrate condition should improve to acceptable levels. Minn. R. ch. 7050.0222 defines “summer average” as a representative average of concentrations or measurements of nutrient-enrichment factors, taken over one summer season; "summer season" is subsequently defined as a period annually from June 1 through September 30. Future evaluations to determine if MIBI improvements will occur should be based upon MIBI thresholds used in the Stressor ID Report [MPCA 2019].

Table 2-2. River Nutrient Region Standards.

River Nutrient Region Name	Total Phosphorus (ug/L)	Chlorophyll-*a* (ug/L)	Dissolved Oxygen Flux (mg/L)	5-Day Biochemical Oxygen Demand (mg/L)	pH
North (2B)	≤ 50	≤ 7	≤ 3.0	≤ 1.5	6.5-9.0
Central (2B)	≤ 100	≤ 18	≤ 3.5	≤ 2.0	6.5-9.0
Southern (2B)	≤ 150	≤ 40	≤ 5.0	≤ 3.5	6.5-9.0

ppb = parts per billion
ppm = parts per million.

2.3 Nutrients (Phosphorus)

The Mississippi-Brainerd TMDL lakes described herein have been assigned beneficial use classifications of 2B and 3C. By Minnesota rules, Class 2 waters shall support “the propagation and maintenance of a healthy community of cool or warm-water sport or commercial fish and associated aquatic life, as well as their habitats. These waters shall be suitable for aquatic recreation of all kinds….” Beneficial use Class 3 corresponds to industrial consumption Minn. R. ch. 7050.0223. Applicable lake eutrophication standards for the NLF and the NCHF ecoregions are listed in Table 2-3.

Table 2-3. Lake Nutrient/Eutrophication Standards for Lakes, Shallow Lakes, and Reservoirs in the NCHF Ecoregion as Specified in Minn. R. ch. 7050.0222.

Ecoregion	Lake Type	Total Phosphorus (ppb)	Chlorophyll-*a* (ppb)	Secchi Depth (m)
NCHF	Deep	≤ 40	≤ 14	≥ 1.4 m
	Shallow	≤ 60	≤ 20	≥ 1.0 m
NLF	All	≤ 30	≤ 9	≥ 2.0 m

ppb = parts per billion
m = meters

For a lake to be classified as impaired, summer-average TP concentrations measured in the waterbody must exceed the TP standard shown in Table 2-3 from Minn. R. ch. 7050.0222 and exceed one or both of the eutrophication response standards for Chl-*a* and Secchi disk transparency (Secchi). “Summer average” is defined as a representative average of concentrations or measurements of nutrient-enrichment factors, taken over one summer season; "summer season" is subsequently defined as a period annually from June 1 through September 30. In developing the lake nutrient standards for Minnesota lakes, the MPCA evaluated data from a large cross-section of lakes within each of the state’s ecoregions [MPCA 2005]. Clear relationships were established between the causal factor TP and the response variables Chl-*a*, Secchi, or Secchi disc depth (SDD). Based on these relationships, the Chl-*a* and Secchi standards are expected to be met by meeting the TP target in each lake.

3. Watershed and Waterbody Characterization

3.1 Historical/Legacy Perspectives

Much of the Mississippi-Brainerd Area Watershed's development occurred after the railroad was established in 1881. Lumber, paper, and agriculture were the primary early industries in the watershed. The first paper mill in the city of Brainerd was built in 1903. In addition to the paper industry, the service industry has been steadily increasing since the early 20th century as tourism has increased. Because there are many pristine lakes in the area, lands surrounding the city of Brainerd have become popular summer vacation destinations. One peat mine was introduced in the watershed in 1976. The peat mine has changed ownership but is still being operated in the watershed. Additionally, open-pit mining for iron ore occurred on the Cuyuna Range, which primarily lies in Crow Wing County. Mining of the Cuyuna Range began in about 1910, and all mines were closed before 1970.

3.2 Demographic Growth Projections

According to demographic projections from the Minnesota State Demographic Center [Dayton 2014], the population will increase by approximately 8% in the Mississippi-Brainerd Watershed between 2015 and 2045. This is a watershed-weighted population growth projection for Aitkin, Crow Wing, Morrison, and Todd Counties.

3.3 Climate

Basic climate data were reviewed to (1) define typical seasonal and annual cycles that affect runoff and water quality, (2) identify wet and dry patterns that affect pollutant loading dynamics, (3) assist in implementing design considerations, and (4) help inform future performance-monitoring efforts. Included in this assessment are typical monthly temperature and precipitation information (normals), annual precipitation, frost-free season lengths, dry and wet periods, and average summer temperatures. Climate variability for the Mississippi-Brainerd Area Watershed was assessed by using available long-term site data from the Midwest Regional Climate Center, gridded precipitation data from the DNR, and database summaries of National Oceanic and Atmospheric Administration's (NOAA) data for east-central Minnesota (Climate Division 6). Few monitoring stations with long-term climate data exist across the Mississippi-Brainerd Area Watershed; hence, interpolated data from the DNR's gridded precipitation network and the NOAA's Climate Division data were evaluated. The monthly normals for Brainerd, Minnesota (USC00210939), and Aitkin 2E, Minnesota (USC00210059) are presented as monthly average precipitation amounts in Figure 3-1, and as maximum, average, and minimum temperatures for the 1981 through 2010 period in Figure 3-2. The monthly normal plots use calculated values that are determined every 10 years by the National Centers for Environmental Information [Peake 2018]. A NOAA plot of average growing season temperatures, as depicted in Figure 3-3, shows a trend of temperature increases.

Via the DNR's gridded precipitation network, the variability of annual precipitation across the watershed from 1970 through 2016 was examined by using representative sites for the central portion of the watershed (Brainerd) and the eastern portion of the watershed (Aitkin), as shown in Figure 3-4.

Figure 3-1. Observed Monthly Climate Normals for Brainerd, Minnesota (USC00210939) From 1981 to 2010 [Midwestern Regional Climate Center 2018]

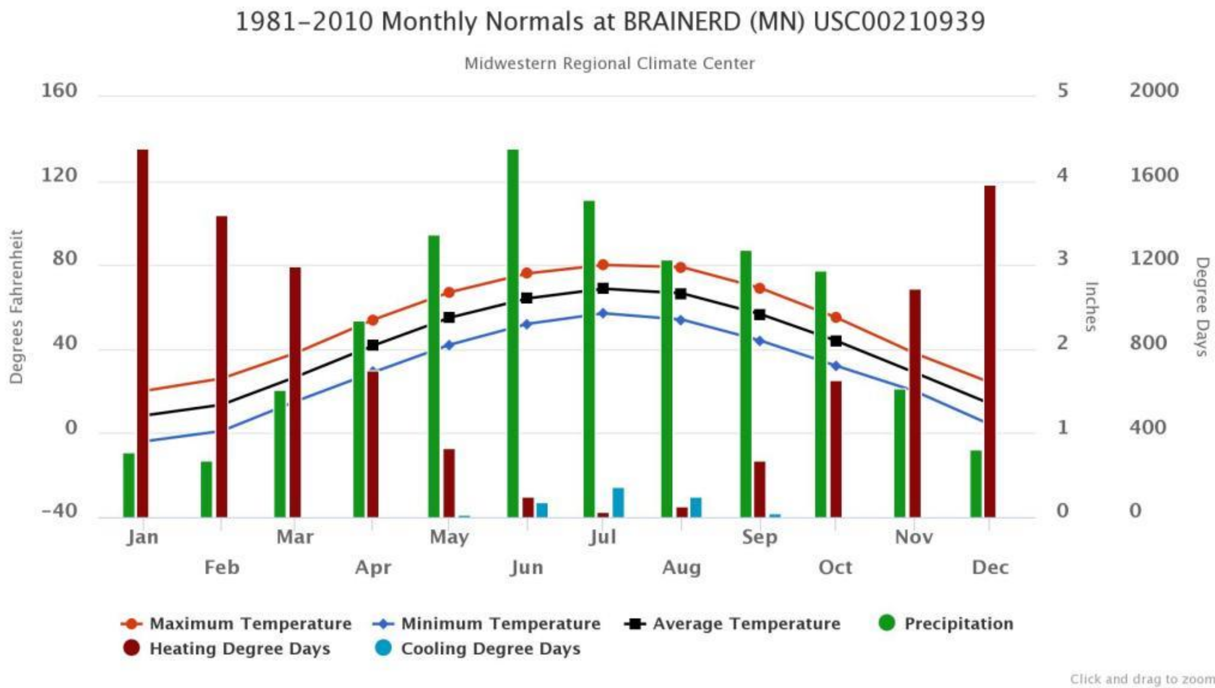
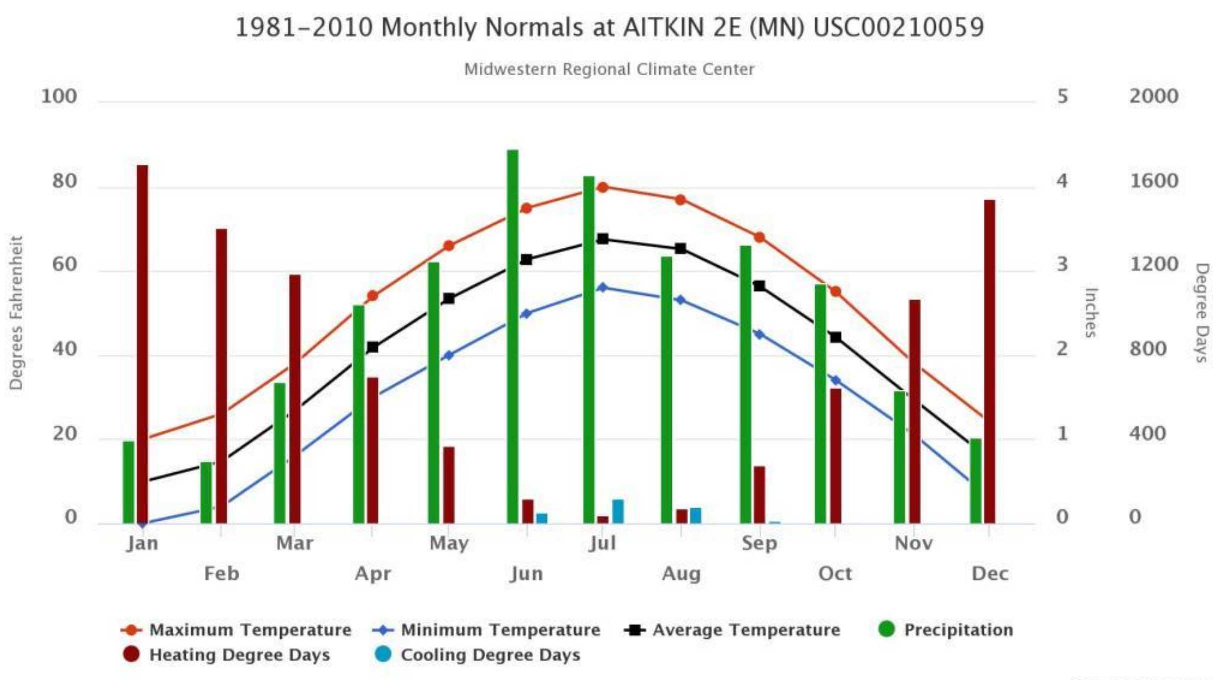


Figure 3-2. Observed Monthly Climate Normals for Aitkin 2E, Minnesota (USC00210059) From 1981 to 2010 [Midwestern Regional Climate Center 2018]



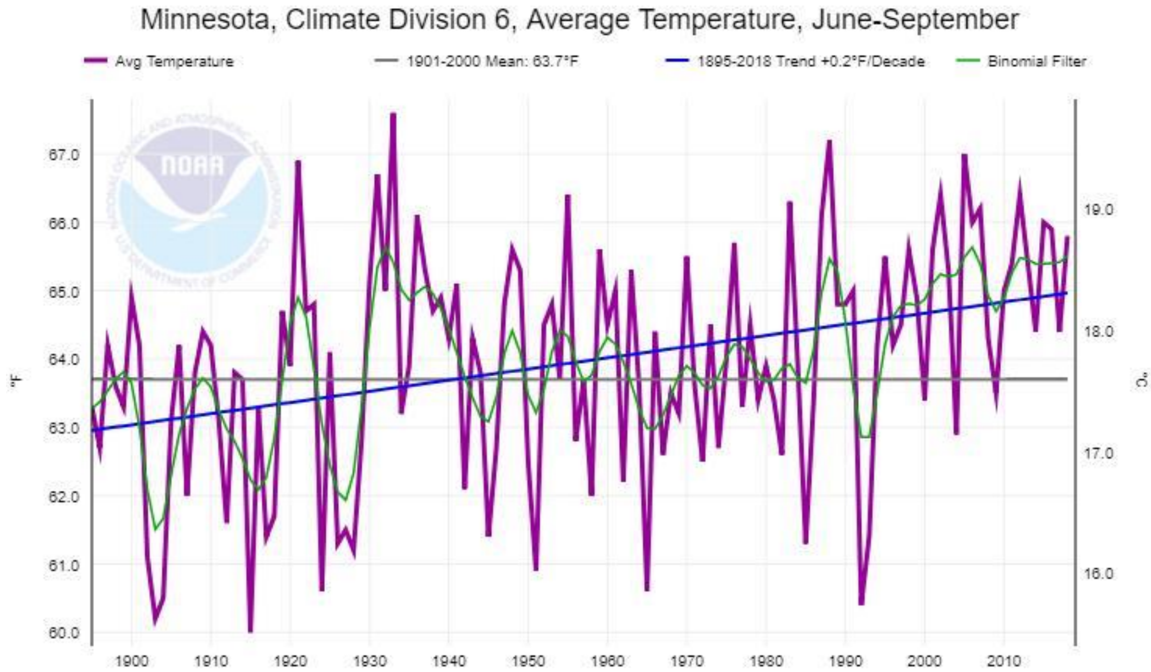


Figure 3-3. Growing Season (June–September) Temperature for 1895–2018 for Minnesota Climate Division 6 [NOAA 2018a]

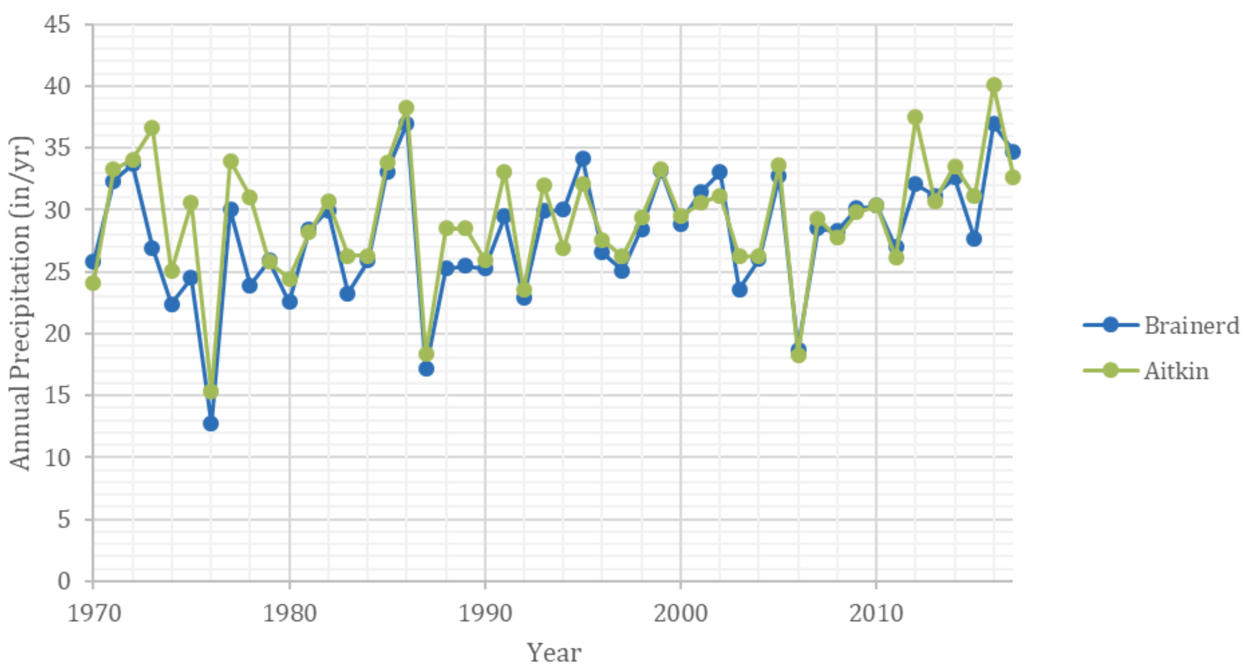


Figure 3-4. Comparison of Annual Precipitation (Inches) for Representative Sites of the Central (Brainerd) and Eastern (Aitkin) of the Mississippi-Brainerd Watershed [DNR 2018a]

Annual precipitation has ranged from approximately 13 inches in Brainerd in 1976 to approximately 40 inches in Aitkin in 2016 across the watershed, with similar annual precipitation patterns for both locations, and generally lower annual totals for Brainerd. Over the TMDL time period (2006 through 2015), the annual precipitation average for the two sites was approximately 29 inches. These generalized average values differ from the more intensive precipitation station data from 1995 to 2015 that were used in developing the HSPF model for the Mississippi-Brainerd Watershed.

A long-term overview (1895 through 2017) of annual precipitation variation and trends for Climate Division 6 that covers east central Minnesota is depicted in Figure 3-5 from NOAA's National Centers for Environmental Information [NOAA 2018a]. Using the smoothed time-series and rolling-averaged plots facilitates observation of longer periods of wet and dry precipitation patterns. From this data, considerable year-to-year variability in annual precipitation is evident with a rolling pattern of multiyear averages noted by the smoothed binomial filter represented by the red line. A variable but generally increasing pattern of annual precipitation was noted since approximately 1990, particularly for the most recent years that encompasses the TMDL report period (2006 through 2015).

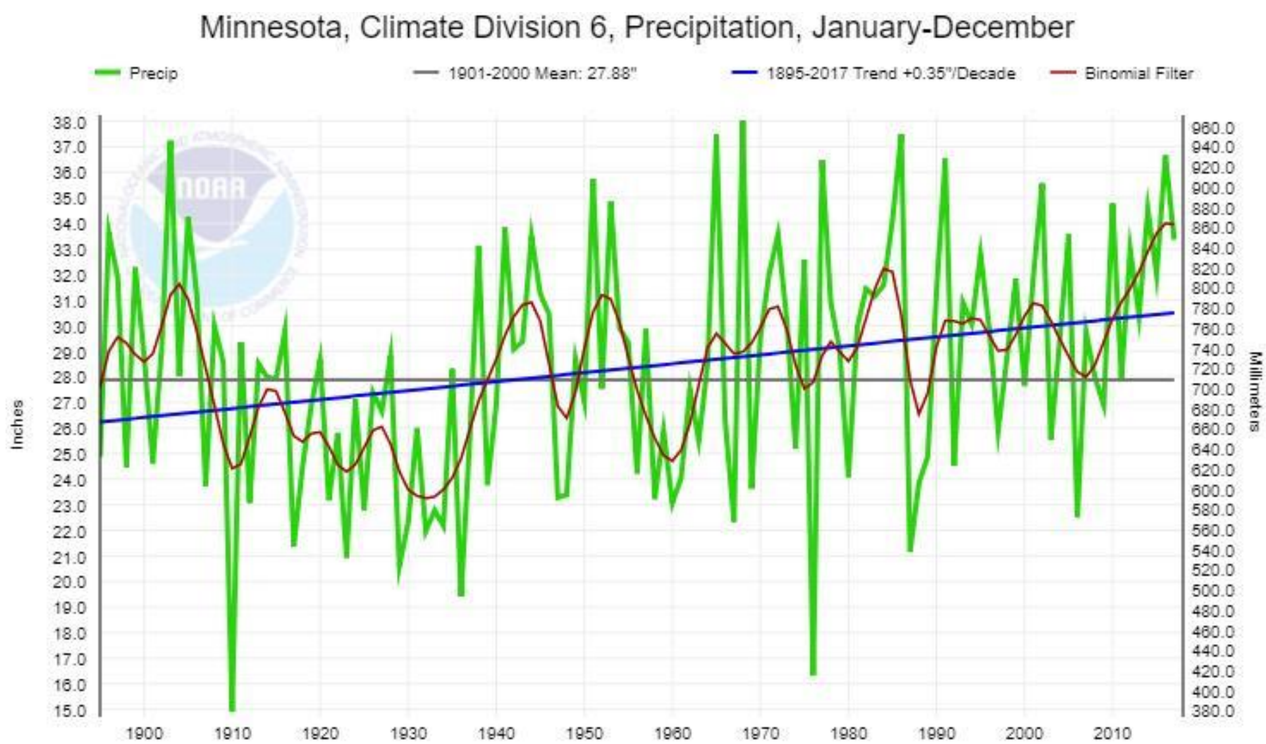


Figure 3-5. Annual precipitation for 1895–2018 from NOAA [2018a] for Minnesota Climate Division 6

Focusing on summer precipitation patterns, a similar NOAA plot for June through September is again presented for Climate Division 6 (east central Minnesota) in Figure 3-6. In this figure, a long-term increase in growing-season precipitation was evident but more muted than noted for annual precipitation and was also quite variable. Over the TMDL period (2006 through 2015), growing season precipitation ranged from 11.25 inches to 21.55 inches, with an average of 14.09 inches.

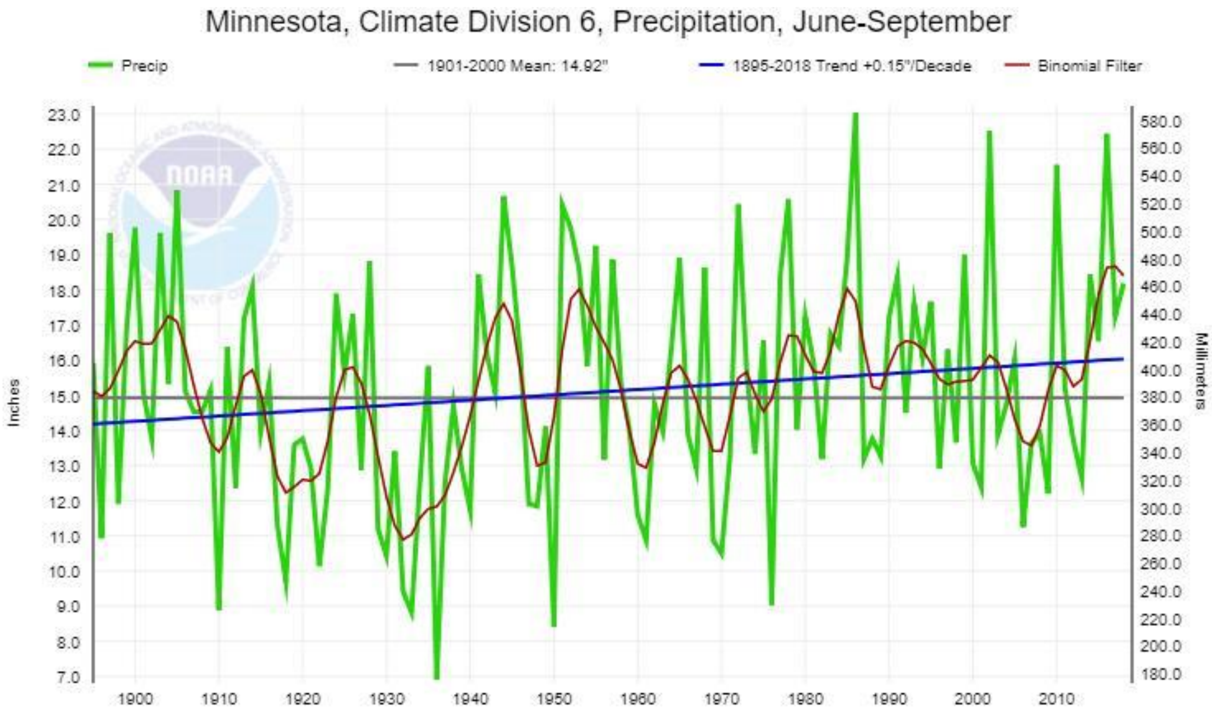


Figure 3-6. Growing Season (June–September) Precipitation for 1895–2018 from NOAA [2018a] for Minnesota Climate Division 6

3.3.1 Characterization of Storm Events

NOAA, in cooperation with the MPCA, DNR State Climatology Office, and the Minnesota Department of Transportation (MnDOT), recently updated precipitation intensity and duration records for the entire state, which are referred to as Atlas 14. Storm event totals, such as those reported in various media weather reports, are typically for 24-hour periods that have been summarized from data reported for stations representative of the central (Brainerd) and eastern (Aitkin) areas of the Mississippi-Brainerd Area Watershed. A comparison of these 24-hour storm records in the watershed is tabulated in Table 3-1 with increases in storm amounts noted across all recurrence intervals (1/1 year to 1/1,000 year occurrence). An average recurrence interval of 1 year has a 100% chance of occurring every year, while an average recurrence interval of 1,000 years has a 0.1% chance of occurring every year. Back-to-back storms over several days often generate much larger totals associated with peak runoff events; therefore, frequencies of 10-day wet-period storms were summarized in Table 3-2. Ten-day wet period precipitation amounts were noted to range from approximately 4.17 inches (annually) to 13.8 inches (1,000 year), with higher storm amounts in the east. From a flooding perspective, wet periods can have large cumulative storm totals that affect watershed runoff, agricultural producers, public safety, and pollutant loading.

Table 3-1. Atlas 14 Summaries of 24-hour Precipitation Amounts (Inches) for Two Representative Mississippi-Brainerd Watershed Locations [NOAA 2018b].

24-Hour Storms Depth (inches)	Average Recurrence Interval (years)	1	2	5	10	25	50	100	200	500	1,000
	Chance of Occurrence (%)	100%	50%	20%	10%	4%	2%	1%	0.5%	0.2%	0.1%
Location	Brainerd	2.29	2.65	3.30	3.88	4.75	5.49	6.27	7.11	8.30	9.26
	Aitkin	2.36	2.73	3.39	3.98	4.85	5.57	6.34	7.16	8.31	9.24

Table 3-2. Atlas 14 Summaries of Frequencies of 10-Day Wet Period Storms [NOAA 2018b].

10-Day Wet Period Depth (inches)	Average Recurrence Interval (years)	1	2	5	10	25	50	100	200	500	1,000
	Chance of Occurrence (%)	100%	50%	20%	10%	4%	2%	1%	0.5%	0.2%	0.1%
Location	Brainerd	4.17	4.67	5.55	6.34	7.51	8.48	9.51	10.6	12.2	13.5
	Aitkin	4.33	4.93	5.94	6.81	8.05	9.05	10.1	11.2	12.7	13.8

3.3.2 Precipitation Variability: Wet and Dry Periods

A closer examination of year-to-year and month-to-month precipitation variability is made possible by using synthetic data from the DNR's *Monthly Precipitation Data from a Gridded Database* [DNR 2018a]. Data were summarized by month and year and are presented in Table 3-3 for East Baxter Township, near Brainerd, in Crow Wing County, Minnesota. In this evaluation, the wet months (greater than 70th percentile months) were color-coded blue, and the dry months (less than 30th percentile months) were color-coded red. The in-between values (normal) are color-coded green. From 2006 through 2017, seven years have been wet (e.g., precipitation greater than 70th percentile), four have been normal, and one has been dry (precipitation less than 30th percentile). Peak spring (April and May) and June precipitation events are of particular note for their potential to generate stormwater runoff from fertilized fields, and to grow crops with undeveloped canopies and urban conveyance systems, just before the peak growing season. The data from 2006 to 2017 also show many substantial rotations between wet (blue) and dry (red) monthly precipitation amounts. Higher precipitation amounts that occur during July and August, which feature established vegetative canopies and higher evaporative losses, may not have peak runoff unless they are caused by extreme events and wet periods from back-to-back storm systems.

Table 3-3. Monthly Precipitation by Year (2006–2017) for East Baxter Township, Brainerd, Minnesota [DNR 2018a].

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Period-of-Record Summary Statistics													
30%	0.37	0.33	0.67	1.46	2.25	2.99	2.54	2.17	1.89	1.14	0.63	0.41	23.53
70%	0.86	0.85	1.59	2.59	4.15	5.24	4.35	4.51	3.31	2.87	1.37	1.00	28.73
mean	0.69	0.68	1.23	2.14	3.33	4.21	3.69	3.52	2.71	2.15	1.20	0.73	26.31
1981–2010 Normals													
normal	0.75	0.65	1.48	2.28	3.29	4.38	3.86	3.15	3.20	2.82	1.41	0.81	28.08
Year-to-Year Data													
2017	0.87	1.06	0.36	3.24	3.73	3.73	3.17	8.40	5.67	3.30	0.42	0.78	34.73
2016	0.59	0.51	1.61	2.75	2.63	3.62	10.94	5.48	3.76	1.52	2.21	1.32	36.94
2015	0.14	0.32	0.55	1.23	5.68	2.16	2.97	3.73	3.78	2.96	2.87	1.26	27.65
2014	0.73	1.19	1.01	3.89	4.96	5.79	2.48	6.63	3.39	0.82	1.23	0.53	32.65
2013	0.58	1.14	2.38	2.89	4.19	5.60	3.43	1.03	3.94	4.05	0.14	1.77	31.14
2012	0.50	0.54	1.77	3.57	8.66	6.64	4.75	1.88	0.51	0.99	0.91	1.35	32.07
2011	0.91	0.47	1.58	2.19	5.17	3.09	6.52	4.64	0.74	1.15	0.33	0.22	27.01
2010	0.65	0.42	0.93	1.05	3.43	4.17	5.60	4.52	3.13	3.85	1.01	1.57	30.33
2009	0.38	1.09	3.54	1.02	1.28	3.62	6.18	2.86	0.89	6.63	1.05	1.58	30.12
2008	0.04	0.37	0.77	3.56	2.72	5.18	3.69	1.01	3.89	4.23	1.16	1.67	28.29
2007	0.25	1.25	2.83	3.04	3.29	2.59	1.78	2.07	4.70	5.25	0.15	1.31	28.51
2006	0.30	0.57	0.74	2.16	2.48	2.12	2.17	2.72	1.90	1.80	0.66	1.11	18.73

Note: October 8, 2018.

Blue values = wet (or greater than 70th percentile)

Green values = mid-range (30th–70th percentile)

Red values = dry (or less than 30th percentile)

3.3.3 Frost-Free Season Length

Along with patterns of average summer ambient temperatures, variations of the frost-free season length were also examined. The frost-free season, as defined by the number of days between the last 32°F day of spring and the first 32°F day of autumn, is plotted for Brainerd, Minnesota (USC00210939) in Figure 3-7. While the Brainerd dataset was limited because of missing data, the long-term pattern generally indicates increasing frost-free periods.

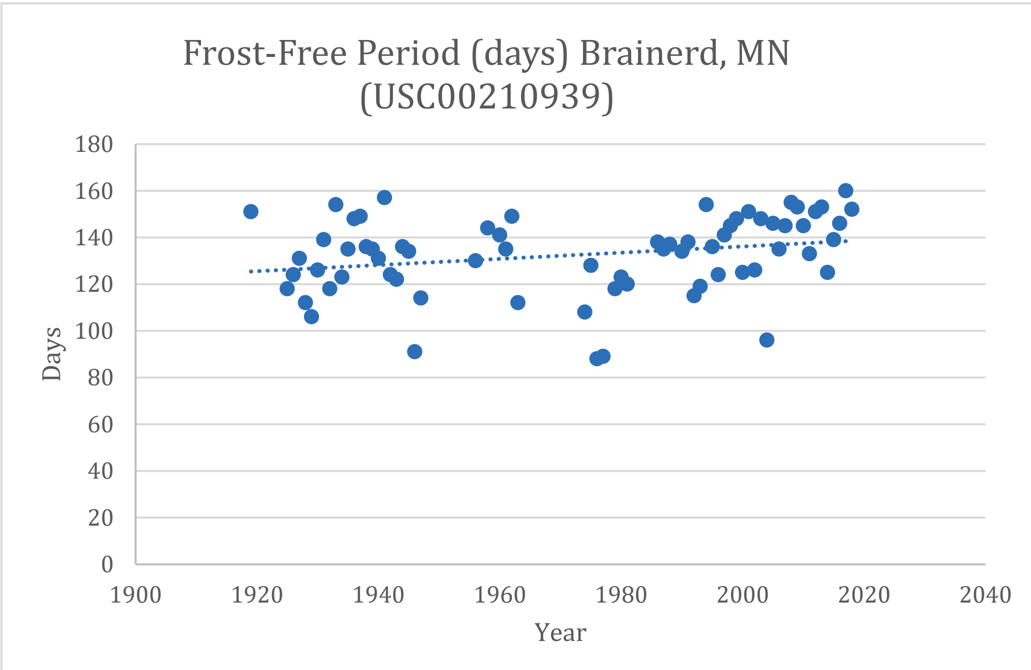


Figure 3-7. Frost-Free Period (Days) in Brainerd, Minnesota

3.3.4 Evaporation

Free water surface evaporation is approximately 31 inches per year (in/yr) in the project area [Farnsworth and Thompson 1982].

3.3.5 Climate Summary

Subtle west-to-east gradients in storm-precipitation intensities and durations, annual precipitation, evaporation, and frost-free periods were noted across the Mississippi-Brainerd Watershed, with higher levels in the south. Growing season runoff can be expected to be affected by wide variations in month-to-month rainfall amounts, increasing average temperatures, and storm intensities. Storm precipitation intensities for the typical 24-hour storm and multiday wet periods can be substantial, with potential wide-ranging impacts that affect communities, agricultural producers, streams, wetlands, and associated aquatic habitats. Collectively, these basic climate and hydrologic cycle components vary considerably from year to year and from season to season, which potentially results in wide ranges of watershed runoff and of the associated runoff-pollutant dynamics. This should be factored into the design of future restoration/protection and monitoring programs.

3.4 Watershed Characteristics

3.4.1 Subwatersheds

Assessment Unit Identification (AUID), length, and drainage area for the impaired reaches addressed in this TMDL are presented in Table 3-4.

Table 3-4. Impaired Reach Lengths, Locations, and Watershed Drainage Areas.

Impaired Reach	AUID No.	Reach Description	Impairment Cause	Length (miles)	Drainage Area (acres)
Swan River	502	Headwaters (Big Swan Lake 77-0023-00) to Mississippi River	*E. coli*	36.68	115,427
Little Elk River	521	T129 R30W S1, north line to Mississippi River	*E. coli*	1.02	80,568
Pike Creek	522	T129 R30W S21, west line to Mississippi River	*E. coli*	7.2	28,307
Unnamed Creek	626	Headwaters to Big Swan Lake	*E. coli*	3.53	1,933
Schwanke Creek	627	Unnamed creek to Big Swan Lake	*E. coli*	1.77	5,642
Unnamed Creek	629	Long Lake (77-0027-00) to Big Swan Lake	*E. coli*	1.32	7,384
Hay Creek	645	Headwaters to Grave Lake	*E. coli*	5.58	7,688
Sisabagamah Creek	659	Unnamed creek to Mississippi River	Macroinvertebrates	2.12	28,393
Unnamed Creek	679	Headwaters to Sand Creek	Macroinvertebrates	3.78	5,493
Buffalo Creek (Little Buffalo Creek)	695	Wright Stream to Mississippi River	*E. coli*	2.43	4,196

3.4.2 Land Cover

Because land use is an important factor that affects runoff quantity and quality, the most current land cover data (2013) were used in developing the HSPF model for the Mississippi-Brainerd Area Watershed and each of the TMDLs described herein. Land cover data layers, as defined by the University of Minnesota Remote Sensing and Geospatial Analysis Laboratory [University of Minnesota 2018], were employed for this study and were based on a 15-meter raster dataset of land cover and impervious surface classifications for 2013. The land cover classifications were created by using a combination of multi-temporal Landsat 8 satellite remote-sensing data and Light Detection and Ranging (LiDAR) remote-sensing data with object-based image analysis [University of Minnesota 2018]. Thus, land surface and vegetation heights were used to discern vegetation cover types, which improved the accuracy of classification.

Figure 3-8 shows the land cover types determined through this process for the Mississippi-Brainerd Area Watershed. Those consist of forest (36%), wetlands (24%), grassland (10%), row crops (10%), pasture (8%), open water (6%), and developed (6%). Summary land covers for impaired streams are listed in Table 3-5 and summary land covers for impaired lakes are listed in Table 3-6. The northeast two-thirds of the Mississippi-Brainerd Area Watershed is in the NLF ecoregion, which features generally better water quality because of the higher percentages of forests, lakes, and wetlands in the region. The southwest one-third of the watershed is in the NCHF ecoregion, with higher percentages of row crops, pasture, and animal feeding operations.

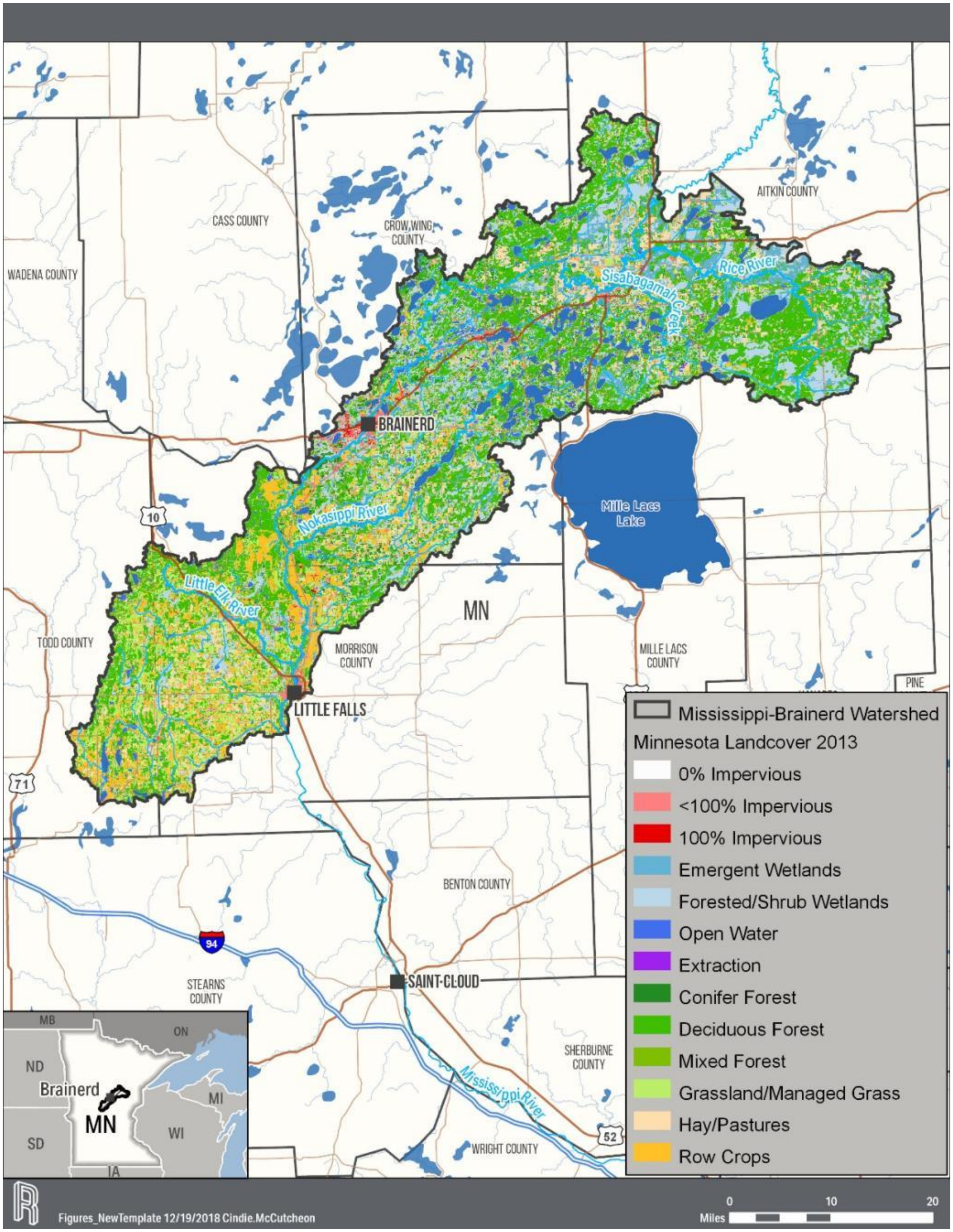


Figure 3-8. Land Cover [University of Minnesota 2018]

Table 3-5. Land Cover Distribution by Impaired Stream.

Name	ID	Drainage Area (Sq. Miles)	Developed (%)	Wetlands (%)	Open Water (%)	Forest (%)	Grassland (%)	Hay/ Pastures (%)	Row Crops (%)
Swan River	502	180.4	6.1	6.1	3.8	27.0	25.3	11.9	19.8
Little Elk River	521	125.9	6.2	11.2	2.0	32.2	22.4	8.5	7.6
Pike Creek	522	44.2	7.6	10.2	0.3	18.9	28.0	17.0	18.1
Unnamed Creek	626	3.0	7.1	0.4	0.6	21.7	27.7	12.6	29.8
Schwanke Creek	627	8.8	5.8	8.4	0.2	15.8	20.4	13.9	35.5
Unnamed Creek	629	11.5	8.7	2.3	13.0	27.6	17.2	7.2	24.0
Hay Creek	645	12.0	4.1	32.5	0.8	41.3	7.4	4.1	9.8
Sisabagamah Creek	659	44.4	6.1	31.4	6.0	31.6	5.6	15.3	3.9
Unnamed Creek	679	8.6	4.0	35.9	2.4	30.8	7.2	10.0	9.7
Little Buffalo Creek	695	6.6	20.5	26.8	0.1	27.1	9.8	8.9	6.9

Table 3-6. Land Cover Distribution by Impaired Lake.

Name	ID	Drainage Area (Sq. Miles)	Developed (%)	Open Water (%)	Wetlands (%)	Forest (%)	Grassland (%)	Hay/ Pastures (%)	Row Crops (%)
Big Swan	77-0023-00	34.8	7.2	5.1	11.5	20.4	18.3	8.8	28.7
Crow Wing	18-0155-00	16.9	8.7	29.9	4.0	39.1	6.8	2.2	9.3
Elm Island	01-0123-00	96.4	5.3	26.8	16.8	38.8	5.5	4.7	2.0
Fawn	18-0240-00	3.9	4.2	34.7	21.2	26.7	5.6	0.1	7.6
Fleming	01-0105-00	7.2	4.3	22.8	14.7	40.9	3.6	10.1	3.3
Gun	01-0099-00	14.9	4.6	55.5	8.6	14.4	1.0	12.3	3.5
Lower Mission	18-0243-00	18.1	5.8	25.2	21.8	40.5	4.1	0.4	2.3
Moose	77-0026-00	1.6	7.8	1.5	13.9	18.2	19.0	9.0	30.7
Ripple	01-0146-00	103.8	5.5	26.2	17.2	38.4	5.4	5.1	1.9
Sebie	18-0161-00	29.8	4.6	17.8	2.7	38.3	15.1	7.1	14.4
Trace	77-0009-00	1.3	11.3	14.6	30.6	1.9	5.6	6.8	29.2

3.4.3 Soils

Watershed soils and their distributions are important factors to consider. Soil types can significantly affect runoff and its quality from differences in particle sizes, nutrients, interflow, and infiltration/groundwater recharge. The project area consists of approximately 69% hydrologic soil groups (HSG) A or A/D soils, 15% HSG B or B/D soils, and 16% HSG C or C/D soils (Figure 3-9). Dual-HSG-classification soils (notably HSG A/D and B/D soils) behave as HSG D soils when undrained. The HSGs, as defined by the Natural Resource Center of the U.S. Department of Agriculture, are summarized in Table 3-7. The distribution of the different land covers, soil types, and aquatic ecoregions are foundational aspects affecting (1) runoff quantity and quality and (2) future implementation of stormwater treatments within the Mississippi-Brainerd Area Watershed.

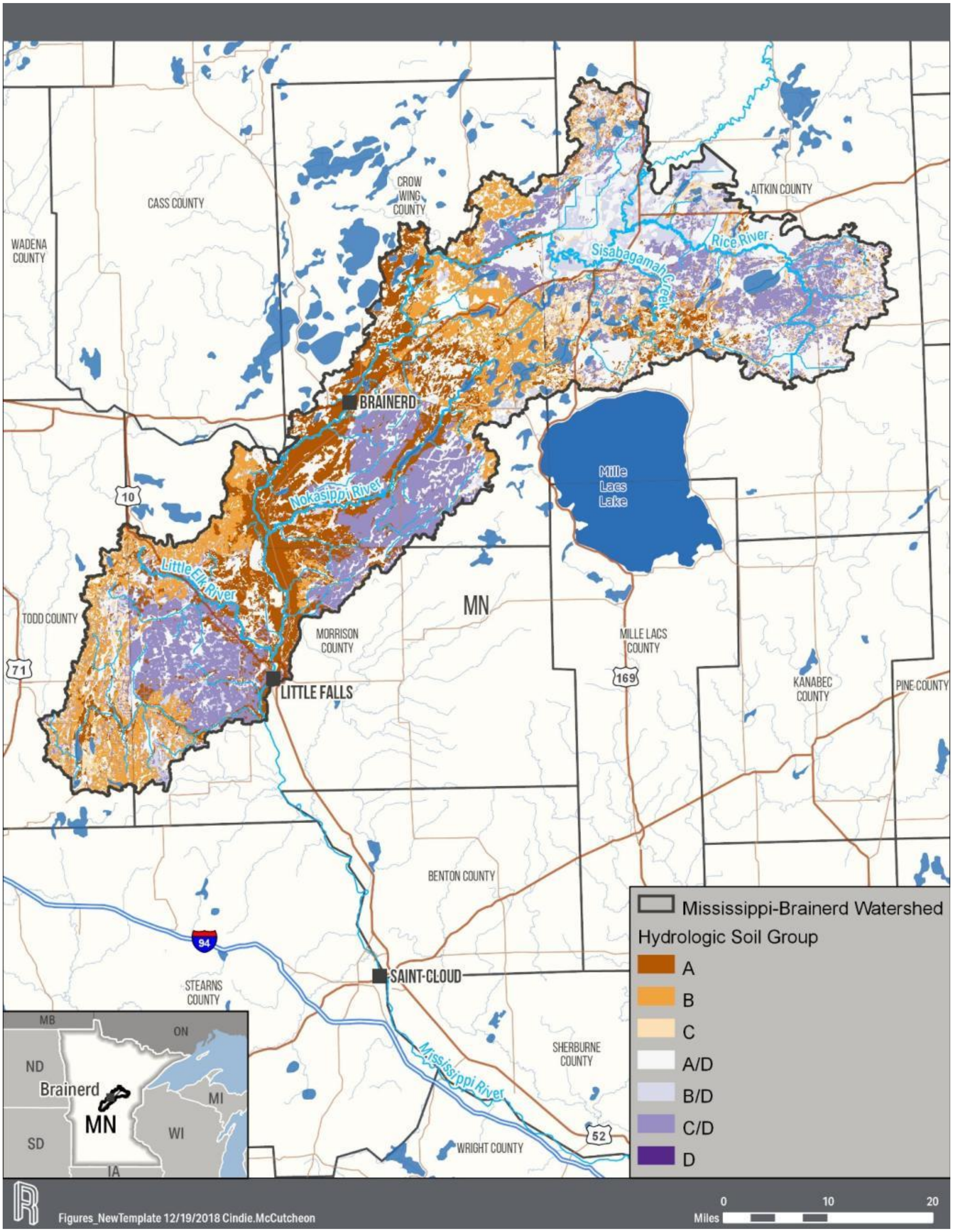


Figure 3-9. Hydrologic Soil Groups

Table 3-7. General Description of Hydrologic Soil Groups [NRCS 2009].

Hydrologic Soil Group	Abbreviated Description
A Soils	Sand, sandy loams with high infiltration rates. Well-drained soils with high transmission.
B Soils	Silt loam or loam soils. Moderate infiltration, moderately drained.
C Soils	Sandy clay loams. Low infiltration rates, impedes water transmission.
D soils	Heavy soils, clay loams, silty, clay. Low infiltration rates that impede water transmission.
Dual soils A/C and B/D	Dual HSG classification soils (notably A/D and B/D) behave as type D soils when undrained.

3.4.4 Lake Characteristics

3.4.4.1 Lake Eutrophication and Physical Characteristics

Minnesota's lake nutrient standards were developed in phases over three decades of monitoring a large cross-section of lakes and lake types in Minnesota's aquatic ecoregions [Heiskary and Wilson 2005]. Distinct relationships were established between the causal factor (TP) and the response variables Chl-*a* and Secchi transparency. TP has often been found to be the limiting factor in freshwater lakes. As lake P concentrations increase, algal abundance increases, thereby resulting in higher Chl-*a* concentrations and reduced lake transparency. Based on these relationships, the Chl-*a* and Secchi standards are expected to be met by meeting the P target for each lake.

Supporting these standards are the following definitions pertinent to the Mississippi-Brainerd Area Watershed Lake TMDLs:

- M. "Lake" means an enclosed basin filled or partially filled with standing fresh water with a maximum depth greater than 15 feet. Lakes may have no inlet or outlet, an inlet or outlet, or both an inlet and outlet.
- W. "Reservoir" means a body of water in a natural or artificial basin or watercourse where the outlet or flow is artificially controlled by a structure such as a dam. Reservoirs are distinguished from river systems by having a hydraulic residence time of at least 14 days. For purposes of this item, residence time is determined using a flow equal to the 122Q10 for the months of June through September.
- CC. "Shallow lake" means an enclosed basin filled or partially filled with standing fresh water with a maximum depth of 15 feet or less or with 80% or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (the littoral zone). It is uncommon for shallow lakes to thermally stratify during the summer. The quality of shallow lakes will permit the propagation and maintenance of a healthy indigenous aquatic community and they will be suitable for boating and other forms of aquatic recreation for which they may be usable. Shallow lakes are differentiated from wetlands and lakes on a case-by-case basis. Wetlands are defined in Minn. R. 7050.0186, subp. 1a.

Minnesota's lake eutrophication standards for the NCHF ecoregion also factor in the effects of lake depth on water quality. Deep lakes that remain thermally stratified can be expected to have stable or declining surface water P concentrations over the summer growing season. While deep-lake sediments may go anoxic, sediment-generated P (e.g., internal loading) can be less susceptible to mixing into surface waters because of thermal stratification. Conversely, shallow lakes are more prone to wind-mixing events and may have widely fluctuating P concentrations as inflow P is mixed with resuspended organic matter and lake-sediment-generated P quantities. Because of the cumulative impacts of these factors, Minnesota's lake eutrophication standards for shallow lakes are higher than those for deeper lakes in terms of TP and Chl-*a* with reduced Secchi transparency.

For a lake to be determined impaired, measured summer-average lake TP concentrations must exceed the TP standard shown in Table 2-1 from Minn. R. ch. 7050.0222 as well as one or both of the eutrophication response standards for Chl-*a* and Secchi transparency. "Summer average" is defined as a representative average of concentrations or measurements of nutrient-enrichment factors taken over one summer season; "summer season" is subsequently defined as a period annually from June 1 through September 30.

Internal loading of P may be an important P source for lakes with temporary thermal stratification that form an anoxic layer near the sediments. This may allow a P release from the lake's sediments that can be periodically mixed into the surface waters and provide nutrients and light for algal growth. However, shallow, well-mixed or well-flushed lakes that maintain oxic conditions near the sediment-water interface over most of the summer may have lower internal loading rates [Nürnberg 1995]. Given these considerations, additional lake physical characteristics were assessed for the Mississippi-Brainerd Area Watershed TMDL lakes.

3.4.4.2 Lake Physical Characteristics

Hondzo and Stefan [1996] evaluated lake thermal stratification via a lake geometry ratio (GR) based on Equation 3-1. Lake GRs are used to classify lakes as (1) shallow (greater than 5.3), (2) medium (1.6 to 5.3), or (3) deep (0.9 to 1.6) [Hondzo and Stefan 1996].

$$\text{Lake Geometry Ratio} = \frac{A^{0.25}}{D_{\max}} \qquad (3\text{-}1)$$

where A is lake surface area (in square meters [m^2]) and $D_{\max}$ is maximum depth (in meters).

The Osgood Index [Osgood 1998] can also be used to characterize lakes by estimating the fraction of a lake's volume involved in mixing. The Osgood Index is defined as:

$$\text{Osgood Index} = \frac{D_{mean}}{\sqrt{A_{surface}}} \qquad (3\text{-}2)$$

where D_{mean} is the mean lake depth in meters, and $A_{surface}$ is the lake's surface area in square kilometers (km^2). Osgood Index values are used to categorize lakes as polymictic (less than four), intermediate (four to nine), or dimictic (greater than nine).

3.4.4.2 Shallow Lakes

Fleming Lake, Fawn Lake, and Trace Lake met the criteria to be defined as shallow lakes. However, Trace was the only lake assessed to the less-stringent shallow lake standards as there is no explicit shallow lake standard for the NLF ecoregion. Lake morphometric and watershed characteristics for lakes are noted in Table 3-8. Lake surface area was 253 acres in Trace with a maximum depth of approximately six feet. Trace has an estimated littoral area of 100%. Hence, Trace Lake was assessed as a shallow lake by definition. Lake surface area was 319 in Fleming Lake with a maximum depth of 15 feet with a littoral area of 99%. Fleming Lake was modeled as a shallow lake and was assessed to the NLF standard for all lakes. Lake surface area was 121 in Fawn Lake with a maximum depth of 24 feet with a littoral area of 89%. Fawn Lake was modeled as a shallow lake and was assessed to the NLF standard.

Corroborating evidence of shallow-lake classification was obtained by estimating lake GRs and Osgood Index values. Estimated lake GRs were 17.4 for Trace Lake and 7.4 for Fleming Lake, both of which are indicative of shallow-lake conditions (e.g., greater than a lake GR of 5.0). The calculated Osgood Index values were 1.3 in Trace Lake and 1.6 in Fleming Lake, which indicates the lake is polymictic, or well-mixed (e.g., values less than 4.0 Osgood Index value). Estimated lake GR for Fawn Lake was 3.6 and calculated Osgood Index value was 4.4. Unlike Fleming Lake and Trace Lake, these numbers do not indicate a polymictic or well-mixed lake but this is due to the deeper maximum depth of Fawn Lake. With a littoral area of 89%, Fawn Lake still meets the states definition of a shallow lake.

The ratios of total watershed area to lake surface area (Ws:Ao ratio) were calculated to be 3.2:1 for Trace Lake, 14.5:1 for Fleming Lake, and 20.8:1 for Fawn Lake. For comparison, the average NCHF Ws:Ao ratio for lakes used in developing the Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) aquatic ecoregion eutrophication assessment was 9.6:1 [Wilson and Walker 1989].

Reinforcing the nature of these large watersheds, average annual runoff volumes calculated from HSPF modeling for the 2006 through 2015 period were used to estimate water residence times, or the time to completely fill the lake. The water residence times for Trace Lake was 2.65 years, Fleming Lake was 0.94 years, and Fawn Lake was 0.62 years. The NCHF lakes used in developing MINLEAP had water residence times ranging from 1 to 30 years [Wilson and Walker 1989].

3.4.4.3 Deep Lakes

TMDL lakes assessed as deep lakes included Big Swan, Crow Wing, Elm Island, Gun, Lower Mission, Moose, Ripple, and Sebie lakes. Surface areas range from 131 acres (Moose Lake) to 947 acres (Big Swan Lake), and maximum depths ranging from approximately 24 feet in Fawn Lake to 45 feet in Big Swan Lake. Estimated lake GRs ranged from 3.1 (Gun Lake) to 5.0 (Elm Island Lake and Lower Mission Lake), which indicates medium lake depths (e.g., less than or equal to a lake GR of 5.0). Calculated Osgood Index values indicated that Moose, and Sebie lakes are intermediate lakes and the rest are polymictic, or well-mixed, with values less than or near 4.0 Osgood Index value.

The total Ws:Ao ratios were then calculated to indicate the relative size of the contributing watershed, with a large range being estimated (e.g., 7.6:1 in Big Swan Lake to 118.8:1 in Elm Island Lake). Again, for comparison, the average NCHF Ws:Ao ratio for lakes used in developing the MINLEAP aquatic ecoregion eutrophication assessment was 9.6:1 [Wilson and Walker 1989].

Runoff volumes calculated from HSPF modeling were used to estimate the lake water residence times (the time to completely fill the lake) that ranged from 0.15 years (Elm Island Lake) to 2.8 years

(Moose Lake). The NCHF lakes used to develop MINLEAP had water residence times that ranged from 1 to 30 years [Wilson and Walker 1989].

Table 3-8. Select TMDL Lake Morphometric and Watershed Characteristics.

Characteristic	Big Swan	Crow Wing	Elm Island	Fawn	Fleming	Gun	Lower Mission	Moose	Ripple	Sebie	Trace	Source
Lake Surface Area (acres)	947	379	520	121	319	712	732	131	630	185	253	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	404	210	389	108	314	292	452	50	295	117	256	DNR LakeFinder Fish Lake Surveys
Mean Depth (ft)	18.0	11.0	9.0	10**	6.0	18.0	11.5*	15**	13.4*	15**	4.4*	DNR LakeFinder Fish Lake Surveys, Calculated (*), or estimated from lake map (**)
Maximum Depth (ft)	45.0	26.0	25.0	24.0	15.0	44.0	27.0	26.0	39.0	27.0	6.0	DNR LakeFinder Fish Lake Surveys
Percent Lake Littoral Surface Area	43	55	75	89	99	41	62	38	47	63	100	Calculated
Drainage Area, Including Lake (acres)	22,265	10,818	61,713	2,512	4,630	9,537	11,594	997	66,408	19,074	819	HSPF Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	23.5	28.5	118.8	20.8	14.5	13.4	15.8	7.6	105.3	102.9	3.2	Calculated
Lake Volume (acre-feet)	14,510	4,638	5,088	1,207	2,570	8,720	8,438	1,961	8,456	2,780	1,122	Calculated
Lake Geometry Ratio	3.2	4.4	5.0	3.6	7.4	3.1	5.0	3.4	3.4	3.6	17.4	Calculated
Osgood Index	2.8	2.7	1.9	4.4	1.6	3.2	2.0	6.3	2.6	5.3	1.3	Calculated
Estimated Water Residence Time (days)	374.3	218.9	54.7	226.5	341.9	529.2	605.3	1,026.9	84.6	71.8	968.8	HSPF Model Application

3.5 Current/Historic Water Quality

3.5.1 Stream Flows

Throughout the project area, several county, regional, state, and federal entities have been actively involved in gathering and reporting stream and river discharge flow data. Six stations throughout the watershed have discharge data available from 1995 through 2015. This dataset was used for calibrating the Mississippi-Brainerd Area Watershed hydrology model, which was the foundation of the TMDLs addressed in this report. Table 3-9 summarizes available flow data by stream reach, years of data, and mean flows, and a map of flow stations is included in Appendix A.

Table 3-9. Locations Throughout the Mississippi-Brainerd Watershed with Flow Data Available From 1996 to 2015.

Site	Description	First Year Available	Final Year Available	Number of Days With Flow	Mean Flow (cfs)
10018001	Rice River near Kimberly, CR56	2007	2013	1,668	228
10015001	Mississippi River at Aitkin, MN	1995	2015	7,656	2,916
10082002	Mississippi River at Brainerd MN	1995	2015	7,676	3,589
10103001	Nokasippi River near Fort Ripley	2003	2015	3,534	100
10048001	Mississippi River near Fort Ripley	1995	2008	2,500	5,370
10067001	Little Elk River near Little Falls, CSAH13	2003	2007	1,208	53

3.5.2 Water Quality

Water quality data were downloaded from the MPCA Environmental Quality Information System database, and all analyses used in developing the stream TMDLs were based on the 10-year period from 2006 through 2015.

3.5.2.1 *E. coli*

E. coli data from 2006 through 2015 are summarized by stream reach in Table 3-10, which includes geometric mean concentrations by month for each impaired reach. Geometric means were above the 126 organisms per 100 milliliter (org/100 mL) standard for every reach during at least one month between April and October. Monthly samples are shown for *E. coli*-impaired reaches in Figures 3-10 through 3-17. A map of monitoring sites is included in Appendix A.

Table 3-10. Observed Monthly Geometric Mean *E. coli* Data Summary From 2006 Through 2015 Between April and October; Months with 5 or More Samples Are Shown in Bold.

Impaired Reach	Description	Month	Number of Samples	Geometric Mean (org/100 mL)
502	Swan River, Headwaters (Big Swan Lake 77-0023-00) to Mississippi River	April	1[a]	1.0[a]
		May	No Data	N/A
		June	3[a]	136.7[a]
		July	4[a]	55.9[a]
		August	3[a]	189.9[a]
		September	No Data	N/A
		October	No Data	N/A
521	Little Elk River	April	No Data	N/A
		May	No Data	N/A
		June	**5**	**82.8**
		July	**5**	**402.5**

Impaired Reach	Description	Month	Number of Samples	Geometric Mean (org/100 mL)
		August	**5**	**106.6**
		September	No Data	N/A
		October	No Data	N/A
522	Pike Creek	April	No Data	N/A
		May	No Data	N/A
		June	2	1565.1
		July	**5**	**2263.3**
		August	4	436.8
		September	No Data	N/A
		October	No Data	N/A
626	Unnamed Creek	April	3	15.2
		May	1	93.3
		June	4	189.0
		July	3	1183.4
		August	4	464.1
		September	1	228.2
		October	2	347.3
627	Schwanke Creek	April	1	3.1
		May	2	10.5
		June	**5**	**275.9**
		July	**5**	**181.8**
		August	**5**	**447.2**
		September	2	618.3
		October	2	968.0
629	Unnamed Creek	April	1	3.1
		May	2	14.3
		June	**5**	**251.4**
		July	**5**	**429.3**
		August	**5**	**216.7**
		September	1	365.4
		October	2	212.7
645	Hay Creek	April	No Data	N/A
		May	No Data	N/A
		June	**6**	**173.2**
		July	**5**	**134.2**
		August	4	93.0
		September	No Data	N/A
		October	No Data	N/A
695	Buffalo Creek (Little Buffalo Creek)	April	No Data	N/A
		May	No Data	N/A
		June	**7**	**214.3**
		July	**6**	**312.6**
		August	**5**	**138.1**
		September	No Data	N/A
		October	No Data	N/A

Geometric means shown in bold text have five or more samples during a month when the standard (126 org/100 mL) applies (April–October).
(a) Data from 2006 through 2016 used because of lack of data (two total samples) during model TMDL period.

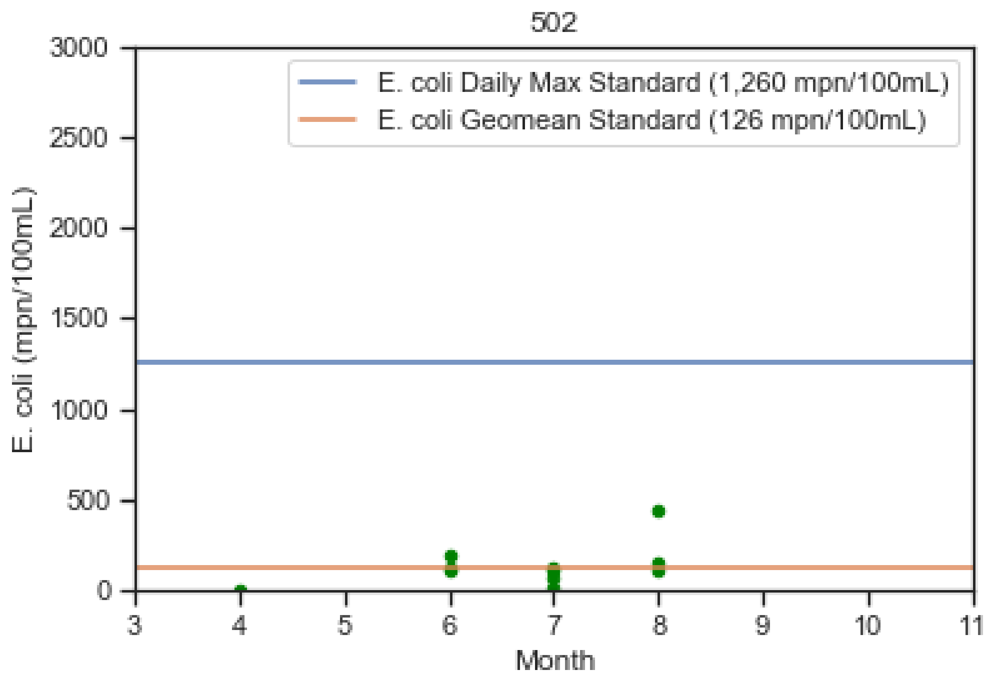


Figure 3-10. Single Sample *E. coli* Concentrations by Month in Reach 502, 2006–2016 (Extended 1 Year From TMDL Time Period Because of Lack of Data)

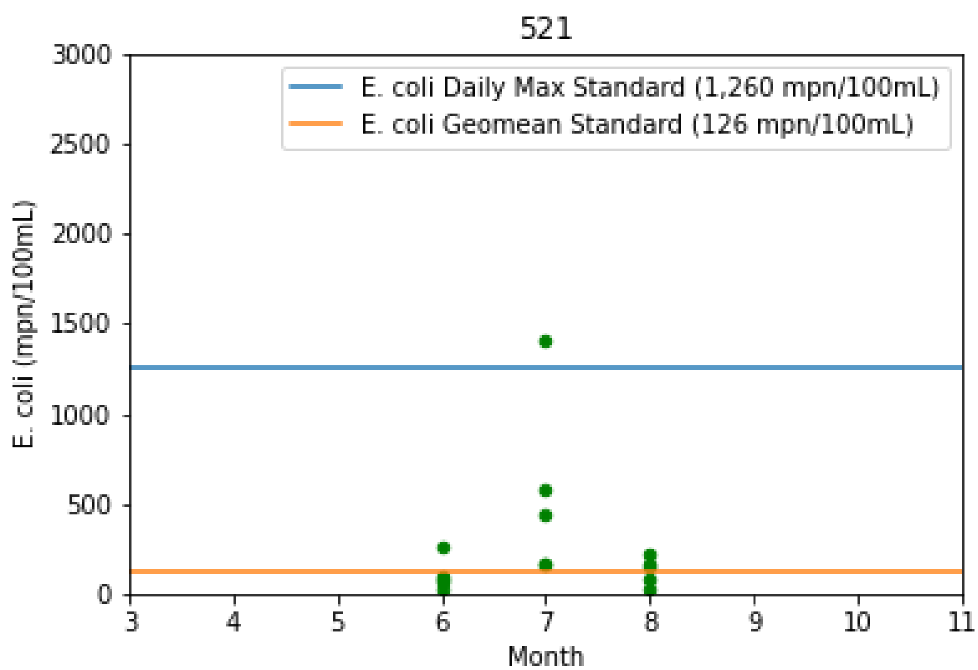


Figure 3-11. Single Sample *E. coli* Concentrations by Month in Reach 521, 2006–2015

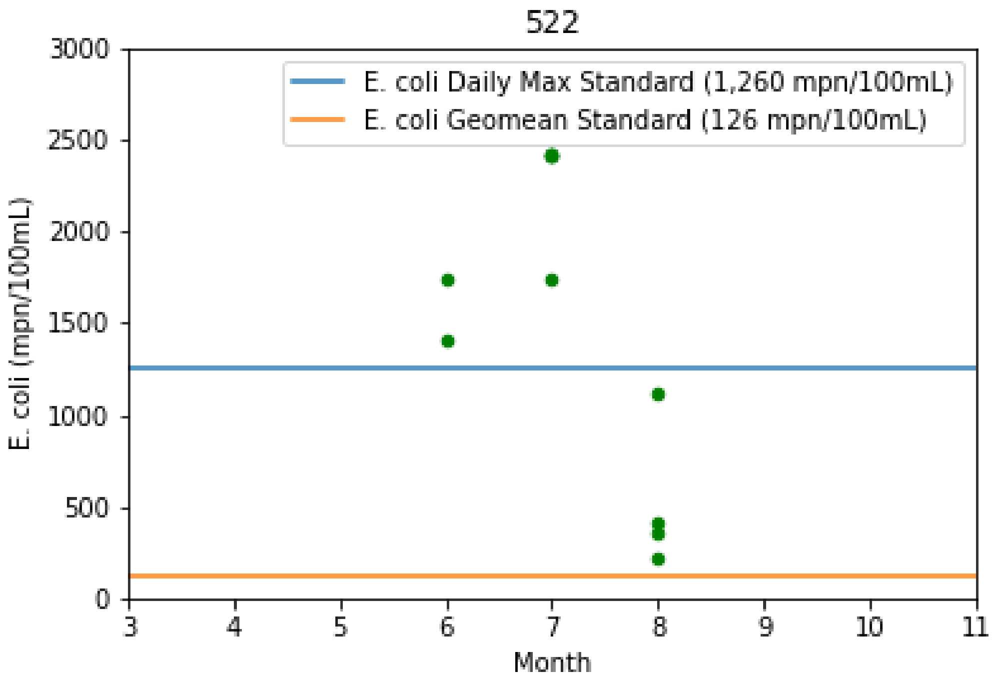


Figure 3-12. Single Sample *E. coli* Concentrations by Month in Reach 522, 2006–2015

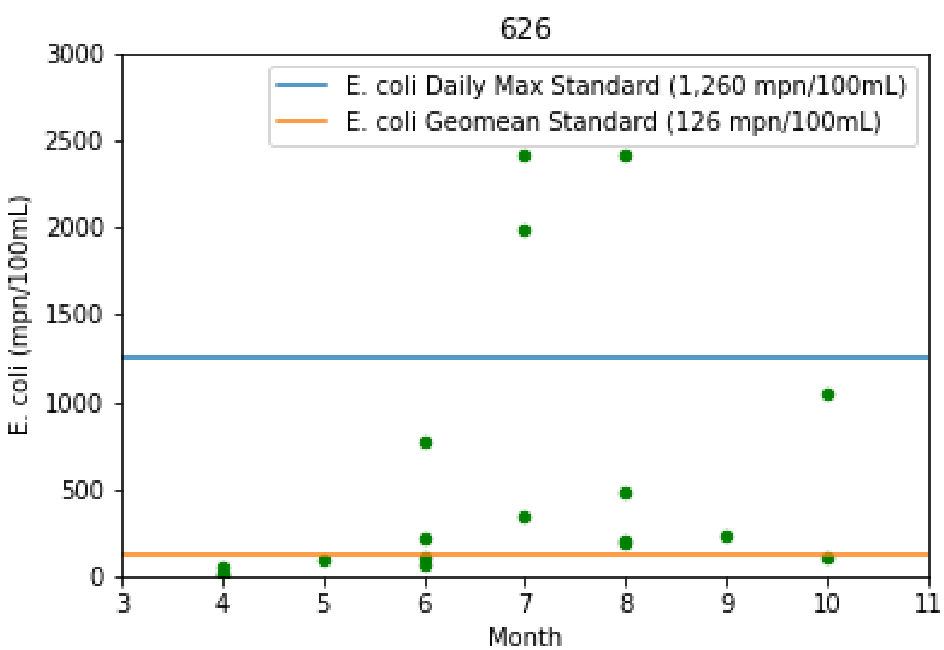


Figure 3-13. Single Sample *E. coli* Concentrations by Month in Reach 626, 2006–2015

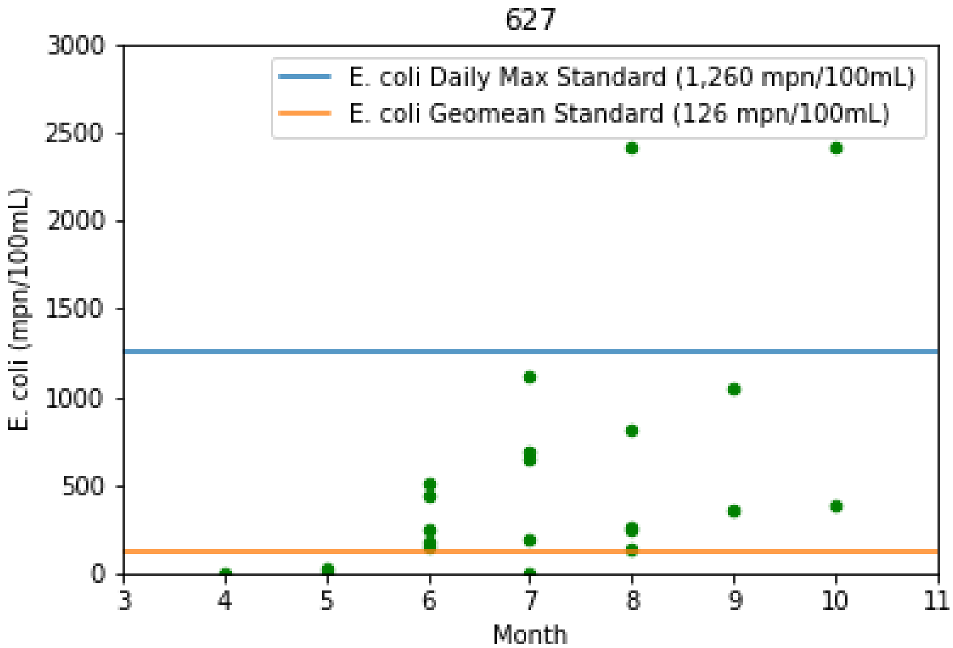


Figure 3-14. Single Sample *E. coli* Concentrations by Month in Reach 627, 2006–2015

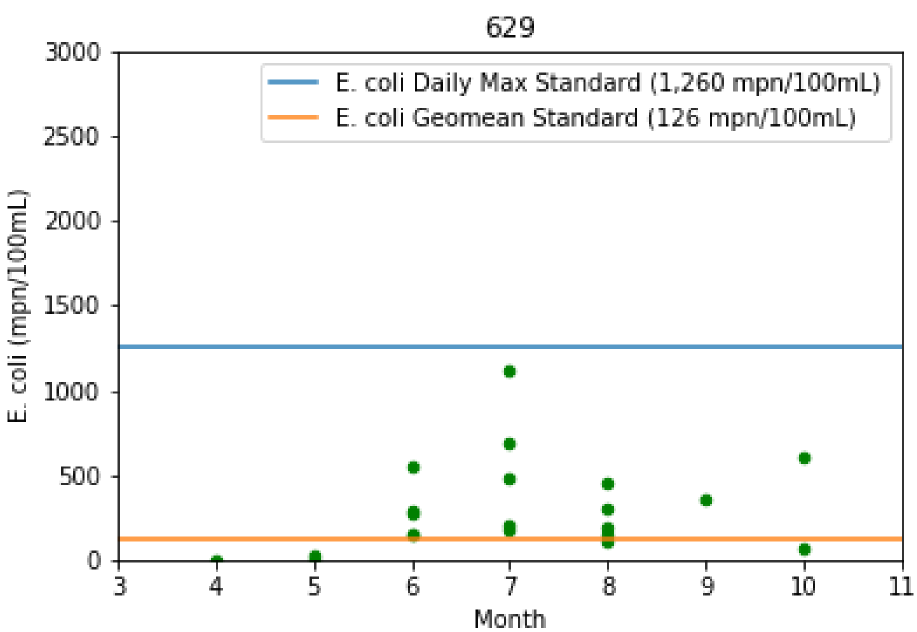


Figure 3-15. Single Sample *E. coli* Concentrations by Month in Reach 629, 2006–2015

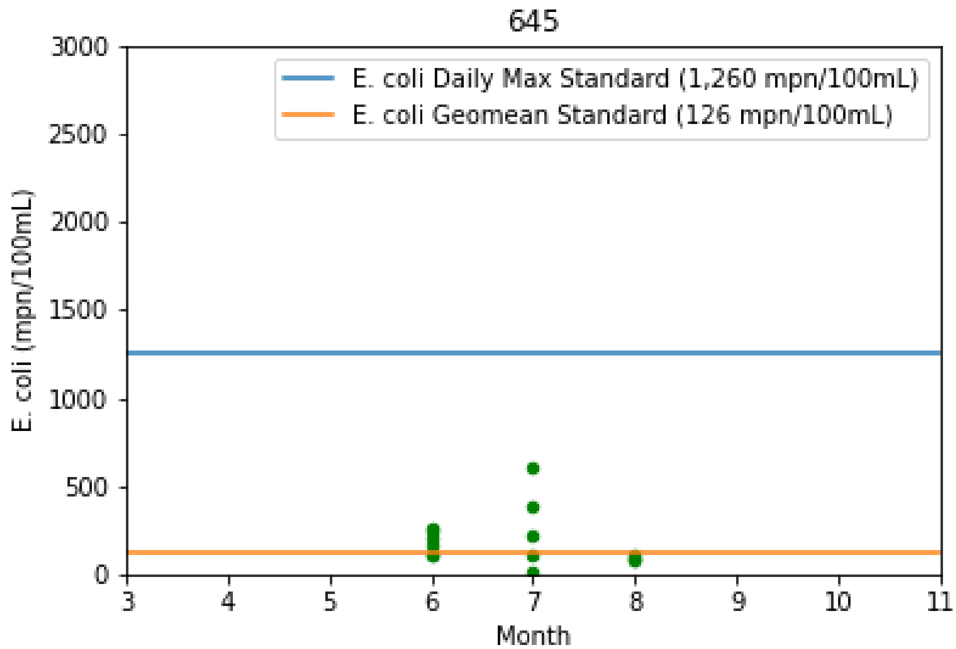


Figure 3-16. Single Sample *E. coli* Concentrations by Month in Reach 645, 2006–2015

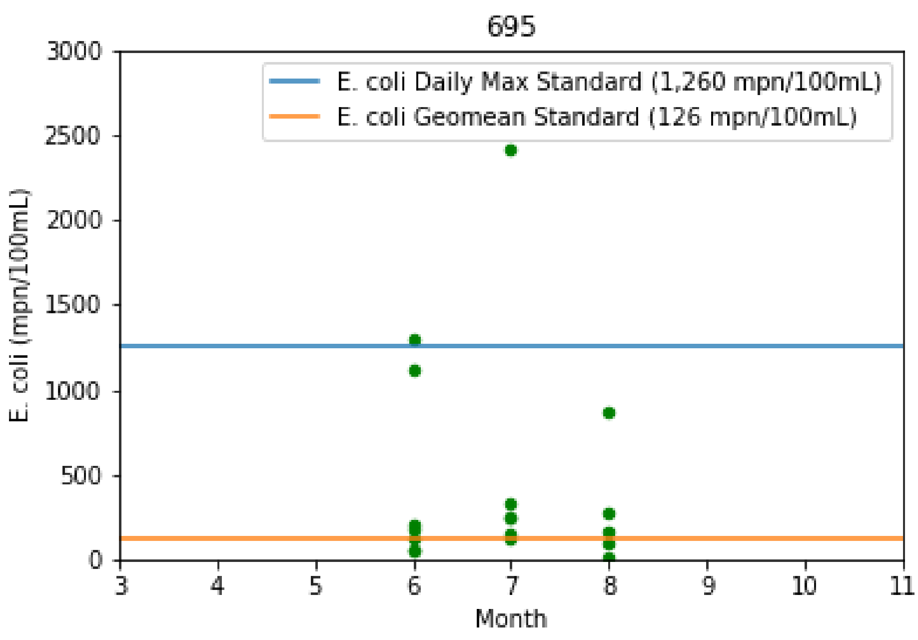


Figure 3-17. Single Sample *E. coli* Concentrations by Month in Reach 695, 2006–2015

3.5.2.2 Aquatic Macroinvertebrate Bioassessments

The Mississippi-Brainerd Stressor ID Report [MPCA 2019] states that the main stressors for the macroinvertebrates in Reach 659, Sisabagamah Creek, are (1) a lack of habitat being caused by flow alteration, and (2) the amount of sediment coming into the stream from stream bank instability and a lack of vegetated ditch banks. It states that TSS is also a stressor for the macroinvertebrates, but that low DO is not a stressor. TSS contributions generally increase because of the flow alteration and stream bank instability. Additionally, high concentrations of TSS decrease the likelihood of a good macroinvertebrate habitat. Therefore, TSS was used as a surrogate for the aquatic macroinvertebrate bioassessment of impaired Reach 659. TSS data for Reach 659 are summarized in Table 3-11. Data were collected in 2016, but not during the TMDL period (2006 through 2015). Figure 3-18 shows the seasonal variation of TSS data. The location of Reach 659 is shown in Figure A-1.

The Mississippi-Brainerd Stressor ID Report [MPCA 2019] states that the main stressors for the macroinvertebrates in Reach 679, a tributary to Sand Creek, are elevated nutrients and low DO, which causes stress to the macroinvertebrates and creates a poor habitat. Therefore, DO and TP were evaluated for Reach 679. DO and TP data are summarized for Reach 679 in Table 3-12. Data were collected in 2017, but not during the TMDL period (2006 through 2015). Figure 3-19 shows the seasonal variation of DO data, and Figure 3-20 shows the seasonal variation of TP data. One of the season's DO samples dropped below 5 milligrams per liter (mg/L), but all of the TP samples were above the river eutrophication standard of 0.05 mg/L. No continuous DO concentrations were collected along Reach 679 (W10097001) in 2016 as a part of the Stressor ID study. It is expected that if TP is decreased that DO will improve, therefore the TMDL surrogate is TP for Reach 679.

Table 3-11. Observed TSS Data Summary From 2006 Through 2015 Between April and September.

Reach	Description	Year	Count	Minimum	Mean	Maximum
659 (S008-826)	Sisabagamah Creek	2016	11	2	6.7	16

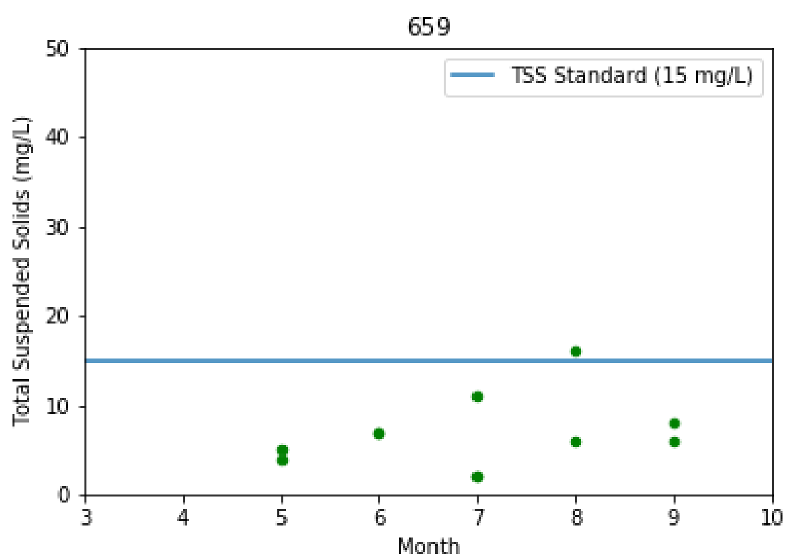


Figure 3-18. TSS by Month in Reach 659 (Station S008-826) from 2016

Table 3-12. Summary of Observed DO and TP data From Reach 679 April–November 2017.

Reach Description	Parameter	Year	Number of Samples	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)
Tributary to Sand Creek	DO	2017[(a)]	5	4.1	6.5	8.2
	TP	2017[(a)]	5	0.19	0.30	0.37

(a) No samples available for TMDL time period 2006–2015.

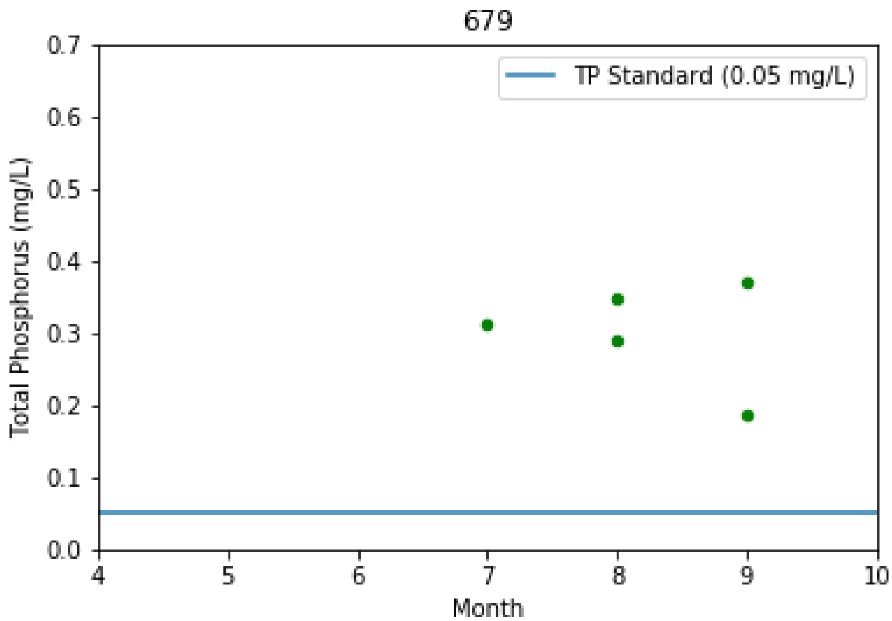


Figure 3-19. DO by Month in Reach 679 From 2017 (No Samples Available for TMDL Time Period 2006–2015)

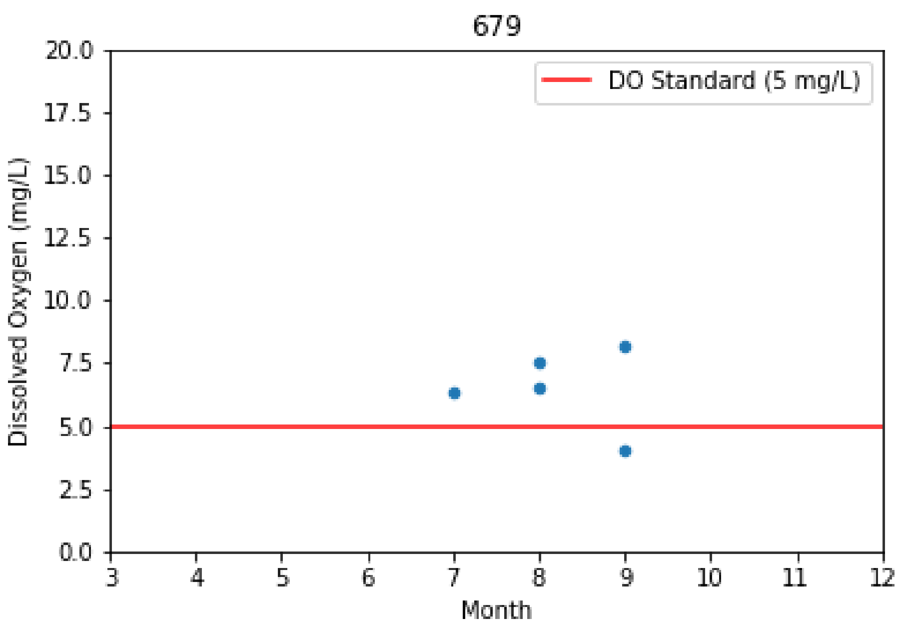


Figure 3-20. TP by Month in Reach 679 From 2017 (No Samples Available for TMDL Time Period 2006–2015)

3.5.2.3 Nutrients

Lake-by-lake summaries of available data for water quality, bathymetry, lake-level fluctuations, DO and temperature profiles (changes by depth), select watershed characteristics, fisheries, and aquatic plant survey information, and the number of samples used in development of the TMDLs are located in Appendixes B–L. Table 3-13 summarizes the 10-year TMDL-period (2006 through 2015) growing season mean TP, Chl-*a*, and Secchi Disk Depth (SDD) by impaired lake. The coefficient of variation (CV) for each parameter is also shown in Table 3-14. Fawn and Moose lakes only had the data for all three parameters in 2016, so for these lakes, Table 3-14 shows 2016 data only. The number and temporal coverage of lake samples used in development of the TMDLs are listed in Appendix K.

Table 3-13. Observed Lake Water Quality (Eutrophication Parameters) Averages for the TMDL Time Period (2006–2015).

Lake Name	Lake AUID	Classification	10-Year Growing Season Observed Averages and CV Means					
			TP (ug/L)	CV	Chl-*a* (ug/)	CV	SDD (m)	CV
Big Swan	77-0023-00	NCHF	45.30	0.10	25.14	0.16	2.22	0.03
Crow Wing	18-0155-00	NLF	37.74	0.12	22.35	0.17	1.62	0.04
Elm Island	01-0123-00	NLF	59.13	0.06	32.81	0.16	1.15	0.03
Fawn	18-0240-00	NLF, Shallow	54.75[(a)]	0.09	42.55[(a)]	0.19	0.72[(a)]	0.04
Fleming	01-0105-00	NLF, Shallow	53.00	0.08	33.24	0.12	1.12	0.04
Gun	01-0099-00	NLF	29.78	0.08	9.61	0.11	2.03	0.05
Lower Mission	18-0243-00	NLF	46.50	0.14	18.78	0.22	2.18	0.06
Moose	77-0026-00	NCHF	49.33[(a)]	0.27	27.14[(a)]	0.38	1.52	0.06
Ripple	01-0146-00	NLF	34.22	0.05	19.98	0.13	1.63	0.05
Sebie	18-0161-00	NLF	42.57	0.07	17.50	0.08	1.42	0.07
Trace	77-0009-00	NCHF, Shallow	83.60	0.09	48.53	0.15	0.82	0.10

(a) Shown from 2016; no data or incomplete dataset available from TMDL time period.

The MINLEAP model developed by Wilson and Walker [1989] was employed to quickly compare observed lake water quality with values generally expected based on the lake's aquatic ecoregion, watershed size, lake surface area, and mean depth. Predicted lake water quality for all but Big Swan Lake suggest that observed water quality is worse than MINLEAP-defined expectations. MINLEAP estimates indicate that the majority of the lakes should have lower P and Chl-*a* concentrations than observed. Observed versus MINLEAP-predicted lake water quality is shown in Table 3-14.

Table 3-14. Observed Versus MINLEAP-Predicted Lake Water Quality.

Lake Name	Classification	Total Phosphorus (ug/L)		Chlorophyll-*a* (ug/L)		Secchi Clarity (m)	
		Observed	MINLEAP Predicted[(a)]	Observed	MINLEAP Predicted	Observed	MINLEAP Predicted
Big Swan	NCHF	45.3	48	25.1	19.0	2.2	1.4
Crow Wing	NLF	37.7	32	22.4	10.2	1.6	2.0
Elm Island	NLF	59.1	41	32.8	14.8	1.2	1.6
Fawn	NLF, Shallow	54.8	30	42.6	9.6	0.7	2.0
Fleming	NLF, Shallow	53.0	32	33.2	10.3	1.1	2.0
Gun	NLF	29.8	23	9.6	6.5	2.0	2.6
Lower Mission	NLF	46.5	28	18.8	8.4	2.2	2.2
Moose	NCHF	49.3	35	27.1	12.1	1.5	1.8
Ripple	NLF	34.2	38	20.0	13.4	1.6	1.7
Sebie	NLF	42.6	37	17.5	13.0	1.4	1.7
Trace	NCHF, Shallow	83.6	47	48.5	18.2	0.8	1.4

3.6 HSPF Model Methodology

HSPF is a comprehensive watershed model of hydrology and water quality that includes modeling of surface and subsurface hydrologic and water quality processes, which are linked to, and closely integrated with, corresponding stream and reservoir processes. This framework can be used to determine the critical environmental conditions (e.g., certain flows or seasons) for the impaired segments by providing continuous flows and pollutant loads at any point within the system. HSPF simulates the fate and transport of modeled pollutants and can simulate subsurface concentrations in addition to surface concentrations (where appropriate). For this project, HSPF was used to assess sources and to determine the loading capacity and current DO, TSS, and nutrient loads. HSPF-generated flows were also used to generate flows for *E. coli*-loading capacities. The following sections provide more detail on the source-assessment approach as well as the quantitative results of the source load assessment.

The primary components of developing an HSPF model application include the following:

- Gathering and developing time-series data
- Characterizing and segmenting the watershed
- Calibrating and validating the model.

Each of these components is described in the following sections.

3.6.1 Gathering and Developing Time-Series Data

Data requirements for developing and calibrating an HSPF model application are both spatially and temporally extensive. The modeling period was updated and calibrated by Tetra Tech in 2018 to include data from 1995 through 2015 [Tetra Tech 2018]. Time-series data used in developing the model application included meteorological data, atmospheric deposition data, and point-source data. Precipitation, potential evapotranspiration, air temperature, wind speed, solar radiation, dew-point temperature, and cloud cover data are needed for HSPF to simulate hydrology (including snow-related processes).

3.6.2 Characterizing and Segmenting the Watershed

The Mississippi-Brainerd Area Watershed was delineated into 152 subwatersheds to capture hydrologic and water-quality variability. The watershed was then segmented into individual land and channel pieces that are assumed to demonstrate relatively homogeneous hydrologic, hydraulic, and water-quality characteristics. This segmentation provides the basis for assigning inputs and/or parameter values or functions to remaining portions of a land area or channel length contained in a model segment. The individual land and channel segments are then linked together to represent the entire project area.

The land segmentation was defined by land cover. Land use and land cover affect the hydrologic and water-quality response of a watershed through their impacts on infiltration, surface runoff, and water losses from evapotranspiration. Water that moves through the system is affected by land cover. Land use (as estimated by land cover) affects the rate of the pollutant accumulation, because certain land uses often support different pollutant sources.

The University of Minnesota's Remote Sensing and Geospatial Analysis Laboratory 2013 land cover categories, which are summarized in Figure 3-21, were combined into 12 groups with similar characteristics. The urban categories were divided into pervious and impervious areas based on an estimated percentage of effective impervious area. The term "effective" implies that the impervious region is directly connected to a local hydraulic conveyance system (e.g., open channel and river), and the resultant overland flow will not run onto pervious areas but will directly enter the reach network.

The channel segmentation considers river travel time, riverbed slope continuity, temporal and spatial cross-section, morphologic changes or obstructions, the confluence of tributaries, impaired reaches, and locations of flow and water quality calibration and verification gages. After the reach network was segmented, the hydraulic characteristics of each reach were computed, and the areas of the land cover categories that drain to each reach were calculated. Reach hydraulics are specified by a reach function table (F-table), which is an expanded rating curve that contains the reach surface area, volume, and discharge as functions of depth. F-tables were developed for each reach segment by using channel cross-sectional data. Unsurveyed tributaries were assigned the geometry of hydraulically-similar channels.

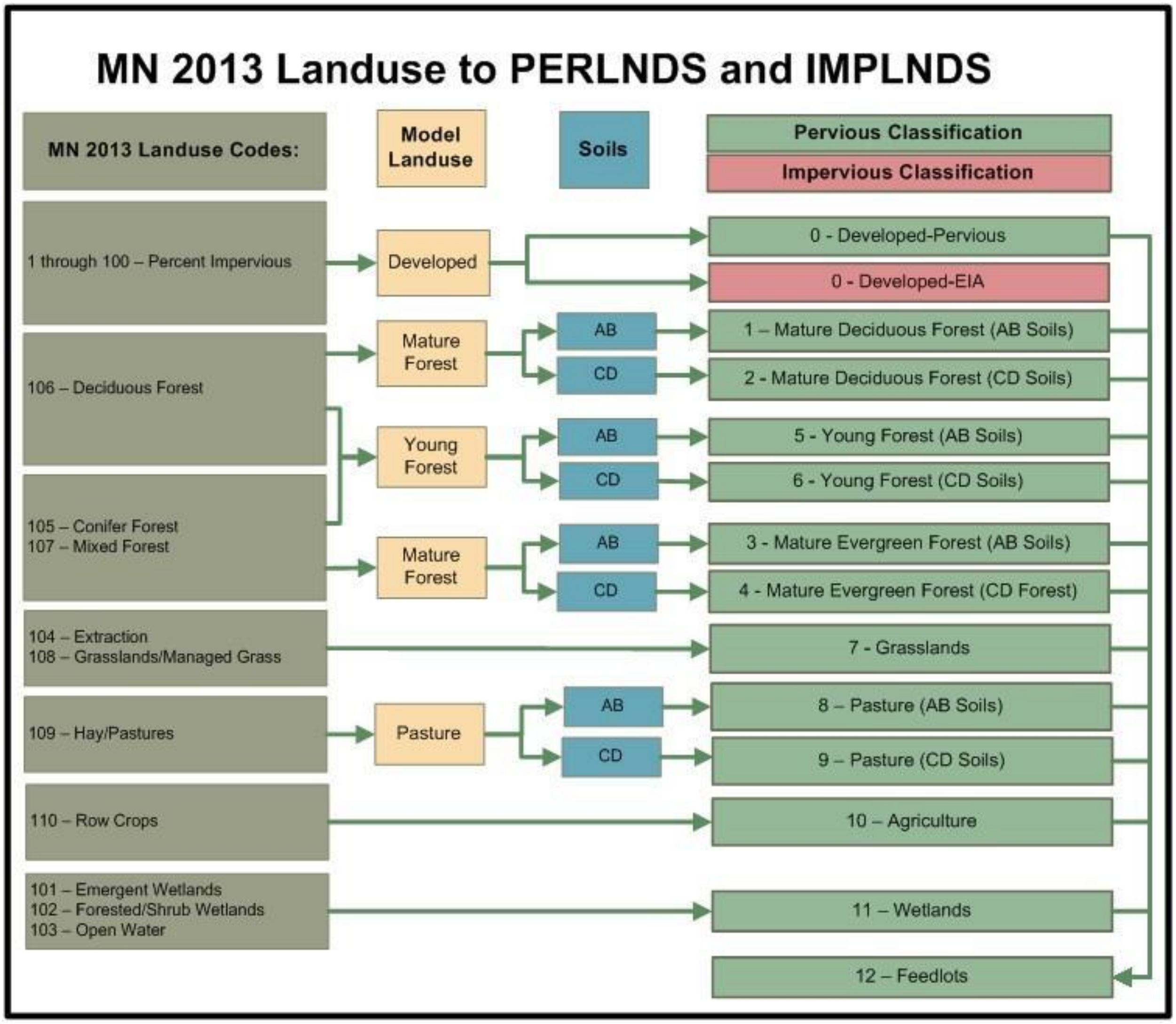


Figure 3-21. Land Cover Category Aggregation

3.6.3 Calibrating and Validating the HSPF Model

Model validation involved hydrologic and water quality calibration by using observed flow and water quality data to compare with simulated results. Because water quality simulations depend highly on watershed hydrology, the hydrology calibration was completed first, followed by the sediment calibration, the temperature calibration, and finally the nutrient/oxygen/Chl-*a* calibration. The stream-discharge sites with time-series data were used for the calibration and validation. Data from all but the first year of the simulation period were used to calibrate the model. The initial year (1995) was simulated for the model to adjust to existing conditions. The 20-year calibration period included a range of dry and wet years. This range of precipitation improves the model calibration and validation and provides a model application that can simulate hydrology and water quality during a broad range of climatic conditions.

Hydrologic calibration is an iterative process intended to match simulated flow to observed flow by methodically adjusting model parameters. HSPF hydrologic calibration is divided into the following four sequential phases of parameter adjustment to improve model performance:

- Annual runoff;
- Seasonal or monthly runoff;
- Low- and high-flow distribution; and
- Individual storm hydrographs.

By iteratively adjusting calibration parameters within accepted ranges, the simulation results are improved until an acceptable comparison of simulated results and measured data is achieved. The procedures and parameter adjustments involved in these phases are more completely described in Donigian et al. [1984] and Lumb et al. [1994].

The hydrology calibration was evaluated using a weight-of-evidence approach based on a variety of graphical comparisons and statistical tests. The performance criteria are described in more detail in Donigian [2002]. Graphical comparisons included monthly and average flow volume comparisons, daily time-series-data comparisons, and flow duration plots. Statistical tests included annual and monthly runoff errors, low-flow and high-flow distribution errors, and storm-volume and peak-flow errors. The flow calibration time series from the Mississippi River at Fort Ripley (Site 10048001, Model Reach 470) is shown in Figure 3-22.

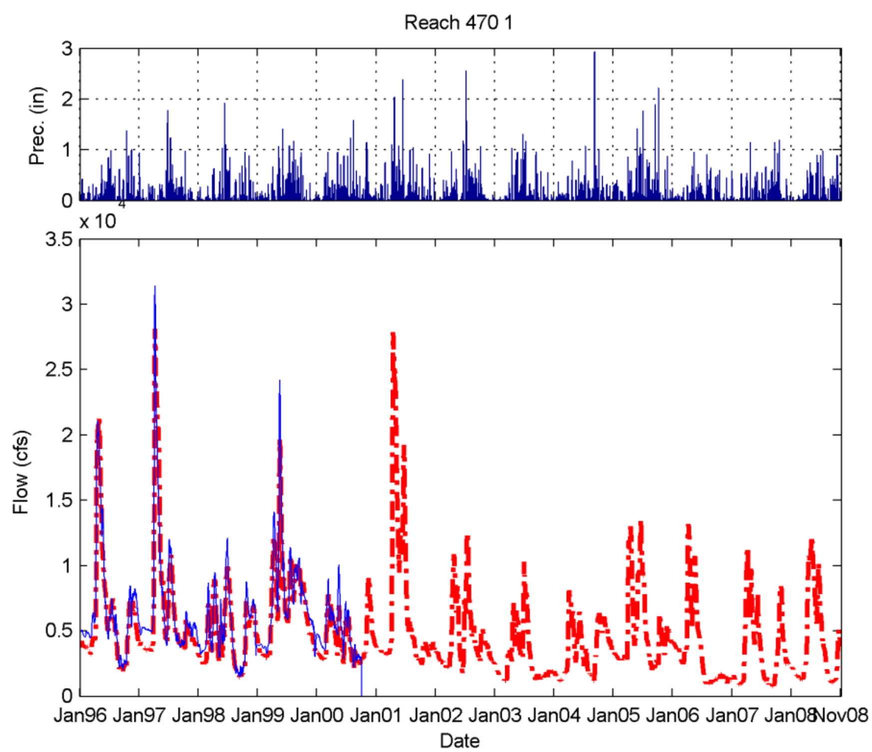


Figure 3-22. Flow Time Series at Mississippi River Near Fort Ripley (10048001/US Geological Survey [USGS] 05261000).

The water quality calibration optimized the alignment between the loads that are predicted to be transported throughout the system, and the observed in-stream concentrations. Water quality data from monitoring sites were used to calibrate the model to observed conditions. Many parameters can be adjusted to calibrate water quality loads and concentrations. The DO concentration calibration time series from the most downstream model reach of Swan River is shown in Figure 3-23. More detailed information on the HSPF model application and model calibration results (hydrology and water quality) can be found in the most recent Mississippi-Brainerd Watershed project modeling memorandum [Lupo 2016].

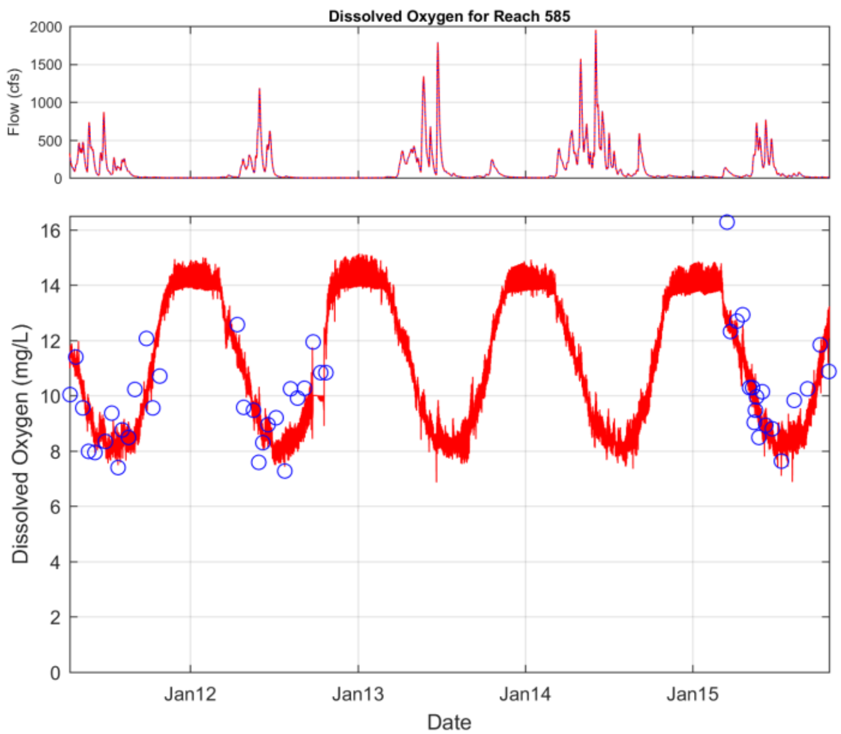


Figure 3-23.Total DO Concentration Time Series on Swan River Model Reach 585 (DO Data Available Between 2006 and 2015)

3.7 Pollutant Source Summary

Pollutant sources are summarized for *E. coli*, DO, aquatic macroinvertebrate, and nutrient impairments in the following sections. *E. coli* that was produced in each impaired stream drainage area was estimated by source by using a GIS approach, while the sources of DO-consuming substances and nutrients were estimated by using the HSPF model application.

3.7.1 *E. coli*

Sources of bacteria-to-stream impairments can include livestock, wildlife, humans and pets. Bacteria from human and animal waste are naturally dispersed throughout the landscape, spread by humans, and/or treated in facilities. Once the bacteria are in the environment, their accumulation and delivery to the stream is affected by die-off and decay, surface imperviousness, detention time, ultraviolet exposure, and other factors.

3.7.1.1 Permitted

Detailed information about specific permitted *E. coli* sources is included in Section 4.2.2 of this TMDL. Four of the fourteen permitted discharging point sources located in the Mississippi-Brainerd Area Watershed drain to an *E. coli*-impaired reach. Effluent from wastewater treatment facilities (WWTFs) is monitored and regulated but contributes an allowable amount of *E. coli* to the stream. A map of point sources is included in Appendix A.

Twenty-four concentrated animal feeding operations (CAFOs) are located within the Mississippi-Brainerd Area Watershed, all but one of which is in an area draining to an *E. coli*-impaired reach. CAFOs are generally not allowed to discharge to surface water except in the event of chronic or catastrophic precipitation, but manure from liquid manure storage areas or dry manure stockpiles can be spread locally and can be washed off during precipitation events to contribute to impairments. A map of animal feedlots and the CAFO is included in Appendix A.

The Baxter City, Brainerd City, and Little Falls City MS4s are located within the Mississippi-Brainerd Watershed. Of these, the Brainerd City MS4 overlaps the watershed of Little Buffalo Creek and the Little Falls City MS4 overlaps the watershed of Pike Creek. Human bacteria sources in MS4s can include cross-connections between sanitary sewers and storm drain systems, leaks or overflows from sanitary sewer systems, and wet-weather discharges from centralized wastewater collection and treatment facilities in MS4 areas. Wildlife, decaying vegetation, eroded organic matter, and pet waste are other potential bacterial sources in MS4 areas. Pet waste that is not properly disposed of along a stream or near a stormwater conveyance system can be washed off during precipitation events [EPA 2001].

Land application of biosolids from WWTFs was not included in these TMDLs as a source of bacteria because of the rigorous monitoring and regulation associated with it. More information about land application of biosolids is available in Minn. R. ch. 7041 (Sewage Sludge Management).

E. coli is not typically contributed from construction stormwater. Also, no benchmark monitoring of bacteria or *E. coli* are required with industrial permits, and *E. coli* is not typically contributed from industrial stormwater.

3.7.1.2 Nonpermitted

Manure from livestock is a potential nonpermitted source of bacteria to streams. Livestock contribute bacteria loads directly, by defecating in the stream, and indirectly, by defecating on cropland or pastures where bacteria can be washed off during precipitation events, snowmelt, or irrigation. Spreading livestock manure on cropland or pasture also contributes *E. coli* to waterbodies. Livestock in the project area mainly include cattle, poultry, hogs, horses, sheep, and goats. Livestock are grazed and/or confined in the areas that drain to *E. coli*-impaired waterbodies. Nearly 350 animal feedlots are within the watersheds of *E. coli*-impaired reaches.

Wildlife (including waterfowl and large-game species) also contribute bacteria loads directly, by defecating while wading or swimming in the stream, and indirectly, by defecating on lands that produce stormwater runoff during precipitation events. According to the Clean Water Legacy Act, “natural background” refers to characteristics of the waterbody that result from the multiplicity of factors in nature, including climate and ecosystem dynamics, that affect the physical, chemical, or biological conditions in a waterbody (in other words, characteristics that fall outside the measurable and distinguishing pollution that is attributable to human activity or influence). Bacteria loads from wildlife are generally considered natural background. Some BMPs that reduce loads from livestock and other sources can also reduce loads from wildlife.

Human bacteria sources in nonMS4 permitted urban settings can include cross-connections between sanitary sewers and storm drain systems, leaks or overflows from sanitary sewer systems, and wet-weather discharges from centralized wastewater collection and treatment facilities. Outside of city domestic wastewater coverage areas, septic systems can be a potential human source of bacteria loads. Pet waste is another potential source of bacteria from nonregulated communities in a watershed.

Research in the last 15 years has found the persistence of *E. coli* in soil, beach sand, and sediments throughout the year in the north-central United States without the continuous presence of sewage or mammalian sources. An Alaskan study [Adhikari et al. 2007] found that total coliform bacteria in soil were able to survive for six months in subfreezing conditions. A study of cold water streams in southeastern Minnesota completed by the MPCA staff found the resuspension of *E. coli* in the stream water column due to stream sediment disturbance. A recent study near Duluth, Minnesota [Ishii et al. 2010] found that *E. coli* were able to grow in agricultural field soil. A study of ditch sediment in the Seven Mile Creek Watershed in southern Minnesota, conducted by Chandrasekaran et al. [2015], found that strains of *E. coli* had become naturalized to the water−sediment ecosystem. Survival and growth of fecal coliform has also been documented in storm sewer sediment in Michigan [Marino and Gannon 1991].

3.7.1.3 Source Assessment

A GIS-based assessment was completed within each impaired drainage area to estimate populations of livestock, wildlife, humans, and pets. Animal populations were multiplied by average excretion rates obtained from scientific literature. Reported literature values for fecal coliform excretion were converted to *E. coli* excretion by using a fecal coliform-to-*E. coli* ratio of 200:126 org/100 mL. Annual excretion estimates for livestock (excluding hogs) and wildlife were obtained from Zeckoski et al. [2005], and bacterial estimates for humans and hogs were obtained from Metcalf and Eddy [1991]. Annual excretion rates for dogs and cats were from Horsley and Witten, Inc. [1996].

Domestic wastewater sewers within each *E.coli*-impaired drainage area were estimated by summing the 2010 population for all 2010 Census Block Centroid Population points located within urban areas that have a WWTF. Points located within the urban areas were assumed to be connected to the WWTFs in applicable impairment drainage areas.

The number of people who use septic systems was estimated by summing the 2010 population for all 2010 Census Block Centroid Population points located outside of urban areas that have a WWTF.

Pet populations were estimated by summing the households from the 2010 Census Block Centroid Population points within each applicable impairment drainage area and assuming 0.58 dogs (36.5% of households times 1.6 dogs per household) and 0.64 cats (30.4% of households times 2.1 cats per household) per household [American Veterinary Medical Association 2016].

The most recent (at the time of the analysis) MPCA feedlot data layer with Animal Counts and Animal Units was obtained from the Minnesota Geospatial Commons [Minnesota Geospatial Commons 2018]. The layer was spatially joined to the drainage area of the impaired reaches, and the total number of birds, bovines, goats and sheep, horses, and pigs from active feedlots was calculated.

Deer were estimated by using deer densities in deer-permit-area boundaries. Boundaries were downloaded from the Minnesota Geospatial Commons (https://gisdata.mn.gov/dataset/bdry-deer-permit-areas) and densities were provided from the DNR [Norton 2018]. Ducks and geese were estimated from the DNR and US Fish and Wildlife Service *2018 Waterfowl Breeding Population Survey* with estimated subwatershed waterbody densities [DNR 2018]. Coots and swans were also estimated. Coots were included in the duck population, while swans were included in the geese population. Small mammals such as beaver, muskrat, and mink, as well as other birds such as swallows, are difficult to estimate but also contribute to the wildlife bacteria.

Table 3-15 shows the total number (head) of each animal estimated for the purposes of this TMDL, the amount of bacteria produced by each animal per day, and the literature source that was used to estimate the amount of bacteria produced by each animal per day. In some cases, such as sheep and goats, the number was an average of the amount produced by sheep and goats because the number of each animal individually in the watershed is unknown.

Table 3-16 shows estimated bacteria produced within the drainage area of each impaired stream from each animal, along with its associated percentage.

Some of the areas draining to the smaller impairments are also located within areas draining to larger impairments. For example, Reach 626 eventually drains to Reach 502. This analysis estimates bacteria produced within the total drainage area contributing to the pour point of each impairment. A majority of the bacteria that is produced in the drainage area of Reaches 502, 521, 522, 626, 627, and 629 (more than 95%) is produced by livestock (cattle, poultry, hogs, sheep/goats, or horses). The drainage area of Reach 645 is still dominated by livestock (73%) but also has a higher percentage of bacteria produced from humans and pets (17%) and wildlife (10%). In contrast, the drainage area of Reach 695 is highly developed, and therefore the highest percentage of bacteria produced is from humans and pets (98%). Other possible sources that may not have been accounted for in the GIS analysis for more developed Reach 695 include backyard hens, geese in the fairgrounds area after the fair (August through October), and the city deer population. These estimates provide watershed managers with the relative magnitudes of total production by source and do not account for wash-off availability, delivery to the impaired reach versus in-stream growth, or die-off dynamics.

Table 3-15. Total Number of Each Animal Producing Bacteria in Drainage Area and Bacteria Production Rates.

Impaired Reach	Total Humans		Total Pets		Total Livestock					Total Wildlife		
	Wastewater Treatment Plant	Subsurface Sewage Treatment Systems	Cats	Dogs	Cattle	Horses	Poultry	Sheep/ Goats	Hogs	Deer	Ducks	Geese
502	902	2,860	935	856	20,749	1,017	2,814,125	503	9,890	4,133	1,912	809
521	631	1,741	595	545	7,742	35	745,563	306	2,154	3,147	1,335	565
522	1,398	198	388	355	3,491	8	349,254	477	673	1,062	469	198
626	0	23	7	6	444	17	30	100	75	66	32	13
627	0	121	25	23	1,467	16	43	0	10	194	93	39
629	139	185	92	84	952	4	139,095	0	102	254	122	52
645	0	181	43	40	98	2	0	0	0	277	127	54
695	2,820	0	654	599	0	0	0	0	0	151	70	30
Bacteria Production Rate (cfu/day/head)	1.3E+09	1.3E+09	3.2E+09	3.2E+09	2.1E+10	2.6E+10	5.9E+07	1.3E+10	5.6E+09	2.2E+08	1.5E+09	5.0E+08
Source of Bacteria Production Rate	[Metcalf and Eddy 1991]		[Horsley and Witten, Inc. 1996]		[Zeckoski et al. 2005]				[Metcalf and Eddy 1991]	[Zeckoski et al. 2005]		

Table 3-16.Total and Percentage of Bacteria Produced in Each Impaired Stream Drainage Area By Source.

Impaired Reach		Total Humans		Total Pets		Total Livestock					Total Wildlife		
		Wastewater Treatment Facility	Subsurface Sewage Treatment Systems	Cats	Dogs	Cattle	Horses	Poultry	Sheep/ Goats	Hogs	Deer	Ducks	Geese
502	Total Bacteria Produced (cfu/day)	1.1E+12	3.6E+12	2.9E+12	2.7E+12	4.3E+14	2.7E+13	1.6E+14	6.3E+12	5.5E+13	9.1E+11	2.9E+12	4.1E+11
521		8.0E+11	2.2E+12	1.9E+12	1.7E+12	1.6E+14	9.3E+11	4.4E+13	3.9E+12	1.2E+13	6.9E+11	2.0E+12	2.8E+11
522		1.8E+12	2.5E+11	1.2E+12	1.1E+12	7.3E+13	2.1E+11	2.0E+13	6.0E+12	3.8E+12	2.3E+11	7.1E+11	1.0E+11
626		0.0E+00	2.9E+10	2.2E+10	2.0E+10	9.2E+12	4.5E+11	1.8E+09	1.3E+12	4.2E+11	1.5E+10	4.8E+10	6.8E+09
627		0.0E+00	1.5E+11	7.8E+10	7.2E+10	3.0E+13	4.2E+11	2.5E+09	0.0E+00	5.6E+10	4.3E+10	1.4E+11	2.0E+10
629		1.8E+11	2.3E+11	2.9E+11	2.6E+11	2.0E+13	1.1E+11	8.1E+12	0.0E+00	5.7E+11	5.6E+10	1.8E+11	2.6E+10
645		0.0E+00	2.3E+11	1.4E+11	1.3E+11	2.0E+12	5.3E+10	0.0E+00	0.0E+00	0.0E+00	6.1E+10	1.9E+11	2.7E+10
695		3.6E+12	0.0E+00	2.1E+12	1.9E+12	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E+10	1.1E+11	1.5E+10
502	Percent of Total Bacteria Produced (%)	0%	1%	0%	0%	62%	4%	24%	1%	8%	0%	0%	0%
521		0%	1%	1%	1%	70%	0%	19%	2%	5%	0%	1%	0%
522		2%	0%	1%	1%	67%	0%	19%	6%	3%	0%	1%	0%
626		0%	0%	0%	0%	80%	4%	0%	11%	4%	0%	0%	0%
627		0%	0%	0%	0%	97%	1%	0%	0%	0%	0%	0%	0%
629		1%	1%	1%	1%	66%	0%	27%	0%	2%	0%	1%	0%
645		0%	8%	5%	4%	71%	2%	0%	0%	0%	2%	7%	1%
695		46%	0%	27%	25%	0%	0%	0%	0%	0%	0%	1%	0%

3.7.2 Aquatic Macroinvertebrate Bioassessments

The Draft Mississippi-Brainerd Stressor ID Report [MPCA 2019] states that the main stressors for the macroinvertebrates in Reach 659, Sisabagamah Creek, are (1) a lack of habitat being caused by flow alteration, and (2) the amount of sediment coming into the stream from stream bank instability and a lack of vegetated ditch banks. It states that TSS is also a stressor for the macroinvertebrates, but that low DO is not a stressor. TSS contributions generally increase because of the flow alteration and stream bank instability. Additionally, high concentrations of TSS decrease the likelihood for good macroinvertebrate habitat. Therefore, TSS was used as a surrogate for the aquatic macroinvertebrate bioassessment of impaired Reach 659. General and potential sources of TSS to Reach 659 are summarized in this section.

The Draft Stressor ID Report [MPCA 2019] also states that the main stressors for the macroinvertebrates in Reach 679, a tributary to Sand Creek, are elevated nutrients and low DO, which causes stress to the macroinvertebrates and creates a poor habitat. Therefore, Reach 679 was treated like a DO-impaired stream for the purposes of this TMDL. Actual and potential sources of oxygen-demanding materials in Reach 679 are summarized in this section.

3.7.2.1 Permitted

Detailed information about specific permitted TSS sources contributing to Reach 659 is included in Section 4.3.2 of this TMDL. One permitted discharging point source drains to Sisabagamah Creek Reach 659, and no permitted point sources drain to the unnamed tributary to Sand Creek Reach 679. Effluent from WWTFs is monitored and regulated but does contribute an allowable amount of TSS to the stream. A map of point sources in the Mississippi-Brainerd Area Watershed is included in Appendix A. No CAFOs drain to Sisabagamah Creek Reach 659 or to the unnamed tributary to Sand Creek Reach 679. CAFOs are generally not allowed to discharge to surface water except in the event of chronic or catastrophic precipitation. A map of animal feedlots and the CAFO is included in Appendix A. No MS4s drain to Sisabagamah Creek Reach 659 or to the unnamed tributary to Sand Creek Reach 679. Industrial and construction stormwater contribute TSS to waterbodies through erosion and wash-off during rainfall events. Similarly, industrial and construction stormwater contribute oxygen-demanding materials to waterbodies.

3.7.2.2 Nonpermitted

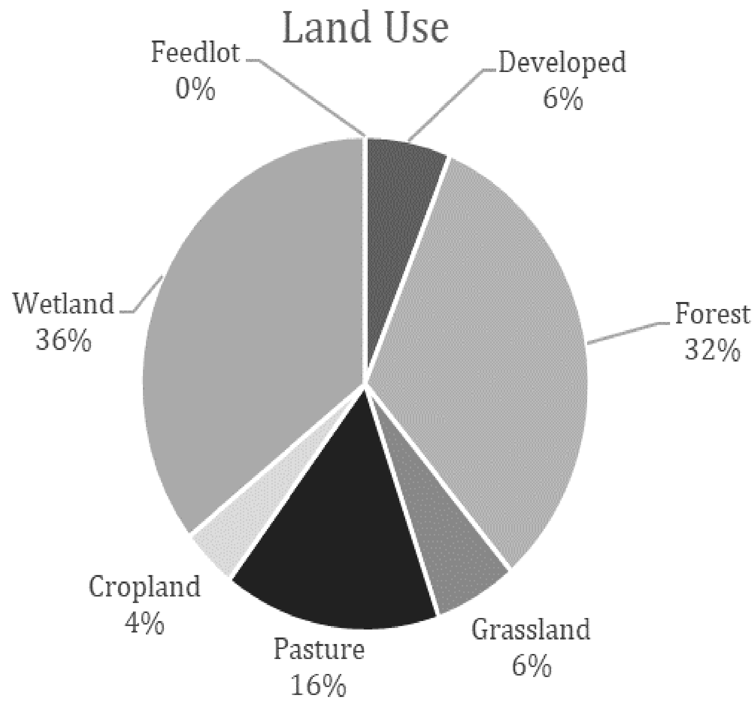
Nonpoint sources of TSS generally come from surface runoff, bed and bank erosion, cropland erosion, and erosion from small construction projects. Pasture/hay, row crops, forest, wetlands, and other land covers contribute to nutrients and oxygen-demanding materials (carbonaceous biochemical oxygen demand [CBOD] and ammonia) via wash-off manure and other organic materials from the land during precipitation events. Additionally, feedlots often have bare ground that could be prone to contributing sediment, nutrients, and oxygen-demanding materials to impaired streams during rainfall events. Natural background sediment occurs from natural background runoff, especially when local soils are composed of very fine clays. Flow alteration, such as stream straightening, shortens the distance water must flow and impacts sediment in streams by increasing the slope and the flow velocities, giving streams the ability to carry more fine sediment from bank erosion and gully erosion. Increased sand and fine sediment filling pools in a stream network cover coarse substrate, preventing rooting and growth of aquatic plants and thereby decreasing the habitat for the macroinvertebrate communities. Natural background nutrients and oxygen-demanding materials also occur in runoff from forest and grasslands. Wetlands in this small drainage area likely have higher nutrients because of surrounding cropland and animal units.

3.7.2.3 Potential Sources

The HSPF model was used to determine the contribution of TSS from identified sources to Sisabagamah Creek Reach 659. Source-assessment modeling results were summarized by using the following categories: point sources, bed/bank, developed, forest, grassland, pasture, cropland, wetland, and feedlots. The pie charts shown in Figure 3-24 were produced at the TMDL endpoint to show the land cover of the drainage area (top pie chart) and the relative contribution of each source from the HSPF model (bottom pie chart). The largest source of sediment in the impaired reach was from bed/bank erosion, which is likely linked to additional drainage routed through this reach. According to the Stressor ID Report [MPCA 2019], Sisabagamah Creek has been significantly altered in terms of the dimension, pattern, and profile of the stream:

> *This AUID has been significantly altered in terms of the dimension, pattern and profile of the stream. There has been a significant amount of additional drainage area added, approximately 9.5 sq. mi., through the CD 24 ditch network. This additional flow, along with stream straightening in the past have changed how the stream can carry its sediment load and affected its ability to be a self-cleaning system. The additional flow carries fine sediment. The stream bank erosion in both the ditch network and the stream corridor are adding sufficient amounts of sand and fine sediment that are filling pools and covering any coarse substrate that was available. The macroinvertebrates have two habitat cover types available: woody debris and undercut banks due to bank erosion. There are no rooted macrophytes found in the stream. Stream turbidity can very high during large rain events. Nutrient levels are elevated along with TSS concentrations during high flow events. Evidence of channel instability is present by the number of unstable stream banks and the amount of fine sediment deposited in the channel. A lack of habitat is the main stressor, being caused by flow alteration and the amount of sediment coming into the stream from stream bank instability and no vegetated ditch banks. TSS is also a stressor to the macroinvertebrates. Low DO is not a stressor.*

Water quality and flow data from the HSPF model were also used to evaluate total oxygen demand (biochemical oxygen demand [BOD] decay, reach sediment oxygen demand [SOD], and nitrogenous oxygen demand [NOD] combined) to the unnamed tributary to Sand Creek Reach 679, as well as the effects of reaeration, phytoplankton, and benthic algae. This is shown in Figure 3-25. The oxygen demand (SOD, BOD, and NOD) within each impaired reach was calculated within the HSPF model, and included total oxygen demand calculated over the simulation period for the model reaches draining to the unnamed tributary to Sand Creek Reach 679. The HSPF model was also used to determine the contribution of TP and oxygen-demanding substances from identified sources. Source-assessment modeling results were summarized by the following categories: developed, mature forest, young forest, grasslands, pasture agriculture, wetlands, feedlots, septic systems, point sources, atmospheric deposition, and stream bed/bank erosion. Most of the ammonia and BOD-related oxygen-demanding substances were contributed from croplands and wetlands, as depicted in Figure 3-26 (in which the topmost pie chart shows the land cover of the drainage area for each reach). Figure 3-27 shows the sources of TP to the unnamed tributary to Sand Creek Reach 679. Note that feedlot manure spread on cropland is accounted for in the cropland category, and not considered part of the feedlot loads, in the HSPF model application source pie charts. It is expected that if TP is decreased that DO will improve, therefore the TMDL surrogate is TP for Reach 679.



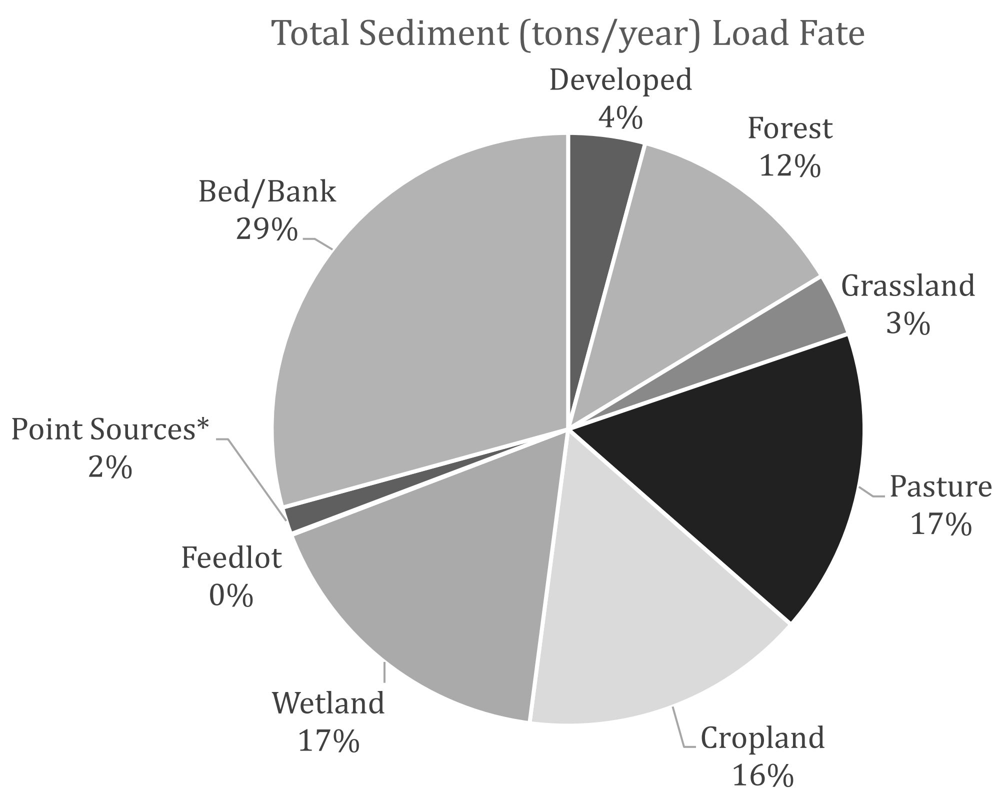


Figure 3-24. HSPF-Modeled Area and Sediment Source Pie Charts in Sisabagamah Creek Reach 659 (*modeled point Source loads were overestimated, and were replaced using loads from 2006 through 2015 monthly average DMR data from the facility which do not represent fate and transport)

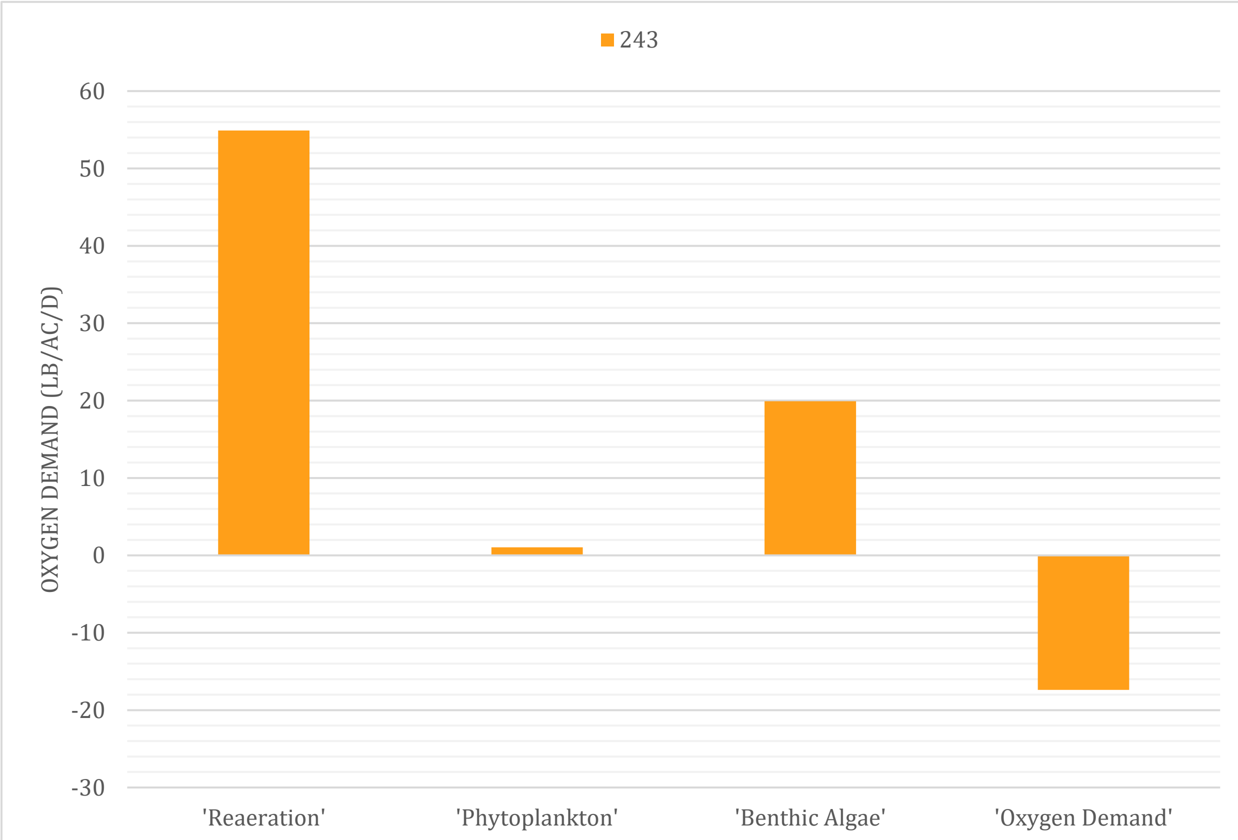


Figure 3-25. HSPF-Modeled In-Stream Drivers of DO in Unnamed Tributary to Sand Creek Reach 679.

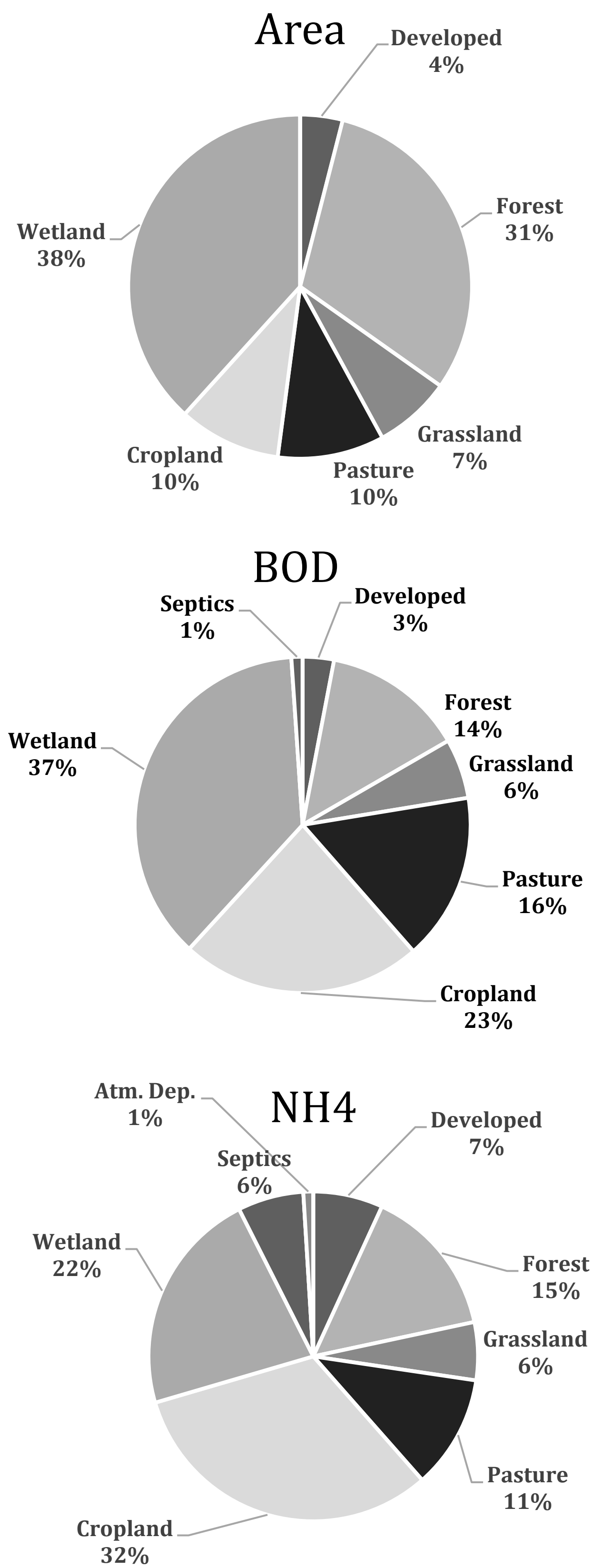
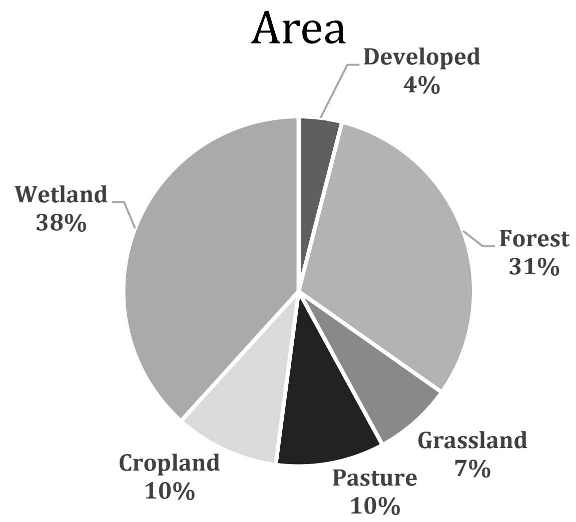
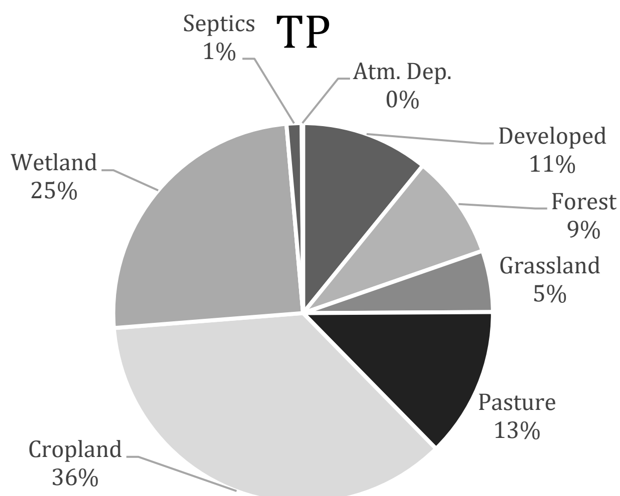


Figure 3-26. Unnamed Tributary to Sand Creek (Reach 679) Watershed Oxygen Demand Source Summary

Figure 3-27. Unnamed Tributary to Sand Creek (Reach 679) Watershed TP Source Summary





3.7.3 Nutrients

This TMDL study addresses numerous nutrient-impaired lakes in the Mississippi-Brainerd Area Watershed. P is the primary nutrient of concern in this TMDL because excess quantities typically drive a wide array of aquatic biological responses that can negatively affect established beneficial uses. High P concentrations are associated with elevated algal production, increased organic content and decay, and increased oxygen depletions that affect fish survival and propagation. Schupp and Wilson [1993] compared the relative abundance and presence of various fish across the spectrum of lake water quality by use of the Carlson Trophic State Index (TSI) [Carlson 1977], as depicted in Figure 3-28. This graphic shows that the highest P concentrations (and TSI values) are associated with carp and black bullheads. Recreational uses are also affected as P concentrations increase, resulting in higher algae production and reduced water clarity. Increased algal abundance and reduced water clarity are negatively related to user preferences for swimmable conditions [Heiskary and Wilson 2005]. Heiskary and Walker [1988] further refined lake quality evaluations based on the frequency of extreme Chl-*a* concentrations (or blooms) as opposed to average summer Chl-*a* concentrations. Both Chl-*a* and transparency exhibit nonlinear responses to increased P concentrations. The observed frequency of Chl-*a* concentrations that exceed 30 ug/L (or severe nuisance conditions in Heiskary and Wilson [2005]) is quite low at P concentrations of approximately 30 ug/L, but those algal blooms increase steadily as P concentrations climb to 100 to 120 ug/L. Algal blooms in severe form are frequently dominated by cyanobacteria that can be periodically toxic. Hence, these interrelationships were the building blocks used to define lake P thresholds that became Minnesota's lake eutrophication standards and the targets for the lake nutrient TMDL allocations described herein.

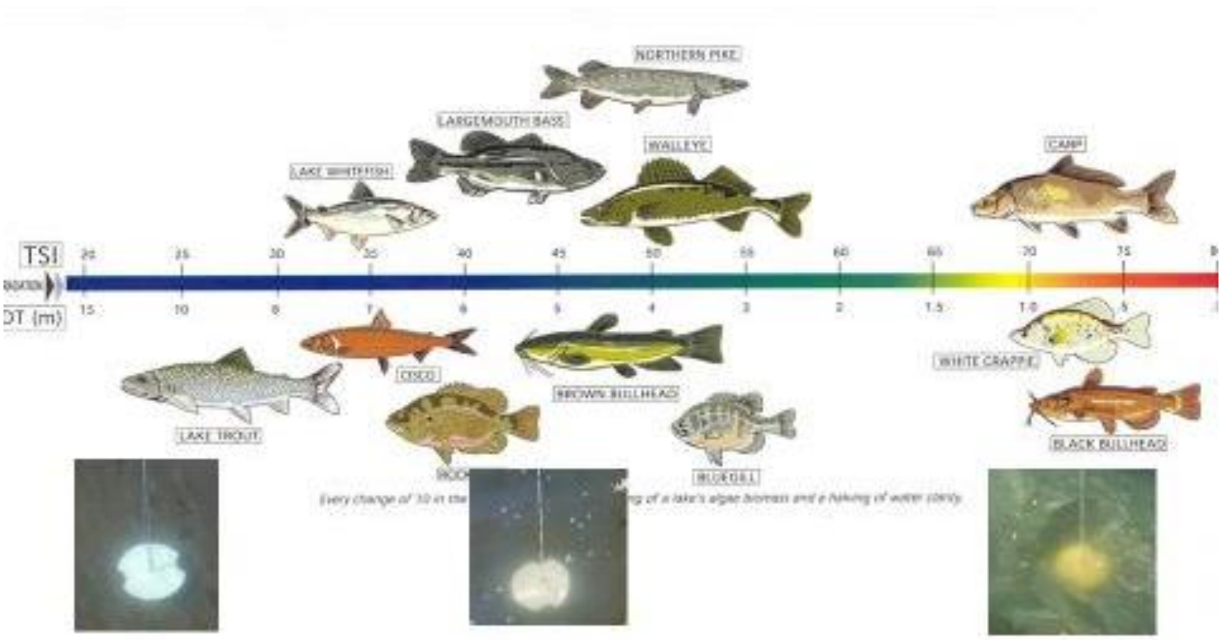


Figure 3-28. Lake Fish Species Relative to Carlson TSI (Top of the Bar) With Average Summer Secchi Transparency (Across the Bottom of the Bar in Meters) (MPCA Graphic Adapted From Schupp and Wilson [1993])

One of the main components of a TMDL is identifying watershed P sources and the magnitude of their contributions to each lake.

Natural background P sources for lakes include surface runoff from the natural landscape, background stream-channel erosion, groundwater discharge, and atmospheric deposition of windblown particulate matter from the natural landscape. Internal loading of P is an additional nonpoint source, which can be of anthropogenic and natural origin. This loading is primarily from release of P from lake sediments or aquatic plants. Typical anthropogenic influences to lakes typically include state- and federal-permitted discharges from wastewater, industrial and commercial entities, shoreland development, impervious surfaces (roads, roofs, and driveways), stormwater via artificial drainages from urban and agricultural lands, row cropping, pastured lands, individual sanitary treatment systems, feedlots, and channelized streams and ditches. The following section provides a brief description of the potential permitted and nonpermitted sources that can contribute to impaired lakes of the Mississippi-Brainerd Watershed.

3.7.3.1 Permitted

Permitted sources are, by definition, point sources, or those that originate from a discrete, identifiable source within the watershed and are regulated by National Pollutant Discharge Elimination System (NPDES) and State Disposal System (SDS) permits. These include the following:

- Regulated municipal and industrial wastewater treatment systems.
- Feedlots requiring NPDES coverage.
- Regulated stormwater.

Detailed information about specific permitted P sources is included in Chapter 4. Any industrial, municipal, or private-entity point source discharging treated wastewater to surface waters of Minnesota must have an NPDES/SDS permit that specifies discharge location(s), volumes, and treated effluent quality. One WWTF (Grey Eagle WWTF) drains to an impaired lake (Trace Lake, and then down to Big Swan Lake), which is addressed in this TMDL.

One permitted CAFO located in the Mississippi-Brainerd Watershed is in the drainage area of Big Swan Lake and is located approximately 1.5 miles east of the lake. Another is located near Moose Lake in the Little Elk River drainage area, but, based on the imagery, are also located in a field 0.5 miles west of Moose Lake that drains to Moose Lake. The CAFO permits state that "in the event of a discharge due to a storm event, as specified in Part IX.A.1.a, from chronic or catastrophic precipitation, from a discharge from a land application site, or any discharge due to noncompliance with the conditions of this Permit, the permittee shall report the discharge in a manner required under Part VIII.B.4.b." CAFOs are generally not allowed to discharge to surface water (with exceptions specified in the permit), but manure from CAFO lagoons is spread locally and can be washed off during precipitation events to contribute to nutrient impairments.

No MS4 areas are located within the watersheds of nutrient-impaired lakes.

As previously mentioned in Section 3.7.2.1, runoff from construction sites is a regulated source as defined by the MPCA's General Permit Authorization to Discharge Stormwater Associated with Construction Activity Under the NPDES/SDS Permit (MNR100001). Permits are required for construction activities disturbing: (1) one acre or more of soil, (2) less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is larger than one acre; or (3) less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. Exposed soil surfaces can erode large quantities of suspended particles from construction sites, including P associated with soils, organic matter, and legacy sources. Industrial stormwater runoff is a regulated source as defined by the MPCA's reissued Multi-Sector Industrial Stormwater NPDES/SDS General Permit (MNR050000), which applies to facilities with Standard Industrial Classification Codes in 10 categories of industrial activities with the potential for significant amounts of materials leaking, leaching, or decomposing and being carried offsite via stormwater. Facilities can obtain a no-exposure exclusion if the site's operations occur under-roof. The permittee is required to develop and implement a storm water pollution prevention plan (SWPPP) that details the stormwater BMPs being implemented to manage stormwater at the facility. Permitted facilities are required to perform runoff sampling and compare those samples to benchmark P concentrations as specified by the EPA. P monitoring is required if a nutrient-impaired waterbody is located within one mile of the facility. A search of the MPCA's Industrial Stormwater Database revealed that 27 industrial facilities exist in Brainerd, Minnesota, with 12 facilities having no-exposure exclusions; 19 industrial facilities exist in Little Falls, Minnesota, with 9 having no-exposure exclusions; and 2 industrial facilities exist in Baxter, Minnesota, with 2 having no-exposure exclusions.

3.7.3.2 Nonpermitted

P sources that are not required to have NPDES/SDS permits include direct watershed runoff, loading from upland watershed tributaries, subsurface sewage treatment systems (SSTSs), atmospheric deposition, and internal loading.

Direct watershed runoff occurs from precipitation and snowmelt events. Runoff from agricultural lands, urban lands, forests, etc. have decomposing organic material, which contributes to P. Additionally, P is attached to sediment and is transferred with sediment into the stream during runoff events.

Loading from upland tributaries occurs from contributing areas outside of the direct lakeshed. These upstream loads are the result of upstream direct watershed runoff, SSTSs, atmospheric deposition, scour/bank erosion, and other sources.

Homes and businesses in each impaired lake watershed are served by SSTSs. A desktop analysis was carried out to estimate the number of homes and cabins around each lake based on manual counting from the latest available Google Earth images for each lake's watershed. The counts were confirmed by county officials and reviewed by local lake groups, if possible. Assumptions and literature values were used to estimate total annual loading from septic systems.

Atmospheric deposition of P on the lake surface can be an important part of the P budget. Atmospheric deposition occurs in wet (carried by precipitation) and dry (dry particles carried as dust) forms. Unlike other nonpoint sources, such as watershed runoff or septic loading, atmospheric P deposition originates at least partly outside of the watershed and cannot be controlled. An atmospheric P deposition of 26.8 mg m^{-2}/yr [Twarowski et al. 2007] was used to quantify average annual total (wet + dry) deposition on the lake surface.

Lake nutrient cycling (or internal loading) refers to several processes that can result in a release of P into the water column, where it can stimulate algal growth as dissolved P forms. In general, lake P cycling can occur from the following types of processes:

1. P released from lake sediments in aerobic and anerobic conditions, as typically moderated by amounts of available iron and other factors such as legacy loading. The historical importance of dairy operations in the area suggests the possibility that manure and dairy cleaning operations may have enriched some sediment/wetland areas and, ultimately, lake sediments.
2. Resuspension of sediments from physical disturbance by bottom-feeding fish (e.g., rough fish such as carp and black bullheads), particularly in shallow-lake areas, can cause resuspension of nutrients, including P. Small particles (clay and silt) are most vulnerable to resuspension; these particles also have the largest specific area (surface area per mass) and, therefore, are capable of holding much more P per unit mass than are larger particles, such as sand.
3. P released from decay of macrophytes, particularly of dense stands of invasive species such as curly-leaf pondweed (*Potamogeton crispus*) and Eurasian watermilfoil (*Myriophyllum spicatum*), which can dominate littoral areas. Curly-leaf pondweed typically dies off in early- to mid-summer and is subject to rapid decay in warm water, thereby potentially contributing to summer P concentrations. In other instances, macrophytes can be effective at stabilizing sediment and limiting resuspension. However, peak macrophyte growth can increase pH and contribute to daily minimum DO

concentrations at the sediment-water interface, which causes P release from sediments. Wave mixing of deeper waters can result in transport of sediment P into the surface waters.

4. High concentrations of TP and dissolved P from tributary and lakeshed runoff pulses can contribute to elevated in-lake concentrations and increased algal growth. The resulting increased biological growth, decay, and deposition may increase the pool of soluble/dissolved P in shallow-lake sediments and, hence, may be mistaken for traditional internal loading sources. Therefore, particular attention was paid to HSPF-generated TP and dissolved P loading rates to each lake.

   Distinguishing internal versus external P loading is more difficult in shallow lakes that are more wind-mixed vertically and subject to tributary-induced horizontal exchange (advective flows).

3.7.3.3 Potential Sources

For the nutrient portion of this TMDL, sources are broken down by what is occurring within each impaired lake and how each potential source needs to be reduced in the TMDL development chapter (Chapter 4). The calibrated HSPF model was used to develop runoff volumes and P load estimates by source within each impaired lake's watershed between 2006 and 2015. This included upland tributaries identified by reach number and direct drainage or lakeshed loading to each lake. Section 3.6 of this report details the HSPF model development that explicitly included regulated and nonregulated sources of P that were, in turn, incorporated into P loads for each lake. The HSPF-generated, lake-specific loadings, along with permitted and nonpermitted sources discussed in Sections 3.7.3.1 and 3.7.3.2, were entered into BATHTUB to quantify each lake's loading capacity by source and to distribute the TMDL allocations and reductions.

4. TMDL Development

4.1 Natural Background Consideration

Natural background conditions refer to inputs that would be expected in natural, undisturbed settings. Sources can include inputs from wildlife and natural geologic processes such as soil loss from upland erosion and stream development, atmospheric deposition, and loading from forested land. For each impairment, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment, which means that natural background is accounted for and addressed throughout the MPCA's waterbody assessment process. Where possible, natural background conditions were also evaluated in the modeling and source assessment portion of this report. These source assessment exercises indicate that natural background inputs are generally low compared to livestock, cropland, streambank, WWTFs, failing SSTSs, and other anthropogenic sources.

Based on the MPCA's waterbody assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest that natural background sources are a major driver of any impairments and/or affect the waterbodies' ability to meet state water quality standards. For all impairments addressed in this TMDL report, natural background sources are implicitly included in the LA portion of the TMDL allocation tables, and TMDL reductions should focus on the major anthropogenic sources identified in the source assessment.

4.2 *E. coli*

LDCs, or the allowable daily *E. coli* load under a wide range of flow conditions, were used to represent each impaired reach's *E. coli*-loading capacity and allocations. This approach results in a flow-variable target that considers the entire flow regime within the time period of interest. Five flow intervals were developed for each reach, and the loading capacity and allocations were developed for each flow interval. The five resulting flow intervals were very high (0 to 10%), high (10 to 40%), mid (40 to 60%), low (60 to 90%), and very low (90 to 100%) in adherence to guidance provided by the EPA [2007].

4.2.1 Loading Capacity

The TMDL is a reach's loading capacity and equals the sum of the LA, the WLA, and a MOS, shown in Equation 4-1:

$$\text{TMDL} = \sum(\text{WLA}) + \sum(\text{LA}) + \text{MOS}. \tag{4-1}$$

LDCs represent the loading capacity, which is another expression for the TMDL. The flow component of the loading capacity curve is the HSPF-simulated daily average flow (2006 through 2015) at the outlet of each impaired reach, and the concentration component is the geometric mean *E. coli* concentration criterion (126 most probable number per 100 milliliters [mpn/100 mL]). Some 2016 observed flow and *E. coli* data were available for Swan River Reach 502, and they were used here in addition to model-simulated flow and *E. coli* data from 2006 through 2015. The loading capacities presented in the TMDL tables are the products of the median-simulated flow in each flow interval, the applicable concentration criterion, and a unit conversion factor. The current load is based on the median flow and the geometric mean of all observed samples in each flow zone. A LDC and TMDL summary table are provided in Section 4.2.5 for each *E. coli*-impaired reach.

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 curve. In this report's *E. coli* TMDL tables, only five points on the entire loading capacity curve are depicted (the midpoints of the designated flow zones). However, the entire curve represents the TMDL and is what the EPA ultimately approved.

4.2.2 WLA Methodology

The WLAs for the TMDLs represent the permitted WWTFs. The five permitted WWTFs that contribute to an *E. coli*-impaired reach are shown in Table 4-1, along with the impairments to which each contributes. The WLAs were calculated as the product of the facility design flows or maximum permitted flow rates, the allowed effluent concentration, and a unit conversion factor. Loads from continuously discharging municipal WWTFs were calculated based on the average wet-weather design flow (AWWDF), which is equivalent to the wettest 30 days of influent flow expected over the course of a year. Loads from controlled municipal discharging WWTFs were calculated based on the maximum daily volume that may be discharged in a 24-hour period. The Grey Eagle, Sobieski, and Flensburg WWTFs are all controlled facilities, and the Swanville and Randall WWTFs are mechanical. The design flow, the *E. coli* concentration limits used to calculate the WLAs, and the WLAs themselves are included in Table 4-1. The WWTFs have fecal coliform regulations instead of *E. coli*, but the *E. coli* standard of 126 org/100 mL was used to calculate the WLAs instead of the fecal coliform permit limit of 200 org/100 mL. The WLAs do not vary based on flow. Occasionally, the portion of the WLA from permitted wastewater dischargers exceeded the low-flow regimes' total daily loading capacity (minus the MOS). In these flow regimes, the WLA and nonpoint-source LAs are denoted by a "*" and should be calculated as the product of the current flow, the *E. coli* concentration limit, and the load conversion factor.

Table 4-1. WWTF Design Flows and *E. coli* WLAs.

Impaired Reach	Facility	Permit	Maximum Daily Volume (mgd)	Permitted Concentration (org/100 mL)	*E. coli* WLA (org/day)	Impaired Reach Point-Source WLA (org/day)
502, Swan River	Grey Eagle WWTF	MN0023566	0.569	126	2.71E+09	4.58E+09
	Sobieski WWTF	MNG580217	0.209	126	9.97E+08	
	Swanville WWTF	MN0020109	0.182	126	8.68E+08	
521, Little Elk River	Randall WWTF	MN0024562	0.182	126	8.68E+08	8.68E+08
522, Pike Creek	Flensburg WWTF	MNG580016	0.163	126	7.77E+08	7.77E+08

mgd = million grams per day
org/day = organisms per day

The Brainerd City MS4 (MS400266) overlaps the watershed of Little Buffalo Creek, and the Little Falls City MS4 (MS400227) overlaps the watershed of Pike Creek. Therefore, allocations were developed for these MS4s by multiplying the loading capacity in each flow zone by a factor representing the percent of the total drainage area located within the MS4 areas as specified by the MPCA. The MS4 factor for Little

Buffalo Creek is 0.024, and the factor for Little Falls City is 0.403. For these TMDLs, the MS4 WLA was calculated separately from the explicit MOS.

E. coli is not typically contributed from construction stormwater, so a construction stormwater WLA was not necessary. No benchmark monitoring of bacteria or *E. coli* is required for industrial permits, and *E. coli* is not typically contributed from industrial stormwater, so an industrial stormwater WLA was not necessary. Because the CAFO is not allowed to discharge except in the event of a chronic or catastrophic precipitation event, no WLA was assigned to the CAFO.

4.2.3 Margin of Safety

The MOS is a portion of the TMDL set aside to account for the uncertainties associated with achieving water quality standards. It is usually expressed in terms of the percentage of the loading capacity, so it may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (expressed in the TMDL as a set-aside load). For *E. coli* TMDLs in the Mississippi-Brainerd Watershed, an explicit MOS was calculated for each impairment as 10% of the loading capacity. This percentage was considered an appropriate MOS because the LDC approach minimizes the uncertainty associated with developing TMDLs. Additionally, 10% is appropriate because no rate of decay or die-off rate of pathogen species was used to calculate the TMDL or create the LDCs.

As stated in the EPA's Protocol for Developing Pathogen TMDLs (EPA 841-R-00-002), the different water factors that affect pathogen survival can include but are not limited to sunlight, temperature, salinity, and nutrient deficiencies, and they vary depending on the water's environmental condition/circumstances. Therefore, asserting that the rate of decay caused by any given combination of environmental variables was sufficient to meet the water quality standard of 126 cfu/100 mL would not be practical.

4.2.4 LA Methodology

The LA represents the load allowed from nonpoint sources or nonregulated sources of *E. coli*. The LA was calculated as the loading capacity minus the MOS and the WLA.

4.2.5 TMDL Summaries

The LDCs and *E. coli* TMDL tables are shown for each impaired reach in Figures 4-1 through 4-8 and Tables 4-2 through 4-9. The required loading capacities, current loads, and load reductions represent the loads for each reach minus any boundary conditions, whereas the LDCs show the entire loading capacity at the outlet of the impaired reach. Based on the geometric mean of available data, reductions are needed for Reach 502 in the mid-flow zone; for Reach 521 in the very-high-, low-, and very-low-flow zones; for Reach 522 in the high-, mid-, and low-flow zones; for Reach 626 in the low- and very-low-flow zones; for Reach 627 in the high-, low-, and very-low-flow zones; for Reach 629 in the mid-, low-, and very-low-flow zones; for Reach 645 in the high-flow zone; and for Reach 695 in the very high-, high-, and mid-flow zones. The percent load reductions needed to meet the loading capacity in each flow interval provide the overall magnitude of the required reductions. Reduction magnitudes also help focus future management actions; if higher reductions are needed in a certain flow interval, management practices should focus on the sources that most likely influence concentrations in those flow conditions.

Exceedances of the *E. coli* target during high flows are typically caused by larger, area-induced, indirect pollutant sources that reach surface waters through watershed runoff. Low-flow exceedances are typically caused by direct pollutant loads or sources near the stream, such as direct defecation by wildlife or livestock in the stream channel or septic system failures [EPA 2007]. The reduction required in each flow zone is shown in the bottom row of Tables 4-2 through 4-9. Reductions represent an overall reduction needed from contributing sources combined and could come from different combinations of sources as long as specified allocations are met.

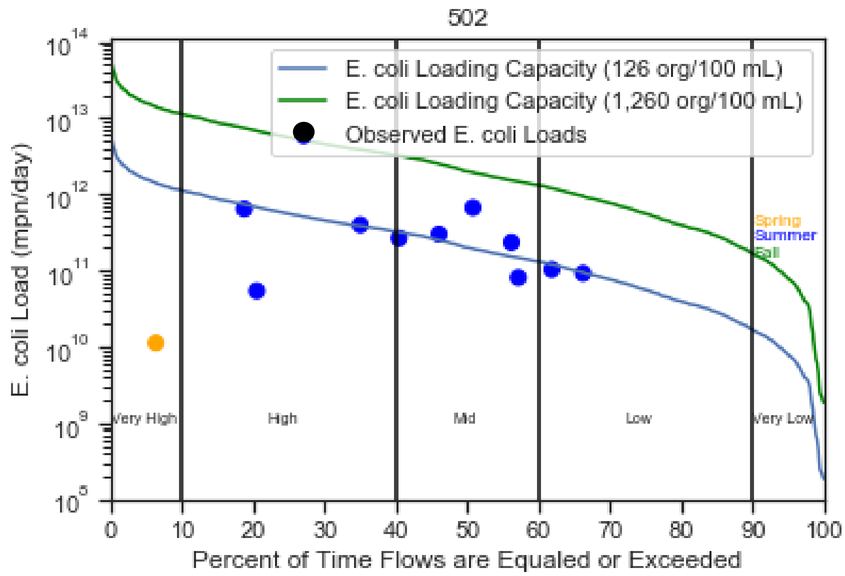


Figure 4-1. Swan River Reach 502 *E. coli* LDC, Generated With Simulated Flow Data for 2006 Through 2015 and Observed 2016 Flow Data From HSPF, and Observed *E. coli* Data From Stations S001-059 and S006-573 From 2006 Through 2016.

Table 4-2. Swan River Reach 502 *E. coli* TMDL Summary, Generated with Simulated Flow Data for 2006 Through 2015 and Observed 2016 Flow Data from HSPF, and Observed *E. coli* Data From Stations S001-059 and S006-573 From 2006 Through 2016.

07010104-502		Flow Zone				
***E. coli* TMDL Component (organisms/day)**		**Very High**	**High**	**Mid**	**Low**	**Very Low**
Allowable Loading at Pourpoint		1.58E+12	5.57E+11	2.00E+11	5.59E+10	7.90E+09
Boundary Condition (BC) Allowable Loading (Reach 626, 627, and 629)		2.51E+11	9.17E+10	2.41E+10	3.78E+09	5.17E+08
Total Daily Loading Capacity (Adjusted for BC)		1.33E+12	4.65E+11	1.76E+11	5.21E+10	7.39E+09
Margin of Safety		1.33E+11	4.65E+10	1.76E+10	5.21E+09	7.39E+08
WLAs	Permitted Wastewater Dischargers	4.58E+09	4.58E+09	4.58E+09	4.58E+09	4.58E+09
	MS4	–	–	–	–	–
	Industrial and Construction Stormwater	–	–	–	–	–
LA		1.19E+12	4.14E+11	1.54E+11	4.23E+10	2.07E+09
Current Load at Pourpoint		1.25E+10	2.30E+11	2.47E+11	5.12E+10	(a)
Current BC Load (Reach 626, 627, and 629)		(a)	1.03E+11	4.75E+10	1.15E+10	1.46E+09
Current Load (Adjusted for BC)		(a)	1.27E+11	2.00E+11	3.96E+10	(a)
Reduction Required		(a)	0%	12%	0%	(a)

(a) No data available to calculate adjusted current load

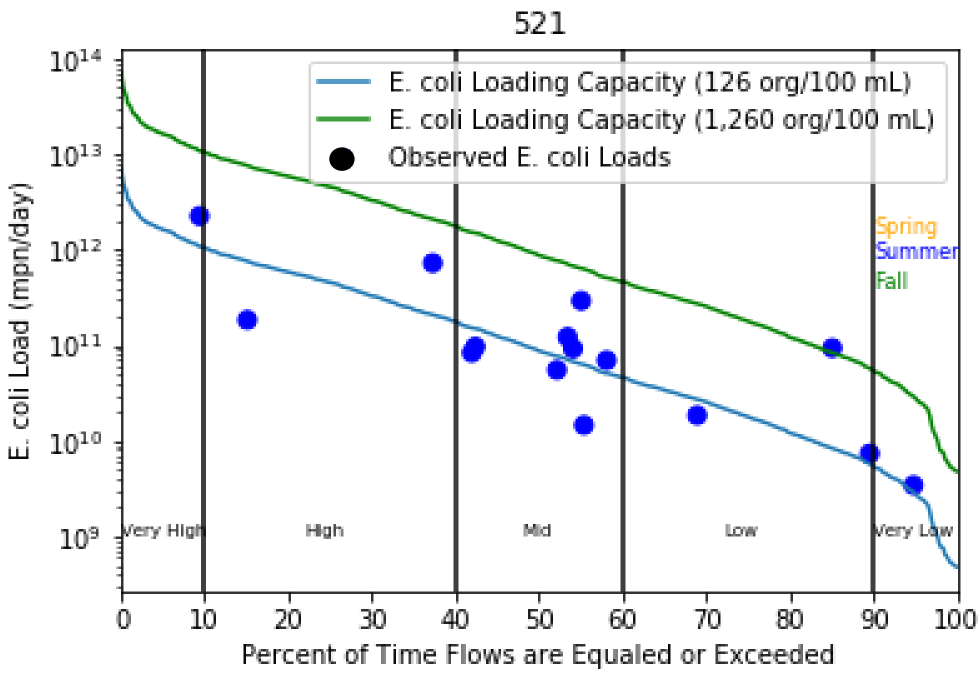


Figure 4-2. Little Elk River Reach 521 *E. coli* LDC, Generated With Simulated Flow Data From HSPF, and Observed *E. coli* Data From Station S002-950

Table 4-3. Little Elk River Reach 521 *E. coli* TMDL Summary.

07010104-521		Flow Zone				
***E. coli* TMDL Component (org/day)**		**Very High**	**High**	**Mid**	**Low**	**Very Low**
Total Daily Loading Capacity		1.62E+12	4.54E+11	8.74E+10	1.77E+10	2.80E+09
Margin of Safety		1.62E+11	4.54E+10	8.74E+09	1.77E+09	2.80E+08
WLAs	Permitted Wastewater Dischargers	8.68E+08	8.68E+08	8.68E+08	8.68E+08	8.68E+08
	MS4	–	–	–	–	–
	Industrial and Construction Stormwater	–	–	–	–	–
LA		1.46E+12	4.08E+11	7.78E+10	1.51E+10	1.65E+09
Total Current Load		3.36E+12	4.15E+11	8.60E+10	3.80E+10	3.29E+09
Reduction Required		52%	0%	0%	53%	15%

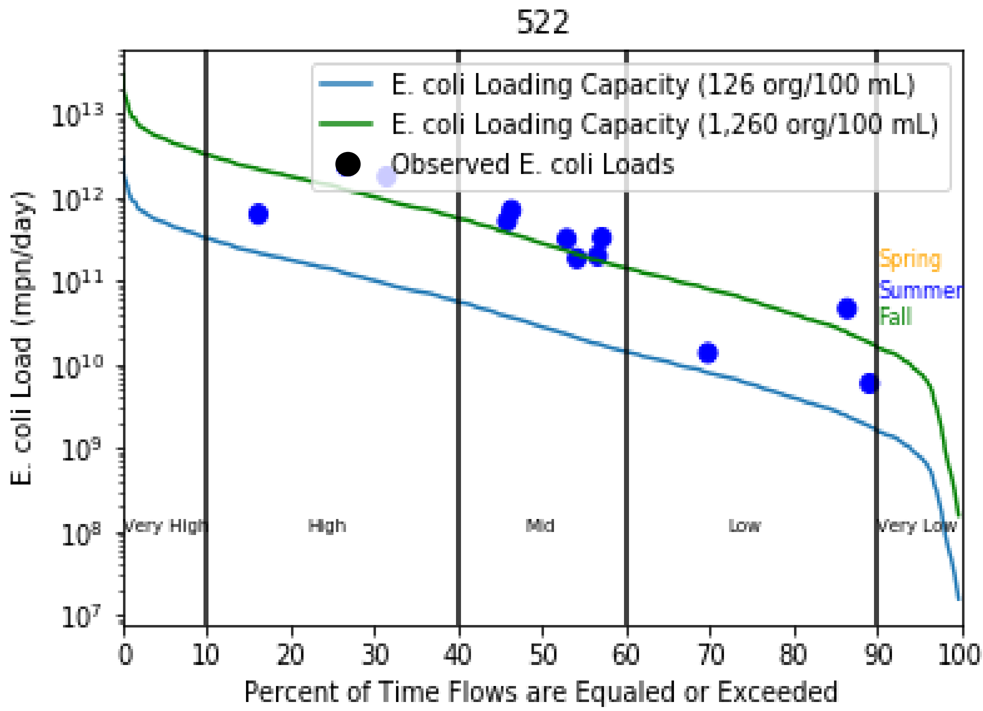


Figure 4-3. Pike Creek Reach 522 *E. coli* LDC, Generated with Simulated Flow Data From HSPF, and Observed *E. coli* Data From Station S006-574

Table 4-4. Pike Creek Reach 522 *E. coli* TMDL Summary.

07010104-522		Flow Zone				
***E. Coli* TMDL Component (org/day)**		**Very High**	**High**	**Mid**	**Low**	**Very Low**
Total Daily Loading Capacity		4.93E+11	1.36E+11	2.75E+10	5.71E+09	7.77E+08
Margin of Safety		4.93E+10	1.36E+10	2.75E+09	5.71E+08	7.77E+07
WLAs	Permitted Wastewater Dischargers	7.77E+08	7.77E+08	7.77E+08	7.77E+08	*
	Little Falls City MS4 (MS400227)	1.20E+10	3.31E+09	6.69E+08	1.39E+08	1.89E+07
	Industrial and Construction Stormwater	–	–	–	–	–
LA		4.31E+11	1.18E+11	2.33E+10	4.22E+09	6.80E+08
Total Current Load		(a)	1.02E+12	3.80E+11	2.72E+10	(a)
Reduction Required		(a)	87%	93%	79%	(a)

Note: The WLAs for the permitted wastewater dischargers are based on facility design flow. The WLA exceeds the low-flow regime total daily loading capacity and is denoted in the table by a "*". For this flow regime, the WLA and nonpoint-source LA is determined by the following formula: allocation = (flow contribution from a given source) × (*E. coli* standard) × conversion factor.

(a) No data available to calculate current load

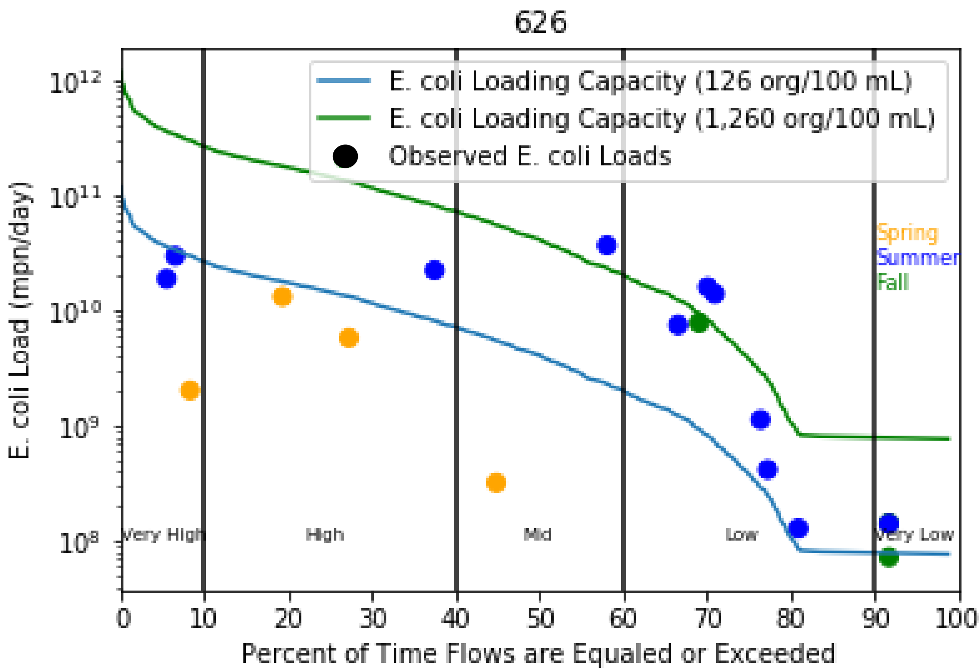


Figure 4-4. Unnamed Creek Reach 626 *E. coli* LDC, Generated With Simulated Flow Data From HSPF, and Observed *E. coli* Data From Station S005-041

Table 4-5. Unnamed Creek Reach 626 *E. coli* TMDL Summary.

07010104-626		Flow Zone				
***E. coli* TMDL Component (org/day)**		**Very High**	**High**	**Mid**	**Low**	**Very Low**
Total Daily Loading Capacity		3.69E+10	1.43E+10	4.08E+09	5.40E+08	7.90E+07
Margin of Safety		3.69E+09	1.43E+09	4.08E+08	5.40E+07	7.90E+06
WLAs	Permitted Wastewater Dischargers	–	–	–	–	–
	MS4	–	–	–	–	–
	Industrial and Construction Stormwater	–	–	–	–	–
LA		3.32E+10	1.29E+10	3.67E+09	4.86E+08	7.11E+07
Total Current Load		1.17E+10	1.38E+10	3.93E+09	3.04E+09	1.13E+08
Reduction Required		0%	0%	0%	82%	30%

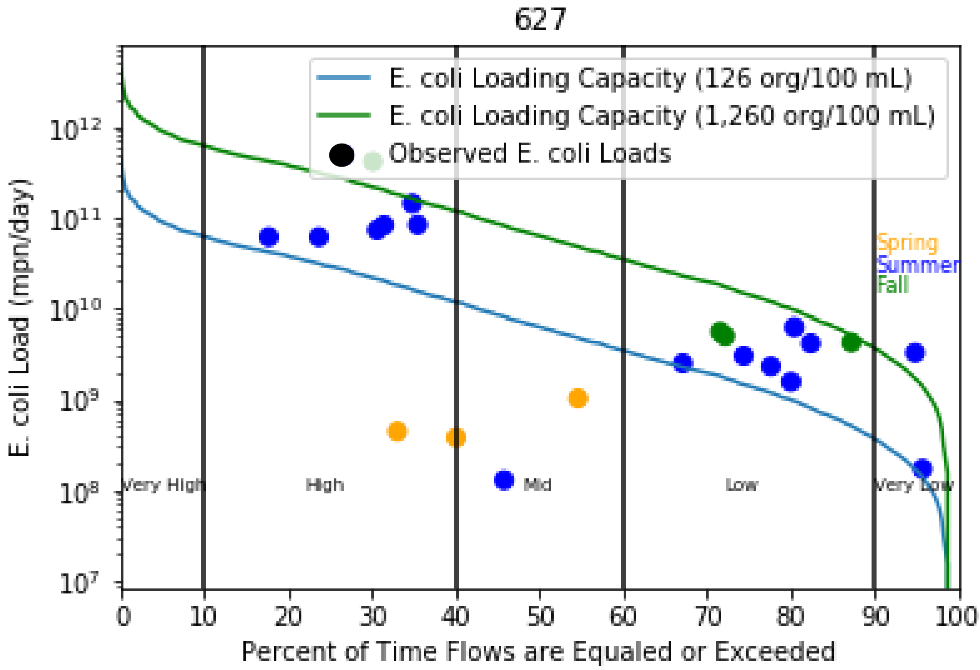


Figure 4-5. Schwanke Creek Reach 627 *E. coli* LDC, Generated With Simulated Flow Data From HSPF, and Observed *E. coli* Data From Station S005-035.

Table 4-6. Schwanke Creek Reach 627 *E. coli* TMDL Summary.

07010104-627		Flow Zone				
***E. coli* TMDL Component (org/day)**		**Very High**	**High**	**Mid**	**Low**	**Very Low**
Total Daily Loading Capacity		8.95E+10	2.90E+10	6.26E+09	1.42E+09	1.71E+08
Margin of Safety		8.95E+09	2.90E+09	6.26E+08	1.42E+08	1.71E+07
WLAs	Permitted Wastewater Dischargers	–	–	–	–	–
	MS4	–	–	–	–	–
	Industrial and Construction Stormwater	–	–	–	–	–
LA		8.05E+10	2.61E+10	5.63E+09	1.28E+09	1.54E+08
Total Current Load		(a)	6.83E+10	3.00E+08	4.21E+09	8.32E+08
Reduction Required		(a)	57%	0%	66%	79%

(a) No data available to calculate current load

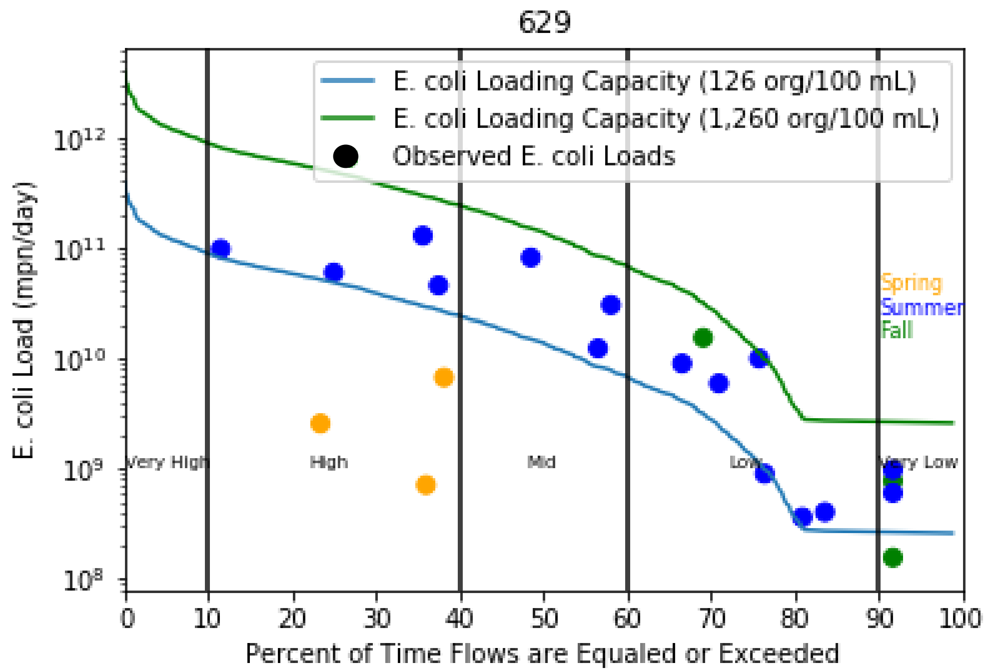


Figure 4-6. Unnamed Creek Reach 629 *E. coli* LDC, Generated With Simulated Flow Data From HSPF, and Observed *E. coli* Data From Station S005-036

Table 4-7. Unnamed Creek Reach 629 *E. coli* TMDL Summary.

07010104-629		Flow Zone				
***E. coli* TMDL Component (org/day)**		**Very High**	**High**	**Mid**	**Low**	**Very Low**
Total Daily Loading Capacity		1.25E+11	4.83E+10	1.38E+10	1.82E+09	2.67E+08
Margin of Safety		1.25E+10	4.83E+09	1.38E+09	1.82E+08	2.67E+07
WLAs	Permitted Wastewater Dischargers	–	–	–	–	–
	MS4	–	–	–	–	–
	Industrial and Construction Stormwater	–	–	–	–	–
LA		1.12E+11	4.35E+10	1.24E+10	1.64E+09	2.40E+08
Total Current Load		(a)	2.14E+10	4.33E+10	4.28E+09	5.16E+08
Reduction Required		(a)	0%	68%	57%	48%

(a) No data available to calculate current load

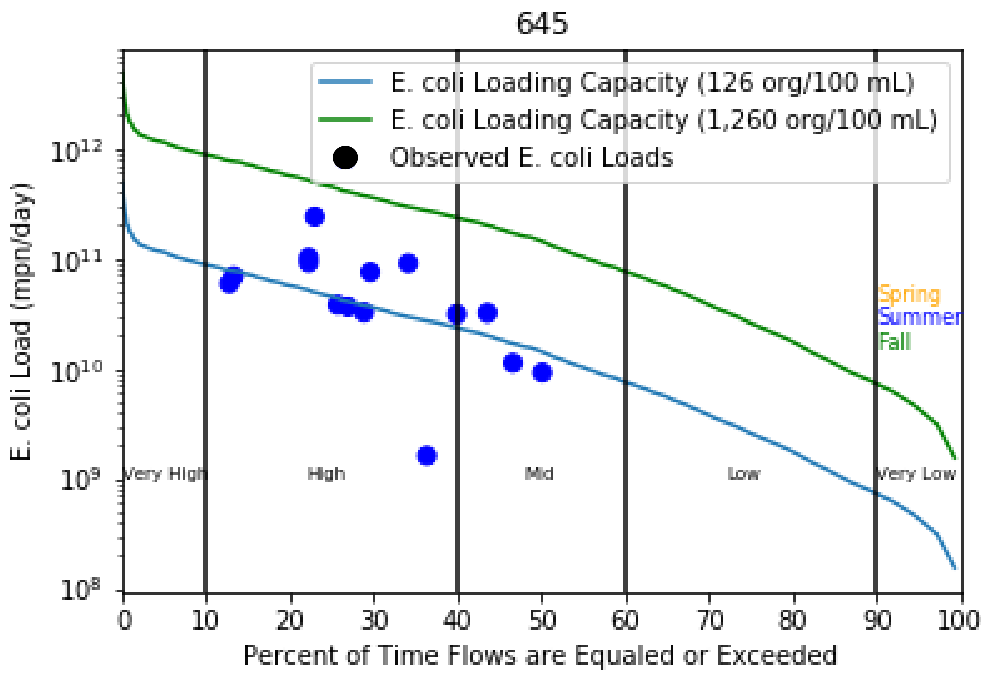


Figure 4-7. Hay Creek Reach 645 *E. coli* LDC, Generated With Simulated Flow Data From HSPF, and Observed *E. coli* Data From Station S006-250.

Table 4-8. Hay Creek Reach 645 *E. coli* TMDL Summary.

07010104-645		Flow Zone				
***E. coli* TMDL Component (org/day)**		**Very High**	**High**	**Mid**	**Low**	**Very Low**
Total Daily Loading Capacity		1.14E+11	4.51E+10	1.43E+10	2.57E+09	4.34E+08
Margin of Safety		1.14E+10	4.51E+09	1.43E+09	2.57E+08	4.34E+07
WLAs	Permitted Wastewater Dischargers	–	–	–	–	–
	MS4	–	–	–	–	–
	Industrial and Construction Stormwater	–	–	–	–	–
LA		1.03E+11	4.06E+10	1.29E+10	2.31E+09	3.91E+08
Total Current Load		(a)	4.98E+10	1.40E+10	(a)	(a)
Reduction Required		(a)	10%	0%	(a)	(a)

(a) No data available to calculate current load

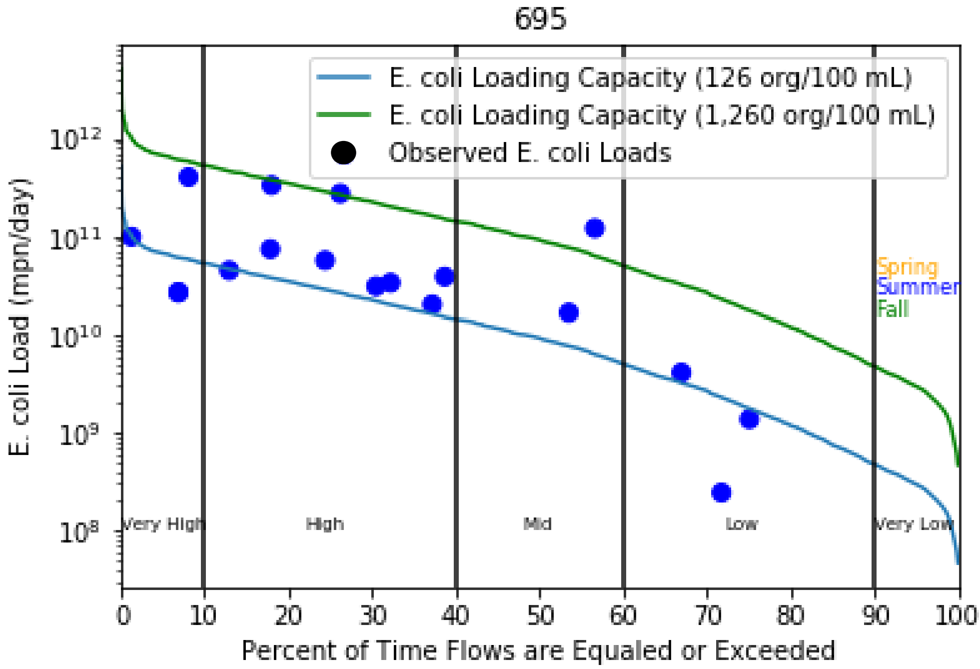


Figure 4-8. Little Buffalo Creek Reach 695 *E. coli* LDC, Generated With Simulated Flow Data From HSPF, and Observed *E. coli* Data From Station S006-602.

Table 4-9. Little Buffalo Creek Reach 695 *E. coli* TMDL Summary.

07010104-695		Flow Zone				
***E. coli* TMDL Component (org/day)**		**Very High**	**High**	**Mid**	**Low**	**Very Low**
Total Daily Loading Capacity		6.69E+10	2.78E+10	9.17E+09	1.77E+09	2.95E+08
Margin of Safety		6.69E+09	2.78E+09	9.17E+08	1.77E+08	2.95E+07
WLAs	Permitted Wastewater Dischargers	–	–	–	–	–
	Brainerd City MS4 (MS400266)	2.70E+10	1.12E+10	3.70E+09	7.14E+08	1.19E+08
	Industrial and Construction Stormwater	–	–	–	–	–
LA		3.32E+10	1.38E+10	4.55E+09	8.80E+08	1.46E+08
Total Current Load		7.16E+10	6.67E+10	5.94E+10	8.36E+08	(a)
Reduction Required		6%	58%	85%	0%	(a)

(a) No data available to calculate current load

4.3 Aquatic Macroinvertebrate Bioassessments

The Stressor ID Study [MPCA 2019] found that the main stressor in Sisabagamah Creek (Reach 659) is a lack of habitat caused by flow alteration and the amount of sediment coming into the stream from streambank instability and no vegetated ditch banks; the study also found that TSS is a stressor to the creek's macroinvertebrates. TSS contributions generally increase because of flow alteration and stream bank instability, and high concentrations of TSS decrease the likelihood of a good instream macroinvertebrate habitat. Therefore, TSS was used a surrogate to address the MIBI impairment in Sisabagamah Creek (Reach 659). In addition, in the tributary to Sand Creek (Reach 679), the study discovered that the main stressor is elevated nutrients and low levels of DO, along with poor habitat. Because elevated nutrients are listed as a main stressor, and they lead to low levels of DO, TP was used as a surrogate to address the MIBI impairment in the unnamed tributary to Sand Creek (Reach 679). The two impaired aquatic macroinvertebrate bioassessment streams addressed in this TMDL did not have continuous flow data available. The model-simulated flow is available for the TMDL time period (2006 through 2015), but no observed data are available during this time period. Applicable observed data are available in Reach 659 for 2016 (TSS) and Reach 679 (DO) for 2017. Poor habitat in both MIBI impaired streams is further addressed in the WRAPS report.

For the TSS invertebrate TMDL in Sisabagamah Creek, the LDC approach was used. LDCs represent the allowable daily load under a wide range of flow conditions and were used to represent the loading capacity and allocations of each impaired reach. This approach results in a flow-variable target that considers the entire flow regime within the time period of interest. Five flow intervals were developed for each reach, and the loading capacity and allocations were developed for each flow interval. The five flow intervals were very high (0% to 10%), high (10% to 40%), mid (40% to 60%), low (60% to 90%), and very low (90% to 100%) in adherence to guidance provided by the EPA [2007]. For the TP invertebrate TMDL in the unnamed tributary to Sand Creek, a LDC is shown, but because the standard is based on the growing season average, the overall loading capacity was based on the overall median growing season flow and the TP standard.

4.3.1 Loading Capacity

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 average flow, virtually the full spectrum of allowable loading capacities is represented by the resulting curve. The TMDL tables in this report depict only five points on the loading capacity curve (one for each flow zone). However, it should be understood that the entire curve represents the TMDL. The TMDL is a reach’s loading capacity and equals the sum of the LA, the WLA, and a MOS, shown in Equation 4-2:

$$\text{TMDL} = \sum(\text{WLA}) + \sum(\text{LA}) + \text{MOS}. \qquad (4\text{-}2)$$

LDCs represent the loading capacity, which is another expression for the TMDL. The flow component of the loading capacity curve is based on HSPF-simulated daily average flows (2006 through 2015), whereas the concentration component is the TSS concentration criteria of 15 mg/L for the TSS TMDL and the TP concentration criteria of 0.05 mg/L for the TP TMDL. The loading capacities in the TMDL tables are the products of the median-simulated flow in each flow zone, the concentration criterion, and a unit conversion factor.

4.3.2 WLA Methodology

No regulated NPDES wastewater dischargers drain to the unnamed tributary in Sand Creek Reach 679. One regulated NPDES wastewater discharger, American Peat Technology LLC, drains to Sisabagamah Creek Reach 659. It has been assigned a TSS WLA for this TMDL that represents the product of the TSS effluent limit, the average daily flow rate, and a unit conversion factor, as shown in Table 4-10. This WLA is the same as that assigned to the downstream South Metro Mississippi River TSS TMDL (34 kg/day or 0.0376 tons/day).

Table 4-10. Permitted TSS Allocations for Point Sources Draining to Sisabagamah Creek.

Impaired Reach	Facility	Permit	Average Daily Flow (mgd)	Permitted Concentration (mg/L)	TSS WLA (tons/day)
659	American Peat Technology LLC	MN0057533	0.3	30	0.0376

MS4 allocations are not needed because no MS4s drain to Sisabagamah Creek.

County estimates of the total area under construction were area weighted to estimate the areas under construction in the impaired waterbody watershed. The percentage of construction acres in each watershed was multiplied by the loading capacity (minus the MOS) to determine the construction stormwater WLA. Average annual construction acres from 2009 through 2014 range from 0.010% of the area to 0.028% of the area. To add in a small MOS, 0.03% of the area in all impairments was assumed to be under construction.

The number of acres regulated under 2015 industrial permits was available from MPCA industrial stormwater permit data by county. The county estimates of total industrial areas were area weighted to estimate industrial areas in the impaired waterbody watershed. The percentage of industrial acres in each watershed was multiplied by the loading capacity to determine the industrial stormwater WLA. The average of annual industrial stormwater acres in 2015 ranged from 0.003% of the area to 0.062% of the area for different impaired reaches; to add in a small MOS, 0.07% of the area in all impairments was assumed to be industrial.

To determine the load allowed from combined industrial and construction stormwater, the loading capacities for all TSS and TP aquatic macroinvertebrate bioassessment TMDLs (minus the MOS) was multiplied by 0.001 to represent 0.03% from construction stormwater and 0.07% from industrial permits. The construction stormwater/industrial stormwater WLA was calculated separately from the explicit MOS.

4.3.3 Margin of Safety

For the Sisabagamah Creek Reach 659 TSS TMDL and the unnamed tributary to Sand Creek Reach 679 DO TMDL, an explicit MOS was calculated for each impairment as 10% of the loading capacity. The calculation of the loading capacity is the product of monitored flow, the target concentration, and a conversion factor. Ten percent was considered an appropriate MOS because the LDC approach minimizes the uncertainty associated with the development of TMDLs.

4.3.4 LA Methodology

The LA represents the load allowed from nonpoint sources or nonregulated sources of TSS or TP for the aquatic macroinvertebrate bioassessment TMDLs. The LAs were calculated as the loading capacity minus the MOS and the WLA.

4.3.5 TMDL Summaries

For the Sisabagamah Creek TMDL, the LDC and TSS TMDL table for the invertebrate impaired reach are shown in Figure 4-9 and Table 4-11. For the unnamed tributary to Sand Creek TMDL, a TP LDC, shown in

Figure 4-10, was developed to show the relative relationship of loads during different flow conditions. The TP LDC does not represent the actual TMDL since the TP standards are based on growing season averages. The TP TMDL table for the invertebrate impaired reach is shown in Table 4-12. Current loads for the Sisabagamah TSS TMDL were calculated using the median flow in each flow zone and the simulated 95th percentile TSS concentration in each flow zone, and the percent load reduction needed to meet the loading capacity in each flow interval were calculated to provide the magnitude of the required reductions at different flows. Reduction magnitudes by flow help focus future management actions; if higher reductions are needed in a certain flow interval, management practices should focus on the sources that most likely influence concentrations in those flow conditions. Exceedances of the TMDL target during higher flows are typically caused by storm-related wash-off or high-flow related in-stream/near-stream erosion and scour (bed and bank loads). Low-flow exceedances are more likely to be caused by direct pollutant loads or sources near the stream [EPA 2007]. In the Sisabagamah Creek TSS TMDL table, reductions are needed during high flows that lead to the impairment of the macroinveretbrates. Overall, observed data collected during 2016 are in agreeance with model results, showing one of eleven samples exceeding 15 mg/L TSS. The focus of implementation for the TSS improvements should focus on the high flow sediment contributions. The TP TMDL for the unnamed tributary to Sand Creek was developed as the product of the median growing season flow (June 1 through September 30) from the HSPF model at the outlet, the North River TP standard of 0.05 mg/L, and a conversion factor. Current loads for the unnamed tributary to Sand Creek TP TMDL were calculated using the simulated median growing season flow and the simulated mean growing season concentration, and the overall percent load reduction needed was calculated. The overall P reduction required in the unnamed Tributary to Sand Creek is 40%.

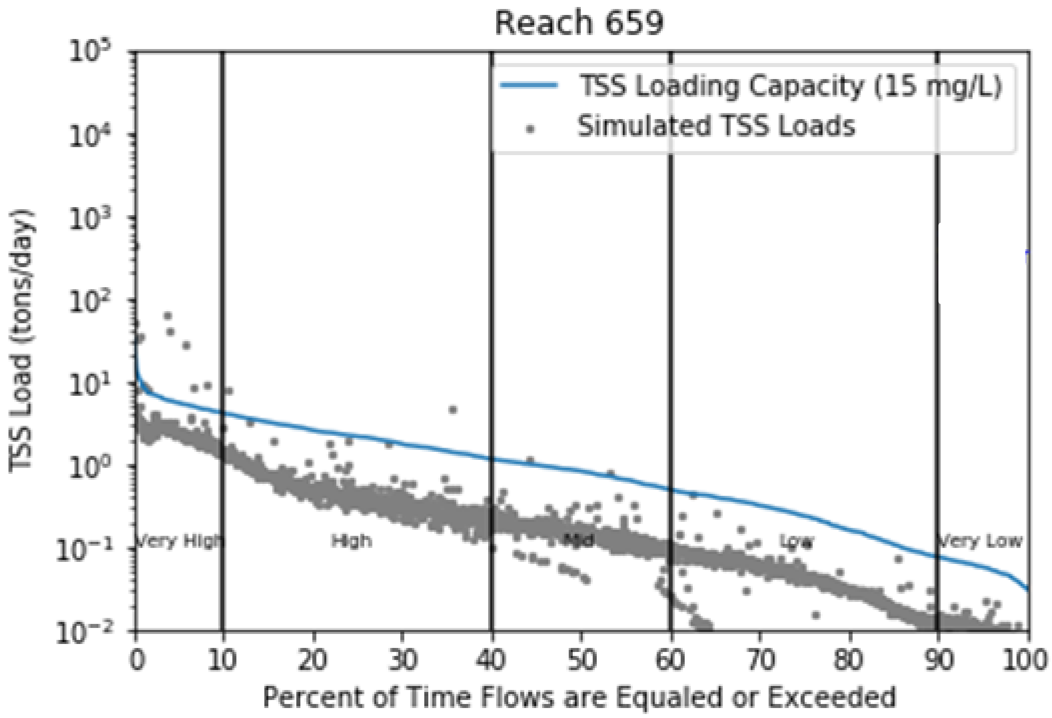


Figure 4-9. Sisabagamah Creek Reach 659 TSS LDC Generated With Simulated Flow and TSS From HSPF

Table 4-11. Sisabagamah Creek Reach 659 TSS TMDL Summary.

07010104-659		Flow Zone				
TSS TMDL Component (tons/day)		Very High	High	Mid	Low	Very Low
TMDL Load at TMDL Reach		5.5	2.1	0.82	0.24	0.058
Margin of Safety		0.55	0.21	0.082	0.024	0.0058
WLAs	Permitted Wastewater Dischargers	0.038	0.038	0.038	0.038	0.038
	MS4	–	–	–	–	–
	Industrial/Construction	0.0049	0.0019	0.0007	0.0002	0.0001
LA		4.9	1.89	0.70	0.18	0.013
Current Load at TMDL Reach		6.1	0.69	0.21	0.054	0.014
Reduction Required		10%	0%	0%	0%	0%
Overall Reduction Required		0%				

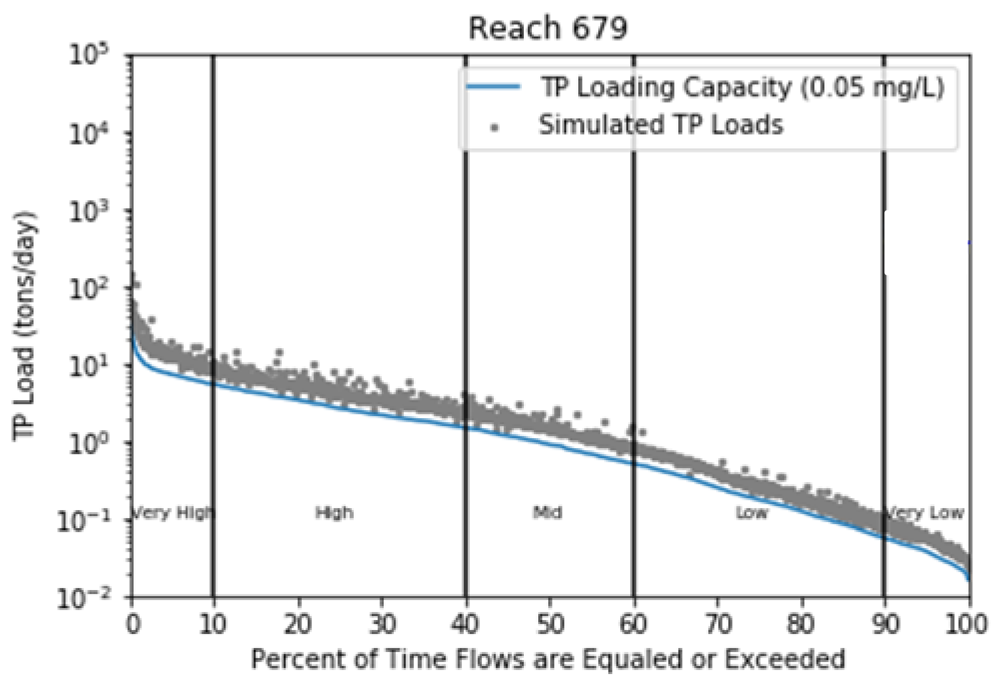


Figure 4-10. Unnamed Tributary to Sand Creek Reach 679 TP LDC Generated With Simulated Flow and TP From HSPF

Table 4-12. Unnamed Tributary to Sand Creek Reach 679 TP TMDL Summary.

07010104-679		
TP TMDL Component (lbs/day)		
TMDL Load at TMDL Reach		0.89
Margin of Safety		0.089
WLAs	Permitted Wastewater Dischargers	–
	MS4	–
	Industrial/Construction	0.0008
LA		0.80
Current Load at TMDL Reach		1.5
Reduction Required		40%

4.4 Nutrients

The loading capacity for impaired lakes was determined by using calibrated BATHTUB models based on HSPF loads and the growing season monitored mean values for TP, Chl-*a*, and Secchi disk from 2006 through 2015. The allowable loading capacity (or the TMDL) is defined as the maximum allowable pollutant load that will allow water quality standards to be met. Loading capacities were defined by using the calibrated BATHTUB models and reducing source loads until the appropriate standards for each lake are achieved.

The TMDL equation is as follows:

$$TMDL = \sum(WLA) + \sum(LA) + MOS. \quad (4\text{-}3)$$

Here, LA is from nonpoint sources, WLA is the load from point sources and permitted discharges, and MOS is an explicit amount (usually expressed as a percent of the TMDL) used to increase the likelihood of compliance by accounting for potentially unknown or unquantifiable nutrient sources.

Watershed loading to the lakes is derived by using the calibrated Mississippi-Brainerd Area HSPF model [Lupo 2016; Tetra Tech 2018]. Mean annual runoff and flow-weighted mean TP concentrations with mean coefficients of variation (CVMeans) for each tributary and lakeshed are inputs to each lake's BATHTUB model as defined in Section 4.4.1.

4.4.1 Lake Model

Developed by Dr. William W. Walker for the US Army Corps of Engineers, the lake-modeling software BATHTUB (Version 6.1) integrates watershed runoff with lake water quality. This publicly available peer-reviewed model has been successfully implemented in lake studies throughout the US for more than 30 years. It uses steady-state annual water and nutrient mass balances to model advective transport, diffusive transport, and nutrient sedimentation [Walker 2006]; lake responses (e.g., Chl-*a* concentration or SDD) are predicted via empirical relationships [Walker 1985]. BATHTUB allows users to specify single lake segments (lake bays) or multiple segments with complicated flow routing, and then calculates lake response for each segment from morphometry and user-supplied lake fetch data. The cumulative annual P load of all external watershed and internal lake sources can be empirically related to lake recreation period (e.g., growing season) conditions [Walker 1996] and expressed as average summer TP, Chl-*a,* and Secchi transparency. This predictive model includes statistical analyses to account for variability and uncertainty.

4.4.1.1 Representation of Lake Systems in BATHTUB Models

Ten of the eleven lakes in this report were represented by a single lake segment as defined by lake surface area, mean depth, and fetch length. Big Swan Lake had two distinct bays that required two separate segments in the BATHTUB model. The lake surface area, its mean depth, and each bay's length and fetch can be determined by using GIS and lake bathometry data. Lakes in series or those that are joined or in close proximity were assessed separately. The HSPF-derived TMDL period (2006 through 2015) average annual water and P inputs to each lake were entered for all upgradient tributaries and each lake's immediate drainage areas (lakesheds). Additionally, lake-specific estimated SSTS (septic) contributions were added, along with Grey Eagle WWTP contributions for Trace Lake. The annual precipitation and evaporation used in these models were 0.73 to 0.79 m/year and 0.6 m/year, respectively, for all lakes. Precipitation values were based on HSPF climate station average values; the evaporation value came from the Minnesota Lake Water Quality Report: Developing Nutrient Criteria [MPCA 2005]. Observed lake water quality data (TP, Chl-*a*, SDD, and conservative substances) were entered as growing season (June through September) mean and CVMean values for the TMDL period. Tributary inflows to each lake segment include mean annual flow volume (hm^3); pollutant concentrations are entered as flow-weighted mean concentrations and CVMeans.

Lakes in series include Elm Island/Ripple lakes and Trace/Big Swan Lakes. TMDL allocations for upgradient lakes were determined separately, with corresponding reductions incorporated into the downstream lake TMDL allocation. Hence, the inclusion of explicit MOS in the upstream lake offers an implicit MOS for the downstream lake.

BATHTUB includes several model choices for predicting TP, Chl-*a*, SDD, and other lake responses, with selected models listed by lake in Appendix M. Additionally, a complete listing of inputs and modeling coefficients is included in Appendix N. Although it is not a model that is typically used, the Second-Order Fixed model was selected for Big Swan, Crow Wing, and Gun lakes because every other P model greatly overpredicts in-lake P concentrations.

4.4.1.2 Modeling Sequence

Lake modeling can determine the present-day P loads that could exceed lake standards as well as the allowable P loads and reductions required to achieve water quality standards and MOS. The modeling of present-day conditions was completed for each lake and calibrated to the TMDL time period's (2006 through 2015) growing season average water quality data. Each of the lake's BATHTUB models was calibrated by adjusting calibration coefficients and/or internal loading rates. The calibration coefficient adjustments were relatively minor for all of the Mississippi-Brainerd Area TMDL lakes.

4.4.2 Loading Capacity

The loading capacity for each lake TMDL was determined by adjusting tributary, lakeshed, internal, and SSTS loads to achieve a targeted average P concentration of 59 ug/L for shallow lakes or 39 ug/L for deep lakes in the NCHF ecoregion, and 29 ug/L for lakes in the NLF ecoregion. In many cases, the reductions required to achieve water quality standards in the lake require the tributaries and lakeshed to be reduced below the ecoregion river standards that the lakes reside in, especially for the Central River Nutrient Region river concentration of 100 ug/L and North River Nutrient Region river concentration of 50 ug/L. To determine how much reduction should be applied to tributaries and lakesheds, a load reduction analysis approach ensures that load reductions are achievable. It was assumed that load reductions are most likely to come from the following land cover types: cropland, pasture land, and developed land. Therefore, reductions were applied based on the percentage of these land cover types existing in the area draining to each impaired lake. The load from these land uses is considered to be the "reducible load." Land use load reductions are weighted based on the contributions of each of the land use's load to the total "reducible load," and from the final reduced loads and areas, a loading rate can be calculated to determine if the reductions are realistic. The SSTS allocation was set to zero P loading and assumes 100% future compliance to county SSTS regulations. Many of the lakes in the Mississippi-Brainerd Watershed have large drainage areas dominated by wetlands that result in highly flushed lakes. This along with river standards of 50 ug/L and lake standards of 30 ug/L require tributary and lakeshed reductions to exceed ecoregion standards.

4.4.2.1 Subsurface Sewage Treatment System Loading

County officials provided the total number of residences on each lake as well as septic compliance rates; officials from Aitkin (Elm Island, Fleming, Gun, and Ripple lakes) and Todd (Big Swan Lake) gave year-round versus seasonal residences figures, with an assumption of 10% seasonal occupancy applied to the remaining lakes. The number of occupied homes (year-round and seasonally), the average house size, the noncompliance rates, and the P loss rates of complying and noncomplying septic systems are included in Table 4-13. Noncomplying TP loss rates were determined based on soil data with sandy soils having a loss rate of 75% and mixed soils having a loss rate of 50%. An estimate of the annual TP loss per capita of 1 kg [Heiskary and Wilson 2005] was used to estimate mean annual TP loading on septic systems.

The HSPF septic loading estimates are based on large-scale county data and, therefore, are not appropriately detailed for a TMDL in small lakesheds. Refined estimates of septic system loading were developed independently for each directly impaired lakeshed, with HSPF lakeshed septic system P loads replacing these refined estimates.

Table 4-13. Subsurface Sewage Treatment System Information.

Lake	Year-Round Residences	Seasonal Residences	Average Household Size	Noncompliance Rate (%)	TP Loss Rate Complying (%)	TP Loss Rate Noncomplying (%)
Big Swan	50	76	2.46	2	5	50
Moose	39	4	2.46	0	5	75
Trace	4	1	2.46	20	5	50
Crow Wing	131	15	2.38	4	5	75
Sebie	25	3	2.38	4	5	75
Fawn	43	5	2.38	4	5	75
Lower Mission	79	6	2.38	4	5	75
Elm Island	32	66	2.02	2	5	75
Fleming	25	64	2.02	1	5	50
Gun	22	110	2.02	2	5	50
Ripple	34	49	2.02	2	5	50

4.4.2.2 Atmospheric Loading

An atmospheric P deposition of 26.8 milligrams per meter squared per year (mg m^{-2}/yr) [Twarowski et al. 2007] was used to quantify average annual total (wet + dry) deposition on the lake surface. Values reported for dry and wet years were 0.249 and 0.29 kilograms per hectare per year (kg/ha/yr), respectively.

4.4.2.3 Internal Loading: Cumulative Weight-of-Evidence Approach

Growing season lake water quality is largely determined by annual P loading rates from all sources. However, excessive P loading can accumulate in lake sediments and influence present-day lake P concentrations. This is called internal loading, or P that is recycled from enriched sediments back into lake waters, and it increases lake P and algal concentrations. This typically occurs when low or no oxygen conditions occur along the sediment–water interface and can be enhanced by other factors such as low sediment iron, calcium or aluminum content, invasive macrophyte species, and rough fish.

Internal loading may also occur with oxygenated sediments but at reduced rates. Assessments of lake TP dynamics, lake mixing, DO concentrations, and mass-balance unexplained residuals were conducted to evaluate each lake's potential for significant internal loading:

- **Growing season lake P dynamics.** Net increases in growing season mean surface water TP concentrations were tabulated. Progressive increases in monthly mean P concentrations reflect both internal and external (watershed) loading sources that affect lakes with limited dilution and that are subject to resuspension potential. The HSPF modeling also provides estimates of dissolved P loading from lakeshed and tributary sources, which can directly influence shallow lake concentrations and can be misidentified as internal loading.

- **Lake mixing.** Lake mixing was evaluated by calculating lake GR and Osgood Index values for each lake. Most lakes were assessed as polymictic (well-mixed) lakes, with a few lakes showing intermittent mixing (Fawn, Moose, and Sebie lakes).
- **DO.** All shallow lakes experience depleting deeper water DO concentrations to values of 2 mg/L or less (Fawn, Fleming, and Trace lakes). All of the deep lakes excluding Moose and Sebie lakes (Big Swan, Crow Wing, Elm Island, Gun, Lower Mission, and Ripple lakes) were noted to develop thermoclines and experience typical declining summer oxygen values in their hypoliminions to concentrations less than 2.0 mg/L. The available data for Moose were from 2016, a year after the TMDL time period, and showed DO depletion down to 6 mg/L. There were no DO data for Sebie Lake.
- **Mass balances.** BATHTUB modeling was conducted for each lake based on HSPF inputs from watershed sources, along with reported Minnesota atmospheric P deposition and estimated P loading from septic tanks. The unexplained residual or P loads needed to balance the income; outgo budgets was assigned as internal load.

Based on these evaluations, lakes with explicit allocations for internal loading include all lakes (excluding Sebie Lake, whose internal loading includes implicit values incorporated into the BATHTUB model).

4.4.3 WLA Methodology

40 CFR § 130.2(h) states that a WLA is “the portion of a receiving water’s loading capacity that is allocated to one of its existing or future point sources of pollution.” WLA components include permitted point sources, MS4s, and industrial and construction stormwater facilities.

4.4.3.1 Permitted Wastewater Treatment Facilities

The City of Grey Eagle has a stabilization pond WWTP (MN0023566) with a controlled discharge and an AWWDF that outlets to Trace Lake. The current permitted effluent limit is 51 kg/yr, which was adopted in late 2011 and is a reduction from the old permitted effluent limit of 129 kg/yr. Modeling during the TMDL time period reflects effluent meeting the old and new permitted amount, so reductions called out in the Trace Lake TMDL table will be achieved by the WWTP meeting the current permitted effluent amounts moving forward.

4.4.3.2 Permitted Municipal Separate Storm Sewer Systems

No MS4s drain to any of the nutrient-impaired lakes addressed in this report.

4.4.3.3 Construction and Industrial Stormwater

The stormwater WLA includes loads from construction, industrial, and WWTF sources. Loads from individual construction stormwater sites are considered to be a small percent of the total WLA and are not practical to quantify.

The WLA for stormwater discharges from sites with construction activity reflects the number of construction sites larger than one acre that are expected to be active in the watershed at any one time; BMPs help determine how to limit the discharge of pollutants at these sites. BMPs and any other stormwater control measures that should be implemented at construction sites are defined in the state’s NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs, and maintains all the BMPs required under the permit, including those related to impaired waters discharges, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. All local construction stormwater requirements must also be met.

County estimates of the total area under construction were area weighted to estimate what portion falls under the impaired waterbody watershed. The percentage of construction acres in each watershed is multiplied by the loading capacity (minus the MOS and NPDES portion of the WLAs) to determine the construction stormwater WLA. Average annual construction acres from 2009 through 2014 ranged from 0.010% of the area to 0.028% of the area. To add in a small MOS, 0.03% of the area in all impairments was assumed to be under construction.

Industrial stormwater is regulated by NPDES permits if an industrial activity has the potential for significant materials to be exposed to stormwater discharges. 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, as well as the BMPs and other stormwater control measures that should be implemented to limit the discharge of pollutants. BMPs and any other stormwater control measures that should be implemented sites are defined in the state’s NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying, and Hot Mix Asphalt Production facilities (MNG490000). If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS permit and properly selects, installs, and maintains all the BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. All local stormwater management requirements must also be met.

The number of acres regulated under 2015 industrial permits is available from the MPCA industrial stormwater permit data by county. County estimates of the total industrial areas were area weighted to estimate what portion falls under the impaired waterbody watershed. The percentage of industrial acres in each watershed is multiplied by the loading capacity (minus the MOS and NPDES portion of the WLAs) to determine the industrial stormwater WLA. The average of annual industrial stormwater acres in 2015 ranged from 0.003% of the area to 0.062% of the area for different impaired reaches. To add in a small MOS, 0.07% of the area in all impairments was assumed to be industrial.

To determine the load allowed from combined industrial and construction stormwater, TP loading capacity was multiplied by 0.001 to represent 0.03% from construction stormwater and 0.07% from industrial permits. To convert annual industrial and construction stormwater WLAs to daily, the annual loads were divided by 365.

4.4.4 Margin of Safety

The MOS is a portion of the TMDL set aside to account for the uncertainties associated with achieving water quality standards. It is usually expressed as an explicit percentage of the loading capacity that also serves as an uncertainty insurance measure. An explicit 10% MOS was included for every lake to ensure that water quality goals are met. Lakes that are joined or are in close proximity include Elm Island/Ripple lakes and Trace/Big Swan lakes. TMDL allocations for upgradient lakes were determined separately and assume future compliance with lake water quality standards; they were also incorporated into downstream lake TMDL allocations. Hence, the inclusion of an explicit MOS in the upstream lake offers an implicit MOS for the downstream lake. Note that endpoint targets for each lake are 1 µg/L below lake eutrophication P standards and offer a slightly implicit MOS for each lake.

4.4.5 LA Methodology

The LA for each lake is apportioned from the loading capacity (TMDL) minus the MOS and the WLAs. It includes all nonregulated sources and those that do not require NPDES permit coverage as well as unregulated watershed runoff, internal loading, and atmospheric deposition.

4.4.6 TMDL Summaries

TMDL allocation tables for each of the impaired lakes are summarized below. BATHTUB modeling determines the allowable load from which the MOS can be subtracted to determine the new total load and apportion the WLAs and LAs. The following tables summarize the existing and allowable loads, the TMDL allocations, and the required reductions by allocation category. Allocation table values reflect the following conventions in reporting significant digits:

- Pounds per year values are rounded to the nearest 0.1.
- Categorical construction and industrial stormwater loading of pounds per day values are reported to four significant digits so that values greater than zero are listed in the tables.
- LA category loading of pounds per day is reported to two significant digits.

The reductions required to achieve lake standards are listed in Table 4-14 and range from 15% in Gun Lake to 66% in Fawn Lake. Sequential improvement of water quality will be realized for lakes in series (i.e., joined or in close proximity), as noted for Elm Island/Ripple lakes and Trace/Big Swan lakes. Of the three shallow lakes, only Trace Lake is located in an ecoregion (NCHF) that has a specific shallow lake standard. Although Fleming and Fawn lakes do not have a specific shallow lake standard, they are grouped as shallow lakes in the TMDL tables. The shallow lake TMDL tables are presented in Section 4.4.6.1 and deep lake TMDL tables are presented in Section 4.4.6.2.

Table 4-14. Required Reductions for Lake TMDLs.

Lake/Type Required TMDL Reductions	
Shallow Lakes	
Trace	46%
Fleming	64%
Fawn	66%
Deep Lakes	
Big Swan	31%
Crow Wing	41%
Elm Island	56%
Gun	15%
Lower Mission	53%
Moose	37%
Ripple	27%
Sebie	46%

4.4.6.1 Shallow Lake TMDL Allocation Tables

Table 4-15. Trace Lake Nutrient TMDL.

Trace Lake Load Allocation		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Loading Capacity				**389.6**	**1.07**		
Margin of Safety: 10%				**39.0**	**0.11**		
Wasteload	**Total WLA**	**225.7**	**0.6185**	**112.9**	**0.3093**	**112.9**	**50**
	Construction/ Industrial Stormwater	*0.4*	*0.001067*	*0.4*	*0.001067*	**0.0**	**–**
	Grey Eagle WWTP[(a)]	225.4	*0.6174*	112.5	*0.3082*	**112.9**	50
Load	**Total LA**	**427.9**	**1.17**	**237.7**	**0.65**	**190.1**	**44**
	Lakeshed	*212.1*	0.58	87.7	0.24	124.4	59
	Internal Loading	*150.5*	0.41	89.2	0.24	61.4	41
	SSTS	*4.4*	0.01	0.0	0.00	4.4	100
	Atmospheric Deposition	*60.9*	0.17	60.9	0.17	0.0	–
Total Load		**653.6**	**1.79**	**350.6**	**0.96**	**303.0**	**46%**

(a) Reductions are achieved by Grey Eagle meeting its current TP effluent limit of 51 kg/yr

Table 4-16. Fleming Lake Nutrient TMDL.

Fleming Lake Load Allocation		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Loading Capacity				**485.2**	**1.33**		
Margin of Safety 10%				**48.5**	**0.13**		
Wasteload	**Total WLA**	**0.5**	**0.001329**	**0.5**	**0.001329**	**0.0**	**0**
	Construction/ Industrial Stormwater	*0.5*	*0.001329*	*0.5*	*0.001329*	**0.0**	**–**
Load	**Total LA**	**1,210.5**	**3.32**	**436.1**	**1.19**	**774.4**	**64**
	Lakeshed	*784.6*	2.15	328.7	0.90	455.9	58
	Internal Loading	*338.6*	0.93	31.2	0.09	307.5	91
	SSTS	*11.0*	0.03	0.0	0.00	11.0	100
	Atmospheric Deposition	*76.2*	0.21	76.2	0.21	0.0	–
Total Load		**1,211.0**	**3.32**	**436.6**	**1.20**	**774.4**	**64%**

Table 4-17. Fawn Lake Nutrient TMDL.

Fawn Lake Load Allocation		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Loading Capacity				**317.6**	**0.87**		
Margin of Safety 10%				**31.8**	**0.09**		
Total Load		**832.3**	**2.28**	**285.9**	**0.78**	**546.4**	**66**
Wasteload	**Total WLA**	**0.3**	**0.000870**	**0.3**	**0.000870**	**0.0**	**0**
	Construction/ Industrial Stormwater	*0.3*	*0.000870*	*0.3*	*0.000870*	**0.0**	**–**
Load	**Total LA**	**832.0**	**2.28**	**285.5**	**0.78**	**546.5**	**66**
	Lakeshed	*344.4*	0.94	118.5	0.32	225.9	66
	Internal Loading	*441.0*	1.21	138.1	0.38	302.9	69
	SSTS	*17.6*	0.05	0.0	0.00	17.6	100
	Atmospheric Deposition	*29.0*	0.08	29.0	0.08	0.0	–
Total Load		**832.3**	**2.28**	**285.9**	**0.78**	**546.5**	**66%**

4.4.6.2 Deep Lake TMDL Allocation Tables

Table 4-18. Big Swan Lake Nutrient TMDL.

Big Swan Lake Load Allocation		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Loading Capacity				**7,718.8**	**21.15**		
Margin of Safety: 10%				**771.9**	**2.11**		
Wasteload	**Total WLA**	**7.7**	**0.02115**	**7.7**	**0.02115**	**0.0**	**0**
	Construction/ Industrial Stormwater	*7.7*	*0.02115*	*7.7*	*0.02115*	**0.0**	**–**
Load	**Total LA**	**10,127.1**	**27.75**	**6939.2**	**19.01**	**3,187.9**	**31**
	Tributary 555	*1868.5*	5.12	890.2	2.44	978.3	52
	Tributary 561[(a)]	*127.9*	0.35	57.3	0.16	70.7	55
	Lakeshed	*4038.0*	11.06	2223.9	6.09	1814.1	45
	Internal Loading	*3856.3*	10.57	3555.7	9.74	300.6	8
	SSTS	*24.3*	0.07	0.0	0.00	24.3	100
	Atmospheric Deposition	*212.1*	0.58	212.1	0.58	0.0	–
Total Load		**10,134.8**	**27.77**	**6,946.9**	**19.03**	**3,187.9**	**31%**

(a) Reductions are achieved by upstream Trace Lake meeting the water quality standard and Grey Eagle WWTP maintaining its current effluent limit of 51 kg/yr

Table 4-19. Crow Wing Lake Nutrient TMDL.

Crow Wing Lake Load Allocation		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Loading Capacity				**1,591.7**	**4.36**		
Margin of Safety 10%				**159.2**	**0.44**		
Wasteload	**Total WLA**	**1.6**	**0.004361**	**1.6**	**0.004361**	**0.0**	**0**
	Construction/ Industrial Stormwater	*1.6*	*0.004361*	*1.6*	*0.004361*	**0.0**	**–**
Load	**Total LA**	**2,432.9**	**6.67**	**1431.0**	**3.92**	**1,001.9**	**41**
	Lakeshed	*1874.6*	5.14	958.9	2.63	915.7	49
	Internal Loading	*412.7*	1.13	381.7	1.05	31.0	8
	SSTS	*55.1*	0.15	0.0	0.00	55.1	100
	Atmospheric Deposition	*90.4*	0.25	90.4	0.25	0.0	–
Total Load		**2,434.5**	**6.67**	**1,432.6**	**3.92**	**1,001.9**	**41%**

Table 4-20. Elm Island Lake Nutrient TMDL.

Elm Island Lake Load Allocation		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Loading Capacity				**2,846.4**	**7.80**		
Margin of Safety 10%				**284.6**	**0.78**		
Wasteload	**Total WLA**	**2.8**	**0.007798**	**2.8**	**0.007798**	**0.0**	**0**
	Construction/ Industrial Stormwater	*2.8*	*0.007798*	*2.8*	*0.007798*	**0.0**	–
Load	**Total LA**	**5,798.6**	**15.89**	**2558.9**	**7.01**	**3,239.7**	**56**
	Tributary 101	*3260.8*	8.93	1978.0	5.42	1282.8	39
	Lakeshed	*413.0*	1.13	253.9	0.70	159.2	39
	Internal Loading	*1985.2*	5.44	202.9	0.56	1782.3	90
	SSTS	*15.4*	0.04	0.0	0.00	15.4	100
	Atmospheric Deposition	*124.1*	0.34	124.1	0.34	0.0	–
Total Load		**5,801.4**	**15.89**	**2,561.7**	**7.02**	**3,239.7**	**56%**

Table 4-21. Gun Lake Nutrient TMDL.

Gun Lake Load Allocation		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Loading Capacity				**3,447.2**	**9.44**		
Margin of Safety 10%				**344.7**	**0.94**		
Wasteload	**Total WLA**	**3.4**	**0.009444**	**3.4**	**0.009444**	**0.0**	**0**
	Construction/ Industrial Stormwater	*3.4*	*0.009444*	*3.4*	*0.009444*	**0.0**	–
Load	**Total LA**	**3,630.5**	**9.95**	**3099.1**	**8.49**	**531.4**	**15**
	Tributary 61	*1297.8*	3.56	939.9	2.58	357.9	28
	Lakeshed	*525.9*	1.44	365.6	1.00	160.3	30
	Internal Loading	*1623.4*	4.45	1623.4	4.45	0.0	0
	SSTS	*13.2*	0.04	0.0	0.00	13.2	100
	Atmospheric Deposition	*170.2*	0.47	170.2	0.47	0.0	–
Total Load		**3,633.9**	**9.96**	**3,102.5**	**8.50**	**531.4**	**15%**

Table 4-22. Lower Mission Lake Nutrient TMDL.

Lower Mission Lake Load Allocation		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Loading Capacity				**1,075.2**	**2.95**		
Margin of Safety 10%				**107.5**	**0.29**		
Wasteload	**Total WLA**	**1.1**	**0.002946**	**1.1**	**0.002946**	**0.0**	**0**
	Construction/ Industrial Stormwater	*1.1*	*0.002946*	*1.1*	*0.002946*	**0.0**	–
Load	**Total LA**	**2,077.0**	**5.69**	**966.6**	**2.65**	**1,110.5**	**53**
	Tributary 218 (Upper Mission Lake)	*166.4*	0.46	112.0	0.31	54.3	33
	Lakeshed	*743.4*	2.04	444.7	1.22	298.7	40
	Internal Loading	*959.4*	2.63	235.0	0.64	724.3	76
	SSTS	*33.1*	0.09	0.0	0.00	33.1	100
	Atmospheric Deposition	*174.9*	0.48	174.9	0.48	0.0	–
Total Load		**2,078.1**	**5.69**	**967.7**	**2.65**	**1,110.5**	**53%**

Table 4-23. Moose Lake Nutrient TMDL.

Moose Lake Load Allocation		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Loading Capacity				**290.1**	**0.79**		
Margin of Safety 10%				**29.0**	**0.08**		
Wasteload	**Total WLA**	**0.3**	**0.0007947**	**0.3**	**0.0007947**	**0.0**	**0**
	Construction/ Industrial Stormwater	*0.3*	*0.0007947*	*0.3*	*0.0007947*	**0.0**	–
Load	**Total LA**	**413.7**	**1.13**	**260.7**	**0.71**	**153.0**	**37**
	Lakeshed	*279.3*	0.77	165.4	0.45	113.9	41
	Internal Loading	*92.1*	0.25	64.0	0.18	28.0	30
	SSTS	*11.0*	0.03	0.0	0.00	11.0	100
	Atmospheric Deposition	*31.3*	0.09	31.3	0.09	0.0	–
Total Load		**414.0**	**1.13**	**261.0**	**0.72**	**153.0**	**37%**

Table 4-24. Ripple Lake Nutrient TMDL.

Ripple Lake Load Allocation		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Loading Capacity				**4,664.3**	**12.78**		
Margin of Safety: 10%				**466.4**	**1.28**		
Wasteload	**Total WLA**	**4.7**	**0.01278**	**4.7**	**0.01278**	**0.0**	**0**
	Construction/ Industrial Stormwater	*4.7*	*0.01278*	*4.7*	*0.01278*	**0.0**	–
Load	**Total LA**	**5,764.8**	**15.79**	**4193.2**	**11.49**	**1,571.6**	**27**
	Tributary 103[(a)]	*3271.1*	8.96	2770.5	7.59	500.5	15
	Lakeshed	*438.7*	1.20	288.5	0.79	150.2	34
	Internal Loading	*1891.1*	5.18	983.6	2.69	907.6	48
	SSTS	*13.2*	0.04	0.0	0.00	13.2	100
	Atmospheric Deposition	*150.7*	0.41	150.7	0.41	0.0	–
Total Load		**5,769.5**	**15.81**	**4,197.9**	**11.50**	**1,571.6**	**27%**

(a) Reductions are achieved by upstream Elm Island Lake meeting the water quality standard

Table 4-25. Sebie Lake Nutrient TMDL.

Sebie Lake Load Allocation		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Loading Capacity				**2,388.9**	**6.55**		
Margin of Safety 10%				**238.9**	**0.65**		
Wasteload	**Total WLA**	**2.4**	**0.006545**	**2.4**	**0.006545**	**0.0**	**0**
	Construction/ Industrial Stormwater	*2.4*	*0.006545*	*2.4*	*0.006545*	**0.0**	–
Load	**Total LA**	**3,999.0**	**10.96**	**2147.6**	**5.88**	**1,851.4**	**46**
	Tributary 433	*588.7*	1.61	305.3	0.84	283.4	48
	Tributary 435	*1006.9*	2.76	509.3	1.40	497.7	49
	Lakeshed	*2348.1*	6.43	1288.7	3.53	1059.4	45
	SSTS	*11.0*	0.03	0.0	0.00	11.0	100
	Atmospheric Deposition	*44.3*	0.12	44.3	0.12	0.0	–
Total Load		**4,001.4**	**10.96**	**2,150.0**	**5.89**	**1,851.4**	**46%**

5. Seasonal Variation

Monthly precipitation, flows, and pollutant concentrations vary seasonally. Average monthly precipitation in the project area is generally the highest from late spring through mid-summer (May through July), as shown in Figure 3-1. Short-duration, high-intensity rainstorms are common during these months and can cause significant runoff, with the potential of increasing pollutant concentrations in a relatively short time period. Occasionally, large events can occur during the drier summer months and have significant wash-off of pollutants while not significantly increasing stream flow.

Monthly average flows in the Mississippi-Brainerd Area Watershed are typically highest during the late spring and early summer months (April through July) and lowest during the winter months (December through February), as shown in Figure 5-1.

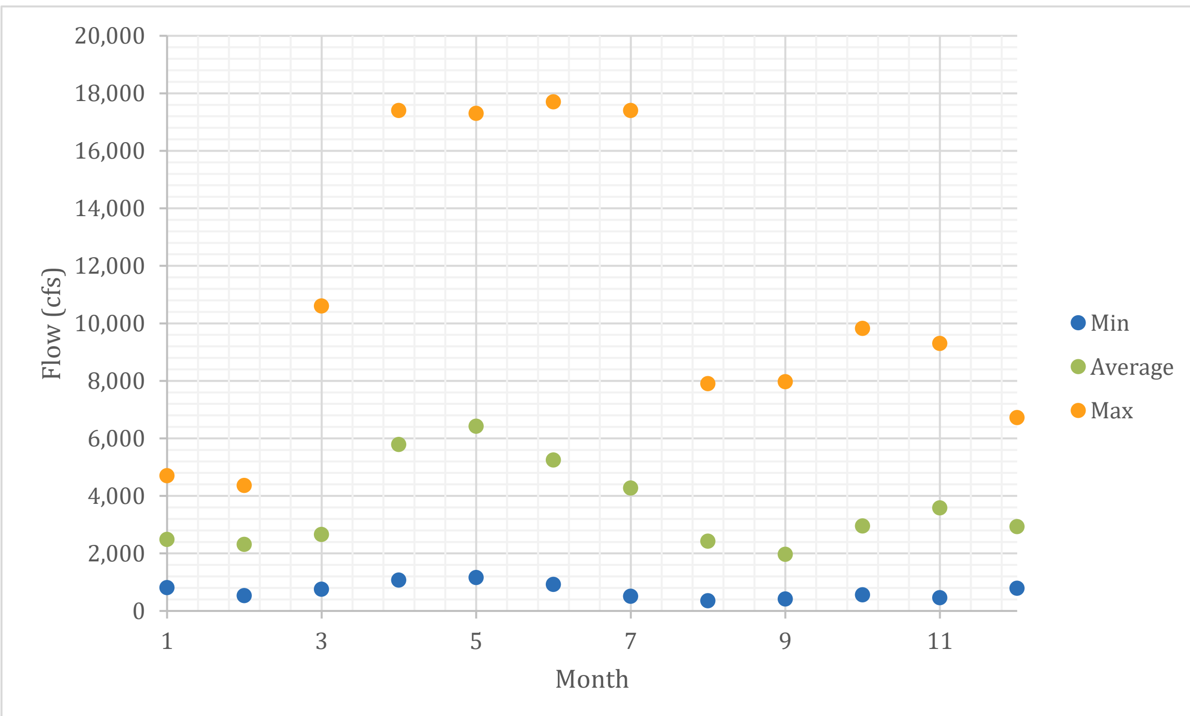


Figure 5-1. Monthly Average Annual Flow (2006–2015) From the Mississippi River Near Brainerd, Minnesota

5.1 *E. coli*

The highest average and median *E. coli* concentrations in the Mississippi-Brainerd Area Watershed impaired streams typically occur in the spring and summer months, with the highest bacteria loads happening during summer, as shown in the *E. coli* LDCs. Figures of bacteria concentrations in impaired reaches by month are shown in Section 3.5.2.1. The LDC approach to TMDL allocations in the five flow zones accounted for seasonal variability in both the flow and *E. coli* loads (e.g., the high-flow zone contains flows that primarily occur in spring and summer). *E. coli* TMDLs are also seasonal, with the *E. coli* criterion active from April through October.

5.2 Aquatic Macroinvertebrate Bioassessments

The stressors identified for the aquatic macroinvertebrate impaired streams described in this document are being addressed with TSS (Sisabagamah Creek Reach 659) and TP (tributary to Sand Creek Reach 679) surrogates. The seasonality of these parameters is shown in the figures included in Section 3.5.2.2. The highest TSS concentrations in Sisabagamah Creek occurred in July and August, and the highest TP concentration in the tributary to Sand Creek occurred in September.

5.3 Nutrients

Lake water quality varies seasonally, with the critical conditions happening during the summer recreational season. Minnesota's lake nutrient standards developed in phases over three decades of monitoring and assessing a large cross-section of lakes and lake types in the state's aquatic ecoregions [Heiskary and Wilson 2005]. Seasonal variation has been factored into the development of Minnesota's lake standards for swimmable and fishable uses in the summer recreational period of June through September [Heiskary and Wilson 2005]. Distinct relationships were established between the causal factor (TP) and the response variables Chl-*a* and Secchi transparency. TP has often been found to be the limiting factor in freshwater lakes; as lake P concentrations increase, algal abundance increases, resulting in higher Chl-*a* concentrations and reduced lake transparency. Based on these relationships, the Chl-*a* and Secchi standards are expected to be met by meeting the P target for each lake. Reducing the P loads defined by these TMDLs will in turn meet water quality standards during critical conditions.

6. Future Growth Considerations

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 which case, the transfer is WLA to WLA.
3. One or more nonregulated 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. Such cases will require either a WLA-to-WLA transfer or an LA-to-WLA transfer.
5. A new MS4 or other stormwater-related point source is identified and covered under an NPDES permit. In this situation, a transfer must occur from the LA.

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

6.2 New or Expanding Wastewater (TSS and *E. coli* TMDLs Only)

Through an EPA-approved TMDL, the MPCA has developed a streamlined process for setting and revising WLAs for new or expanding wastewater discharges to waterbodies [MPCA 2012]. This procedure will be used for dischargers whose permitted effluent limits are at or below the instream target to ensure that effluent concentrations do 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 from the EPA) once a permit request or reissuance is submitted. The overall process will use the public notice permitting process to allow both the public and the EPA to comment on permit changes resulting from any proposed WLA modifications. Once these 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 TMDL WLAs will be made. For more information on the overall process, visit the MPCA's TMDL Policy and Guidance webpage.

7. Reasonable Assurance

An important part of the TMDL implementation strategy is to provide reasonable confidence or assurance that TMDL allocations (1) were properly developed, documented, and calibrated, and (2) will be implemented by local, state, and federal entities. The TMDL allocations described herein are based on the best and latest available information, and any report-defined goals are consistent with the objectives defined in local water plans refined by the MPCA's Mississippi-Brainerd Area WRAPS Report. Mississippi-Brainerd Area Watershed local governmental units have been active participants in the TMDL planning and development process, with most of them having decades of water quality management experience. Stakeholder meetings have been conducted to provide comment/feedback and support, including local governmental units that receive these allocations. Future water quality restoration efforts will be led by Mississippi-Brainerd Watershed local and county entities. Funding resources may be obtained from the following state and/or federal programs:

- Minnesota Clean Water, Land, and Legacy Funds.
- EPA funding such as CWA Section 319 grants.
- Natural Resources Conservation Services (NRCS) cost-share funds.
- Local governmental funds and utility fees.
- Local and lake association-related resources.

7.1 Nonregulatory

At the local level, soil and water conservation districts (SWCDs) have a long history of completing water quality improvement projects with a well-developed infrastructure (i.e., technical assistance, administrative support, and fiscal oversight) in place. The implementation strategies described in Chapter 9 have been demonstrated to be effective in reducing the pollutant loads in Minnesota waters. Performance monitoring will continue to guide adaptive management and further evaluate progress-to-goals in achieving water quality standards and established beneficial uses.

Water quality improvements/projects are happening throughout the Mississippi Brainerd Watershed. The state's Legacy Amendment allocates 33% of its sales tax revenue to the Clean Water Fund, which is spent to protect, enhance, and restore water quality. Projects funded by the Fund can be found online (https://www.legacy.mn.gov/projects?f%5B0%5D=project_facet_watershed%3A36). An example of a recent watershed project in the Mississippi Brainerd Watershed is an alum treatment on a nearby lake that drains into Serpent Lake. A major stormwater retrofit and holding basing was installed in nearby Deerwood, and rain gardens installed in Crosby treat urban stormwater runoff prior to its entry in Serpent Lake. Minnesota also has a new buffer rule that establishes 50-foot perennial vegetation buffers on all lands that border public waters and 16.5-foot buffers on all lands that border a public drainage system to help filter out pollutants such as bacteria, P, nitrogen, and sediment. More detailed information regarding nonregulatory reasonable assurance is included in Section 9.3.

Substantial evidence suggests that voluntary reductions from nonpoint sources have occurred in the past and can be reasonably expected to occur in the future. The Nutrient Reduction Strategy [MPCA

2015] provides substantial evidence of existing state programs designed to achieve reductions in nonpoint-source pollution as evidence that such reductions have been achieved and can reasonably be expected to continue to occur in the future.

7.1.1 Pollutant Load Reduction

Reliable means of reducing nonpoint-source pollutant loads are addressed in the Mississippi-Brainerd Area WRAPS Report [RESPEC 2019], a document written as a companion to this TMDL report. For the impaired waters to meet water quality standards, the majority of pollutant reductions in the Mississippi-Brainerd Area Watershed will need to come from nonpoint sources. The strategies and BMPs described in the WRAPS report have been demonstrated to be effective in reducing the transport of pollutants to surface water. The combinations of BMPs discussed throughout the WRAPS process were derived from Minnesota's Nutrient Reduction Strategy [MPCA 2015] and related tools. As such, they have been vetted in a statewide engagement process.

BMP selection will be led by local government units (LGUs), including SWCDs, watershed districts, and county planning and zoning offices, with support from state and federal agencies. These BMPs are supported by programs administered primarily by SWCDs, the Board of Water and Soil Resources (BWSR), and the Natural Resource Conservation Service (NRCS). Local resource managers are well-trained in promoting, placing, and installing BMPs, but state and local agencies will still need to work with landowners to identify priority areas for BMPs that can help reduce runoff, as well as streambank and overland erosion. These BMPs can in turn reduce both the pollutant loads from runoff (i.e., P, sediment, and pathogens) and the loads delivered through drainage tiles.

To achieve nonpoint-source reductions, the watershed's citizens and communities will need to voluntarily adopt BMPs at the necessary scale and rates to meet the 10-year targets in the Mississippi-Brainerd Area WRAPS Report, which also includes allocations for pollutants/stressors, goals and targets for primary sources, and estimated years to meet these goals. The strategies identified and the relative adoption rates developed by the WRAPS Local Work Group were used to calculate the pollutant/stressor 10-year targets.

In addition to public participation, several government programs are in place to support a political and social infrastructure with the aim of supporting the adoption of strategies that will improve watershed conditions and reduce loading from nonpoint sources. One example of such a government program is the Minnesota Agricultural Water Quality Certification Program. This program is a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing conservation practices that protect our water. Those who implement and maintain approved farm management practices are certified and receive the following:

- regulatory certainty for 10 years (certified producers are deemed to be in compliance with any new water quality rules or laws during the period of certification);
- recognition (certified producers may use their status to promote their business as protective of water quality); and
- priority for technical assistance (producers seeking certification can obtain specially designated technical and financial assistance to implement practices that promote water quality).

7.1.2 Prioritization

The WRAPS report details several tools for local water planners that provide a means for identifying priority pollutant sources and implementation work in the watershed. Furthermore, LGUs in the Mississippi-Brainerd Area Watershed often employ their own local analysis for determining work priorities.

7.1.3 Funding

On November 4, 2008, Minnesota voters approved the Clean Water, Land, and Legacy Amendment to the Minnesota State Constitution, which

- protects drinking water sources;
- protects, enhances, and restores wetlands, prairies, forests, and fish, game, and wildlife habitats;
- preserves arts and cultural heritage;
- supports parks and trails; and
- protects, enhances, and restores lakes, rivers, streams, and groundwater.

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

Additionally, there are many other funding sources for nonpoint-source pollutant reduction work, including include but not limited to the CWA Section 319 grant program, BWSR state Clean Water Fund implementation funding, and NRCS incentive programs. Various programs and activities also occur at the LGU level, where county staff, commissioners, and residents work together to address water quality issues.

7.1.4 Planning and Implementation

The WRAPS report, the TMDLs, and their supporting documents provide a foundation for planning and implementation. Subsequent local water planning will draw on the goals, technical information, and tools to describe strategies and actions for implementation. For the purposes of reasonable assurance, the WRAPS report is sufficient in that it provides strategies for achieving pollutant reduction goals. In addition, the commitment and support from LGUs will ensure that this TMDL project is carried successfully through implementation.

7.1.5 Tracking Progress

Water monitoring efforts in the Mississippi-Brainerd Area Watershed are diverse and constitute a sufficient means for tracking progress and supporting adaptive management (see Section 9.4).

In summary, significant time and resources have been devoted to identifying BMPs, providing a means of focusing them in the Mississippi-Brainerd Area Watershed, and supporting their implementation via state initiatives and dedicated funding. The Mississippi-Brainerd Area Watershed WRAPS Report and TMDLs encourage engaged partners to arrive at reasonable examples of BMP combinations that can attain pollutant reduction goals. Minnesota is a leader in watershed planning as well as in monitoring and tracking progress toward water quality goals and pollutant load reductions.

7.2 Regulatory

7.2.1 Construction Stormwater

State implementation of the TMDL will be through NPDES permits for regulated construction stormwater. To meet the categorical WLA that includes construction stormwater, construction stormwater activities must meet the conditions of the Construction General Permit under the NPDES program and properly select, install, and maintain all the BMPs required under that permit. Alternatively, these activities must meet local construction stormwater requirements if they are more restrictive than the permit's requirements.

7.2.2 Industrial Stormwater

To meet the categorical WLA that includes industrial stormwater, industrial stormwater activities must meet the conditions of the Industrial Stormwater General Permit or the Nonmetallic Mining & Associated Activities General Permit (MNG49) under the NPDES program and properly select, install and maintain all the BMPs required under the permit.

7.2.3 MS4 Permits

Phase II MS4 NPDES-permitted stormwater communities are required by permit (the General Permit Authorization to Discharge Stormwater Associated with Small MS4s Under the NPDES/SDS Permit [MNR040000]) to develop and implement a SWPPP.

More specifically, this permit requires MS4s to develop regulatory mechanisms, including enforcement of construction sites under the MPCA's General Permit, Discharges of Stormwater Associated with Construction Activity (MNR100001), and post-construction stormwater management. MS4s are also required to inventory and map the storm sewer system and implement a minimum of six control measures (public education and outreach, public participation and involvement, illicit discharge detection and elimination, construction site runoff controls, post-construction stormwater runoff controls and pollution prevention, and good housekeeping measures). Measurable goals must be specified for each of these six control measures, including public participation and involvement in the review of the SWPPP. Routine inspection and maintenance of the MS4 conveyance system is required as well. Additionally, the MS4 permit requires permittees with an applicable WLA for DO or oxygen demand, nitrate, TSS, or TP to provide reasonable assurance that progress is being made toward achieving all the EPA-approved TMDL WLAs before the effective date of the MS4 permit, which is issued at five-year intervals. MS4s must determine that the WLAs are being met; if they are not being met, a compliance schedule is required, with interim milestones (expressed as BMPs) to be implemented over the current five-year permit term. As MS4 management activities occur across 10-year capital budgetary cycles, target date for full compliance to the WLAs must be included. More information about the MS4s in Minnesota can be found at https://www.pca.state.mn.us/water/municipal-stormwater-ms4. The MS4 General Permit is currently going through reissuance. Draft permit language follows:

For permittees with applicable WLAs for bacteria, the draft permit contains specific requirements to address these pollutants. These pollutant-specific requirements can be found within the Minimum Control Measures (MCMs) sections of the permit. Each permittee with a WLA for bacteria must comply with the MCM requirements for these WLAs. Because the permit includes pollutant-specific requirements, a compliance schedule will not be required for applicable WLA(s) for bacteria.

All MS4 permittees are required to distribute educational materials focused on pet waste to residents. The educational materials must include information on the impacts of pet waste on water quality; proper management of pet waste; and any existing permittee regulatory mechanism regarding pet waste. If the permittee has a bacteria WLA, the permittee must maintain a written or mapped inventory of potential areas and sources of bacteria (e.g., dense populations of waterfowl or other bird, dog parks). The permittee must also maintain a written plan to prioritize reduction activities to address the areas and sources identified in the inventory. The written plan must include BMPs the permittee will implement over the permit term to reduce bacteria. For cities, townships, and counties, the permittee's regulatory mechanism must require owners or custodians of pets to remove and properly dispose of feces.

If a permittee has an applicable WLA for TSS, or TP, a compliance schedule is required. The compliance schedule is based on information provided by the permittee in the SWPPP document (i.e., the Part 2 permit application). The SWPPP document becomes part of the permit and is subject to public notice (see item 5.4 in the draft permit).

1. *For each applicable WLA not being met for TSS, and TP, a compliance schedule is required. For lake TMDLs, individual compliance schedules must be developed for each applicable WLA. For stream TMDLs, a compliance schedule will be developed for groupings of WLAs. For example, if the permittee has WLAs for TSS on four stream reaches in a single project, the WLAs will be grouped for the purposes of a compliance schedule and reporting.*

   Information on each permittee's applicable WLAs and reporting requirements will be provided in a customized compliance schedule. In the compliance schedule, the permittee must provide the following information:

   a. *proposed BMPs or progress toward implementation of BMPs to be achieved during the permit term;*
   b. *the year each BMP will be implemented; and*
   c. *a target year the applicable WLA(s) will be achieved.*

2. *For each applicable WLA not being met for TSS and TP, the permittee must also provide a quantitative estimate of load reductions that will be achieved during the permit term; and the method used to determine the quantitative estimate (e.g., P8, WinSLAMM, Minimum Impact Design Standards (MIDS) calculator, MPCA simple estimator tool, etc.).*

7.2.4 Wastewater NPDES and SDS Permits

The MPCA issues permits for WWTFs or industrial facilities that discharge into the state's waters. These permits have site-specific limits on pollutants such as *E. coli*, TSS, and CBOD5 that are based on water quality standards. The permits also regulate discharges with the twin goals of protecting public health and aquatic life, and assuring that every facility treats wastewater. In addition, NPDES and SDS permits set limits and establish controls for land application of waste and byproducts. See Section 9.1.6 for a summation of discharge monitoring reports (DMRs) from WWTFs in the Mississippi-Brainerd Area Watershed.

7.2.5 Subsurface Sewage Treatment Systems Program

SSTS, commonly known as septic systems, are regulated by Minnesota State §§ 115.55 and 115.56. Counties and other LGUs that regulate SSTS must meet the requirements for local SSTS programs in Minn. R. ch. 7082; specifically, they must adopt and implement SSTS ordinances in compliance with Minn. R. chs. 7080 through 7083. These regulations detail

- the minimum technical standards for individual and mid-size SSTS;
- a framework for LGUs to administer SSTS programs; and
- statewide licensing and certification of SSTS professionals, SSTS product review and registration, and establishment of an SSTS Advisory Committee.

Counties and other LGUs enforce Minn. R. chs. 7080 through 7083 via their local SSTS ordinance and issue permits for systems designed with flows up to 10,000 gallons per day. There are approximately 200 LGUs across Minnesota, and depending on location, these LGUs can represent a county, city, township, or sewer district. LGU SSTS ordinances vary across the state, with some requiring SSTS compliance inspections prior to property transfer, others requiring permits for SSTS repair and septic tank maintenance, and additional requirements that are stricter than state regulations.

Compliance inspections by counties and other LGUs are required by Minn. Stat. § 115.55 for all new construction works and for existing systems if the LGU issues a permit for the addition of a bedroom. To increase the number of compliance inspections, the MPCA has developed and administers several grants to LGUs for various ordinances and actions. Additional grant dollars are awarded to counties that have provisions in their ordinance above the minimum program requirements. The MPCA has worked with counties through the SSTS Implementation and Enforcement Task Force to identify the most beneficial way to use these funds to accelerate SSTS compliance statewide.

The MPCA staff keep a statewide database of known “imminent threat to public health or safety” systems, such as straight pipe systems, which are reported to counties or the MPCA by the public. Upon confirmation of a straight pipe system, the county sends out a notification of noncompliance, which starts a 10-month deadline to fix the system and bring it into compliance. From 2006 through 2017, the MPCA has tracked 742 straight pipe systems, 701 of which were abandoned, fixed, or found not to be a straight pipe system as defined in Minn. Stat. § 115.55, subd. 1. Seventeen Administrative Penalty Orders have been issued and docketed in court; the remaining straight pipe systems received a notification of noncompliance.

7.2.6 Feedlot Program

All feedlots in Minnesota are regulated by Minn. R. ch. 7020. The MPCA has regulatory authority over feedlots, but counties may choose to participate through a delegation of the feedlot regulatory authority to the LGU. Delegated counties are then able to enforce Minn. R. ch. 7020 (along with any other local rules and regulations) within their respective counties for facilities that are under the CAFO threshold. In the Mississippi-Brainerd Area Watershed, Todd County and Morrison County are the delegated feedlot regulatory authority and will continue to implement the feedlot program and work with producers on manure management plans. The MPCA is responsible for implementing feedlot rules and regulations in the more northern counties of Crow Wing and Aitkin.

The MPCA regulates the collection, transportation, storage, processing, and disposal of animal manure and other livestock operation waste. The MPCA's 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 both feedlots and manure-handling facilities.

There are two primary concerns about feedlots and water protection: (1) ensuring that manure on a feedlot or manure storage area does not run into water and (2) ensuring that it is applied to cropland at a rate, time, and method that prevents bacteria and other possible contaminants from entering streams, lakes, and groundwater.

7.2.7 Nonpoint Source

For most of the TMDLs addressed in this report, pollutant loads are attributed to nonpoint sources. Thus, for TMDLs that require reductions in pollutant loads, nonpoint sources will become the main targets for reductions. The existing state statutes/rules pertaining to nonpoint sources include the following:

- Perennial vegetative buffers of up to 50 feet along lakes, rivers, and streams to help filter out P, nitrogen, sediment, and pathogens. The deadline for implementation of buffers on public waters was November 1, 2017. Approximately 98% of parcels adjacent to Minnesota waters are compliant with the Buffer Law [BWSR 2020].
- Perennial vegetative buffers of 16.5 feet along public ditches to help filter out P, nitrogen, sediment, and pathogens. The deadline for implementation of buffers on public ditches was November 1, 2018. As of July 2019, approximately 98% of parcels adjacent to Minnesota waters are compliant with the Buffer Law [BWSR 2020].
- Highly erodible land within the 300-foot shoreland district (Minn. Stat. § 103F.201) must be protected.
- There is a statute for excessive soil loss (Minn. Stat. § 103F.415).
- There is a provision for nuisance nonpoint-source pollution (Minn. R. ch. 7050.0210, subp. 2).

8. Monitoring Plan

Tracking progress toward achieving TMDL load reductions will rely primarily on (1) monitoring each impaired watershed for BMP implementation and (2) evaluating attainment to water quality standards. The Mississippi-Brainerd Area Watershed SWCDs and other local units of government will track and report implementation projects annually within their jurisdictions. Therefore, existing tools, such as the pollutant reduction calculators, input into Minnesota BWSR web-based eLINK tracking system [BWSR 2016], and other methods of tracking will be used to report on progress. BMP effectiveness may be estimated by BWSR and MPCA calculators based on BMP designs, construction, and operation and maintenance considerations.

Water monitoring will be conducted by a combination of volunteer monitors and county/SWCD technicians as part of the ongoing Watershed Approach. The monitoring level of effort will vary among the Mississippi-Brainerd Area Watershed entities, as staffing and budgets vary. Annual reporting by the Mississippi-Brainerd Area Watershed partners will provide benchmarks for measuring the progress of the implemented TMDLs and for adaptive management. Details of the monitoring were specified in the Mississippi-Brainerd Area Watershed WRAPS process, including the 10-year cycle of Intensive Watershed Monitoring overseen by the MPCA. The next round of IWM is tentatively scheduled to begin in 2026. Some monitoring also occurs in the Mississippi-Brainerd Area Watershed at the local and state level independently of the WRAPS schedule; for example, the MPCA's watershed pollutant load-monitoring network and the DNR's cooperative stream gaging both provide useful continuous long-term water-monitoring data.

9. Implementation Strategy Summary

Rehabilitation actions within the impaired river reach watersheds will require cooperative planning and implementation by nonregulated and regulated entities with partnering counties; SWCDs; regional, state, and federal agencies; and funding sources. Pollutant reductions can be achieved primarily by using BMPs, land use changes, benchmark assessments, and monitoring to identify critical areas.

9.1 Permitted Sources

9.1.1 Phase II MS4

Phase II MS4 NPDES-permitted stormwater communities are required by permit (the General Permit Authorization to Discharge Stormwater Associated with Small MS4s Under the NPDES/SDS Permit [MNR040000]) to develop and implement a SWPPP.

More specifically, this permit requires MS4s to develop regulatory mechanisms, including enforcement of construction sites under the MPCA's general permit to Discharge Stormwater Associated with Construction Activity (MN R100001), and post-construction stormwater management. MS4s are also required to inventory and map the storm sewer system and implement a minimum of six control measures (public education and outreach, public participation and involvement, illicit discharge detection and elimination, construction site runoff controls, post-construction stormwater runoff controls and pollution prevention, and good housekeeping measures). Measurable goals must be specified for each of these six control measures, including public participation and involvement in reviewing the SWPPP. Routine inspection and maintenance of the MS4 conveyance system is also required. Additionally, the MS4 permit requires regulated communities to provide reasonable assurance that progress is being made toward achieving all EPA-approved TMDL WLAs before the effective date of the general MS4 permit, which is issued at five-year intervals. MS4s must determine that the WLAs are being; if they are not being met, a compliance schedule is required, with interim milestones (expressed as BMPs) that are not one of the six control measures and that will be implemented over the current five-year permit term. As MS4 management activities occur across 10-year capital budgetary cycles, a long-term implementation strategy and target date for full compliance to the WLAs must be included. The stormwater manual can be found at https://www.pca.state.mn.us/water/minnesotas-stormwater-manual and includes specific BMPs to improve water quality for pollutants addressed in this TMDL.

9.1.2 Baseline Year

Several cities (Brainerd, Baxter, and Little Falls) have MS4 loads allocated in the TMDLs, so for them, the baseline year will be the beginning of the TMDL time period (2006). A baseline year is used because the effects of BMPs are not always immediate. Any BMPs implemented since 2006 will qualify toward MS4 load reductions for these TMDLs. Appropriate implementation strategies and MS4 BMPs are further defined in the WRAPS report.

9.1.3 Concentrated Animal Feeding Operations

Twenty-four CAFOs are located in the Mississippi-Brainerd Watershed. CAFOs are not allowed to discharge to surface water (with permit-specified exceptions) and were not given a WLA.

9.1.4 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, along with BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants. These BMPs and other stormwater control measures are defined in Minnesota's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs, and maintains all required BMPs, including those related to impaired waters discharges, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. Construction activity must also meet all local government construction stormwater requirements.

9.1.5 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, along with BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants. These BMPs and other stormwater control measures are defined in Minnesota's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000] or the NPDES/SDS General Permit for Construction Sand and 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 required BMPs, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. Industrial activity must also meet all local government construction stormwater requirements.

9.1.6 Wastewater

DMR data for each facility in the impaired watersheds were downloaded from the MPCA database to assess effluent levels.

A bacteria effluent evaluation was completed for facilities in the watersheds of bacteria-impaired reaches with monthly average DMR monitoring data. The current fecal coliform bacteria permit limit for these facilities is 200 colony-forming units per 100 milliliters (cfu/100 mL). The monitoring data show that all facilities contributing to a bacteria-impaired reach typically discharge at fecal coliform concentrations below 200 cfu/100 mL. The Swanville WWTP exceeded the 200 mg/L cfu/100 mL four times in 2008, once in 2010, once in 2012, and once in 2016.

A TSS effluent evaluation was completed for the facility contributing to the Sisabagamah Creek aquatic macroinvertebrate impaired Reach 659 with monthly average DMR monitoring data. Because the permit for this facility was reissued in February 2017 under the name American Peat Technology from Sampson Farms, data after the reissuance (outside of the TMDL time period, February 2017 through September 2018) were summarized. The monitoring data show that one out of 16 samples were above the limit of 30 mg/L for the SD001 outfall, and five out of the 17 samples were above the limit of 30 mg/L for the SD003 outfall. The instream standard (15 mg/L) is lower than the permit limit for the facility (30 mg/L). The monitoring data show that one out of 16 samples were above 15 mg/L for the SD001 outfall and nine out of 17 samples were above 15 mg/L for the SD003 outfall.

The TP WLA for the Grey Eagle WWTF was based on a concentration of 0.4 mg/L at the AWWDF. The monthly average concentration in discharges from the Grey Eagle WWTF exceeded 0.4 mg/L 85% of the time between 2006 and 2017.

The point sources perform very well the majority of the time. Because some permit-limit exceedances occur, the point-source contributions in the Mississippi-Brainerd Watershed can be improved.

9.2 Nonregulated Sources

Nonregulated rehabilitation actions within the impaired river reach watersheds will require cooperative planning and implementation by partnering counties, SWCDs, watershed districts, and regional, state, and federal agencies.

9.2.1 *E. coli*

BMPs that are expected to reduce *E. coli* loads to impaired streams are identified below, with details provided by *The Agricultural BMP Handbook for Minnesota* [Miller et al. 2012] and *Minnesota Stormwater Manual* [MPCA 2016b]. Cost, targets, and other BMP information are further discussed in the WRAPS report, but highlighted BMPs include the following:

- **Animal access control.** Off-stream watering and fencing aid in restricting animal access to stream and sensitive streambank areas and allow growth of riparian vegetation.
- **Buffers and streambank stabilization.** Riparian vegetation helps filter pollutants and stabilize banks. All lands that border public waters require 50-foot on average (30-foot minimum) vegetation buffers, and all lands that border a public drainage system require 16.5-foot vegetation buffers. The deadline to seed these buffers on public waters was November 1, 2017; the deadline f county ditches was November 1, 2018. The Clean Water Legacy Fund included $5 million to BWSR for local government implementation. SWCDs are identifying the priority for placing perennial vegetation buffers along small streams, headwater areas, and county ditches.
- **Manure management.** Proper manure management assists in reducing the amount of manure-related organic matter that is carried in runoff volumes. Manure management techniques include applying at the recommended rates, controlling manure stockpile runoff, avoiding manure application near open inlets, and avoiding winter manure spreading.
- **Pasture management.** Rotational grazing, off-stream watering, and maintenance of riparian vegetation aid in keeping bacteria from entering stream systems.
- **Pet waste management**. Public education and enforcement of pet waste regulations can help ensure that local ordinances are being followed.
- **Channelization and artificial drainage.** Exporting organic substrates, nutrients, and bacteria to downstream segments of the flow network will only increase, so targeted monitoring of potential critical areas or specific areas of concern should be considered in the WRAPS monitoring plan.
- **County SSTS compliance and inspection programs.** County ordinances developed to protect human health and the environment need the public's support. Upgrades of noncompliant systems may be required to obtain building permits or upon property sale. County support via

the Mississippi-Brainerd Area WRAPS process may result in designating grants or loans to help upgrade old and failing septic systems. Failing and noncompliant SSTS adjacent to lakes, streams, and associated drainages should receive the highest priority.

- **Public education, public outreach, and civic engagement.** Education, outreach, and engagement in the benefits of these practices should continue with the Mississippi-Brainerd Area Watershed. SWCDs, LGUs, and partnering counties should provide core materials for reinforcing messages aimed at target audiences.

9.2.2 Aquatic Macroinvertebrate Bioassessments

Two of the reaches addressed in this TMDL had aquatic macroinvertebrate bioassessment impairments. One of them, Sisabagamah Creek (Reach 659), was impaired because of the lack of habitat from flow alteration and the amount of sediment coming into the stream from streambank instability and no vegetated ditch banks. The other, an unnamed tributary to Sand Creek (Reach 679), was impaired because of elevated nutrients and low DO levels that caused stress to the macroinvertebrates in addition to their poor habitat.

BMPs that are expected to reduce TSS and TP loads to impaired reaches are summarized below with greater detail provided by *The Agricultural BMP Handbook for Minnesota* [Miller et al. 2012] and the *Minnesota Stormwater Manual* [MPCA 2016b]. Cost, targets, and other BMP information are discussed further in the Mississippi-Brainerd WRAPS Report. BMPs listed here help decrease instream TSS and TP and also improve the habitat for macroinvertebrates:

- **Buffers and streambank stabilization.** Riparian vegetation helps filter pollutants and stabilize streambanks. All lands that border public waters require 50-foot on average (30-foot minimum) vegetation buffers, and all lands that border a public drainage system require 16.5-foot vegetation buffers. The deadline to seed these buffers on public waters was November 1, 2017; the deadline for county ditches was November 1, 2018. The Clean Water Legacy Fund included $5 million to BWSR for local government implementation. SWCDs are identifying the priority for placing perennial vegetation buffers along small streams, headwater areas, and county ditches.
- **Agricultural BMPs.** Cropland BMPs such as conversion to pasture with rotational grazing, conversion to grassland/perennials, the use of no-till cropping systems, the use of cover crops, and many others help filter out or reduce the sediment and nutrients that move into the stream system. Cropland BMPs also help redirect overland flow into interflow and groundwater flow to reduce system flashiness and, therefore, sediment and nutrient issues.
- **Restoration of hydrology to altered watercourses and wetland complexes.** Wetland restoration, tile-drain reduction, and altered waterway restoration would help reduce system flashiness and, therefore, the in-stream sediment issues related to high flows such as bed and bank scour. Hydrology restoration would also be expected to reduce sediment (and therefore nutrient) delivery to the flow network's downstream segments.
- **Tracking and implementing agricultural BMPs.** Encouraging and tracking implementation of agricultural BMPs, as detailed in *The Agricultural BMP Manual for Minnesota*, substantially reduce sediment loadings on agricultural land. Proper site design, construction, and maintenance are key components for effective best practices.

- **Tracking and implementing urban BMPs.** Encouraging and tracking the implementation of urban BMPs, as detailed in the *Minnesota Stormwater Manual* and Minimal Impact Design Standards (MIDS), covers the spectrum of source, rate, and volume controls that substantially reduce developed land's sediment and nutrient loadings. Proper site designs, construction, and maintenance are key components for effective urban BMPs.
- **Public education.** The benefits of the above practices should continue with Mississippi-Brainerd Area Watershed partnering counties providing core materials for reinforcing the messages aimed at targeted audiences.

9.2.3 Nutrients

BMPs that are expected to reduce nutrient loads to impaired reaches and lakes are summarized below, with greater detail provided by *The Agricultural BMP Handbook for Minnesota* [Miller et al. 2012] and the *Minnesota Stormwater Manual* [MPCA 2016b], which includes MIDS information. Cost, targets, and other BMP information are further discussed in the WRAPS report, but highlighted BMPs include the following:

- **Lakeshore buffers and SSTS compliance.** Encouraging and tracking the adoption of lakeshore buffers and SSTS compliance rates are efforts where lake associations can provide local leadership through information campaigns, acquiring local/state funding to aid homeowners, and tracking lakeshore buffers and septic compliance rates with support provided by local counties.
- **Buffers and streambank stabilization.** Riparian vegetation helps filter pollutants and stabilize streambanks. All lands that border public waters require 50-foot on average (30-foot minimum) vegetation buffers, and all lands that border a public drainage system require 16.5-foot vegetation buffers. The deadline to seed these buffers on public waters was November 1, 2017; the deadline f county ditches was November 1, 2018. The Clean Water Legacy Fund included $5 million to BWSR for local government implementation. SWCDs are identifying the priority for placing perennial vegetation buffers along small streams, headwater areas, and county ditches.
- **Tracking and implementing urban BMPs.** Encouraging and tracking the implementation of urban BMPs, as detailed in the *Minnesota Stormwater Manual* and MIDS, covers the spectrum of source, rate, and volume controls that substantially reduce developed land's pollutant loadings of BOD and related sediment losses, nutrients, and bacteria. Proper site design, construction, and maintenance are key components for effective urban BMPs.
- **Tracking and implementing agricultural BMPs.** Encouraging and tracking the implementation of agricultural BMPs, as detailed in *The Agricultural BMP Manual for Minnesota*, substantially reduces agricultural land's pollutant loadings of BOD and related sediment losses, nutrients, and bacteria. Proper site design, construction, and maintenance are key components for effective best practices.
- **General nutrient reduction.** Internal loading can comprise an important portion of the P income to impaired lakes and legacy source-impacted wetlands. Internal P loading is typically the result of excessive historical watershed loading, so a recommended first step is to reduce watershed P loading as much as possible, which includes reducing runoff from shorelands, developed land,

noncompliant SSTS, and other upland sources (potentially including wetlands). Wetland pulsing is possible after successive dry and wet periods, resulting in shifting water levels that can induce P release from legacy sources. During dry periods, water levels recede and provide greater oxygen concentrations for aerobic digestion of organic substrates, including mobilization of various dissolved and particulate P forms [Dunne et al. 2010]. Upon refilling during wet periods, growing season oxygen concentrations can quickly be depleted, which results in the release of digested P concentrations that depend on other factors, such as sediment iron, aluminum, and calcium. The extent of this occurrence from watershed wetland complexes is generally not known but can be initially characterized by relatively simple P monitoring, such as sequential diagnostic grab sampling of upgradient and downgradient waters following summer storm events.

- **Alum treatment.** Whole-lake treatment by alum can be very effective in reducing a lake's internal P loading for 10 to 30 years. In alum treatment, a white alum band is deposited along the top of the lake's sediments, serving to trap the released P. However, effectiveness in shallow lakes may be reduced because of wind mixing and disruption of the sediment's alum layer [Cooke et al. 1986]. After reducing watershed P loading sources, the appropriateness of a whole-lake alum treatment can be assessed through a detailed feasibility study. Mobilization and treatment costs could amount to about $1,000 per acre depending on dosage requirements and alum costs.
- **Other treatments.** Hypolimnetic treatments include ferric chloride, aeration, and oxygenation:
  - — A recommended total iron-to-TP concentration ratio of 3:1 for lake-bottom water has been used to control lake sediment released P. If the total iron-to-TP ratio is less than 3:1, then iron is likely not effectively reducing sediment liberated P concentrations. In the latter case, iron augmentation of lake sediments may be required by using ferric chloride or similar iron compounds. The details, including oxygen supply rates, would have to be determined by an engineering design study.
  - — High oxygen depletion rates can be expected to accompany elevated lake productivity (e.g., algal concentrations). Replenishing oxygen supplies via oxygenation of bottom waters may be a viable option in some cases. This would require installing a series of pipes and diffusers on the lake bottom along with a pump house and oxygenation system on land. The details, including oxygen supply rates, would have to be determined through an engineering design study. Lake aeration (without oxygenation) requires careful examination if intended for something other than reduced winter fish kill potential. Whole-lake aeration during the growing season can result in increased P concentrations that feed increased algal growth and potentially degrade lake quality.
- **Public education.** Public education about the benefits of the above practices should continue with partnering counties providing core materials for reinforcing the messages aimed at targeted audiences.

9.3 Cost

The Clean Water Legacy Act Minn. Stat. § 114D.25 requires that a TMDL include an overall approximation of the cost to implement it. The cost estimate for this TMDL includes implanting buffers along the public streams and ditches and around lakes in impaired drainage areas (50-foot buffers on both sides of approximately 1,174 stream miles at approximately $200 per acre after cost share [Shaw 2016]), alum treatment on impaired lake acres (approximately 4,860 acres at $1,000 per acre [Kretsch 2016]), septic updates around impaired lakes (4% replacement of approximately 883 septic systems at $10,000 a system), and MIDS on high- and medium-intensity developed lands (approximately 86 acres at $5,000 per acre) [BWSR 2016]. The initial estimate for implementing the Mississippi-Brainerd Area WRAPS process is approximately $5,270,000 for nonpoint-source implementation such as stream buffers, lake chemical treatments, and SSTS updates, and approximately $432,000 for implementation of MIDS in medium- and high-intensity developed areas. Urban BMP costs estimated in this overview are primarily based on construction and maintenance costs. Land areas required for constructed BMPs generally require 2% to 5% of the watershed drainage area, but land costs are not generally included because they can vary. This estimate is, by nature, a very general approximation that has considerable uncertainties associated with design complexity, local regulatory requirements, unknown site constraints, and BMP choices with widely variable costs per water quality volume treated. This is a large-scale estimate, and many other implementation strategies will likely be used in addition to (or in replacement of) the general practices used in this estimate.

9.4 Adaptive Management

The list of implementation elements and the more detailed WRAPS report that will be prepared following this TMDL assessment will focus on adaptive management as illustrated in Figure 9-1. Continued monitoring and "course corrections" that respond to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL. Management activities will be changed or refined to efficiently meet the TMDL and provide the groundwork for delisting the impaired waterbodies. Currently, the cycle depicted in Figure 9-1 is repeated every 10 years. Ongoing monitoring and analysis of trend data and BMP implementation information will assist managers to make informed decisions on adapting management approaches.

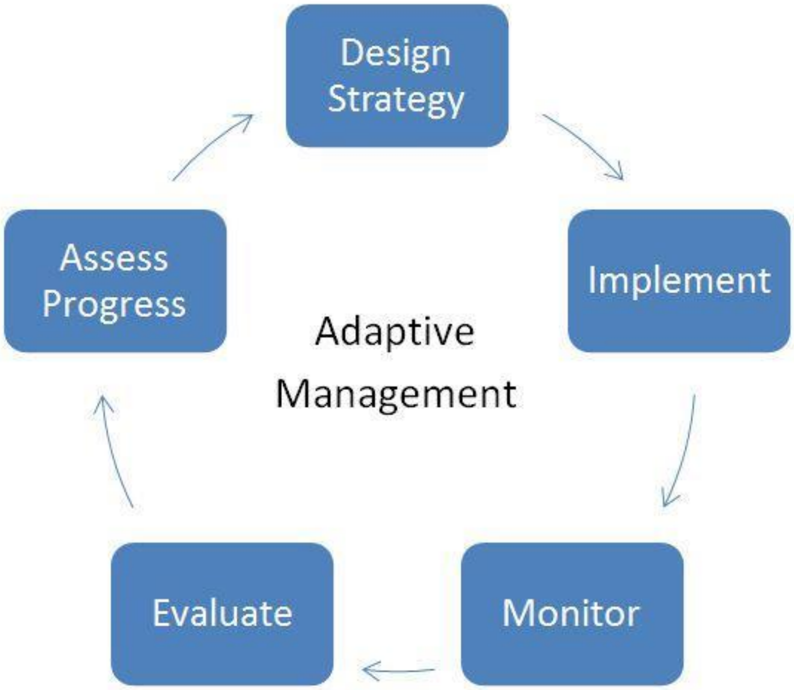


Figure 9-1. Adaptive Management Cycle

10. Public Participation

Efforts to facilitate public education, review, and comment when developing the Mississippi-Brainerd Area Watershed TMDLs included meetings with local groups in the watershed on the assessment findings, and a 30-day public notice period for public review of and comment on the draft TMDL document. All input, comments, responses, and suggestions from public meetings and the public notice period were addressed or were taken into consideration in developing the TMDL. The draft TMDL report was made available via public notice in the state register from June 1, 2020 through July 1, 2020. One comment letter was received and responded to from EPA. Regular updates regarding the TMDL process with the Mississippi-Brainerd Area Watershed WRAPS team included meetings to discuss TMDL processes and results. Public and team meetings are listed below:

- A project kickoff meeting was held with the project team on May 19, 2016.
- Project team meetings were held on June 24, 2015, March 20, 2016, October 19, 2016, March 29, 2017, January 31, 2018, June 20, 2018, and March 7, 2019 to discuss the project timeline, methods, and TMDL segments to be addressed.
- Public meetings to discuss assessment results were held in the Center Township on July 26, 2018, in Todd and Morrison Counties on September 13, 2018, and in Aitkin on September 19, 2018.
- A virtual public presentation was available for interested citizens in May, 2020 to present the draft TMDL report and allocations and receive public comments and concerns during the public notice.

11. Literature Cited

Adhikari, H., D. L. Barnes, S. Schiewer, and D. M. White, 2007. "Total Coliform Survival Characteristics in Frozen Soils," *Journal of Environmental Engineering*, Vol. 133, No. 12, pp. 1098–1105.

American Veterinary Medical Association, 2016. "US Pet Ownership Statistics," *avma.org*, accessed June 30, 2016, from *https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx*

Carlson, R., 1977. "A Trophic State Index for Lakes," *Limnology and Oceanography*, Vol. 22, No. 2.

Chandrasekaran, R., M. J. Hamilton, P. Wanga, C. Staley, S. Matteson, A. Birr, and M. J. Sadowsky, 2015. "Geographic Isolation of Escherichia coli Genotypes in Sediments and Water of the Seven Mile Creek — A Constructed Riverine Watershed," *Science of the Total Environment*, Vol. 538, pp. 78–85.

Cooke, G. D., E. B. Welch, S. A. Peterson, and P. R. Newroth, 1986. *Restoration and Management of Lakes, Second Edition*, CRC Press, Boca Raton, FL.

Dayton, M., 2014. "Minnesota County Population Projections by Age and Gender, 2015–2045," *mn.gov*, accessed December 14, 2014, from *http://mn.gov/admin/assets/2015-2070-mn-statewide-age-sex-projections-regular-series-msdc-aug2015-excel_tcm36-219373.xlsx*

Donigian, Jr., A. S., 2002. "Watershed Model Calibration and Validation: The HSPF Experience," *Water Environment Federation National TMDL Science and Policy 2002,* Phoenix, AZ, November 13–16.

Donigian, Jr., A. S.; J. C. Imhoff; B. R. Bicknell; and J. L. Kittle, Jr., 1984. *Application Guide for the Hydrological Simulation Program-FORTRAN,* EPA 600/3-84-066, prepared by Environmental Research Laboratory, US Environmental Protection Agency, Athens, GA.

Dunne, E. J., M. W. Clark, J. Mitchell, J. W. Jawitz, and K. R. Reddy, 2010. "Soil Phosphorus Flux From Emergent Marsh Wetlands and Surrounding Grazed Pasture Uplands," *Ecological Engineering*, Vol. 36, No. 11, pp. 1392–1400.

Farnsworth, R. and E. S. Thompson, 1982. *Evaporation Atlas for the Contiguous 48 United States*, National Oceanic and Atmospheric Administration Technical Report #33, prepared by the Office of Hydrology, National Weather Service, Washington, DC, for the National Oceanic and Atmospheric Administration, Washington, DC.

Heiskary, S. A. and C. B. Wilson, 2005. *Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria*, Third Edition, prepared for the Minnesota Pollution Control Agency, St. Paul, MN.

Heiskary, S. and W. W. Walker, Jr., 1988. "Developing Nutrient Criteria for Minnesota Lakes," *Lake and Reservoir Management*, Vol. 4, No. 1, pp. 1–19.

Hondzo, M. and H. Stefan, 1996. "Dependence of Water Quality and Fish Habitat on Lake Morphometry and Meteorology," *Journal of Water Resources Plan and Management*, Vol. 122, No. 5, pp. 364–373.

Horsley and Witten, Inc., 1996. *Identification and Evaluation of Nutrient and Bacterial Loadings to Maquoit Bay, New Brunswick and Freeport, Maine*, prepared by Horsley and Witten, Inc., Barnstable, MA, for Casco Bay Estuary Project, Portland, ME.

Ishii, S., T. Yan, H. Vu, D. L. Hansen, R. E. Hicks, and M. J. Sadowsky, 2010. “Factors Controlling Long-Term Survival and Growth of Naturalized Escherichia coli Populations in Temperate Field Soils,” *Microbes and Environments*, Vol. 25, No. 1, pp. 8−14.

Johnson, C., 2019. Personal Communication between C. Johnson, Minnesota Pollution Control Agency, Brainerd, MN, and C. McCutcheon, RESPEC, Rapid City, SD, March 1.

Kretsch K., 2016. Personal communication between K. Kretsch, Lake Restoration, Inc., Rogers, MN, and B. Wilson, RESPEC, Roseville, MN, May 25.

Lumb, A. M., R. B. McCammon, and J. L. Kittle, Jr., 1994. *Users Manual for an Expert System (HSPEXP) for Calibration of the Hydrological Simulation Program-FORTRAN,* US Geological Survey Water Resources Investigations Report 94-4168, US Geological Survey, Reston, VA.

Lupo, C., 2016. *Model Extension and Review for the Mississippi Headwaters, Leech Lake, Mississippi-Grand Rapids, Mississippi-Brainerd, Pine River, Crow Wing, Redeye, Long Prairie, Mississippi-Sartell, Sauk, Mississippi-St. Cloud, North Fork Crow, South Fork Crow, and Rum River Watersheds*, RSI(RCO)-2146/6-16/26, prepared by RESPEC, Rapid City, SD for C. Regan, Minnesota Pollution Control Agency, St. Paul, MN, June 30.

Marino, R. P. and J. J. Gannon, 1991. “Survival of Fecal Coliforms and Fecal Streptococci in Storm Drain Sediments,” *Water Research*, Vol. 25 No. 9, pp. 1089–1098.

Metcalf and Eddy, 1991. *Wastewater Engineering: Treatment, Disposal and Reuse*, 3rd Edition, McGraw-Hill, New York.

Midwestern Regional Climate Center, 2018. “cli-MATE, the MRCC’s Application Tools Environment Database,” *illinois.edu*, accessed August 17, 2018, from *http://mrcc.illinois.edu/CLIMATE*

Miller, T. P., J. R. Peterson, C. F. Lenhart, and Y. Nomura, 2012. *The Agricultural BMP Handbook for Minnesota*, prepared for the Minnesota Department of Agriculture, St. Paul, MN.

Minnesota Board of Soils and Water Resources, 2016. “eLink Web-Based Conservation Tracking System Development,” accessed August 5, 2016, from *http://www.bwsr.state.mn.us/outreach/eLINK/*

Minnesota Board of Soils and Water Resources, 2020. “Minnesota Buffer Law,” accessed May 14, 2020, from *https://bwsr.state.mn.us/minnesota-buffer-law*

Minnesota Department of Natural Resources, 2018a. *2018 Waterfowl Breeding Population Survey Minnesota*, prepared by Minnesota Department of Natural Resources, Bemidji, MN.

Minnesota Department of Natural Resources, 2018b. “Monthly Precipitation Data From Gridded Database,” *state.mn.us*, accessed September 10, 2018, from *http://www.dnr.state.mn.us/climate/historical/monthly.html*

Minnesota Department of Natural Resources, 2018c. “Cooperative Stream Gaging (CSG),” *state.mn.us*, accessed September 10, 2018, from *https://www.dnr.state.mn.us/waters/csg/index.html*

Minnesota Geospatial Commons, 2018. “Feedlots in Minnesota,” *gisdata.mn.gov*, accessed October 10, from *https://gisdata.mn.gov/dataset/env-feedlots*

Minnesota Pollution Control Agency, 2005. *Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria, 3rd Edition*, prepared by the Minnesota Pollution Control Agency, St. Paul, MN.

Minnesota Pollution Control Agency, 2012. *Zumbro Watershed Turbidity Total Maximum Daily Load*, prepared by the Minnesota Pollution Control Agency, St. Paul, MN, for US Environmental Protection Agency, Washington, DC.

Minnesota Pollution Control Agency, 2015. "Nutrient Reduction Strategy," *state.mn.gov*, accessed December 14, from *http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/nutrient-reduction/nutrient-reduction-strategy.html*

Minnesota Pollution Control Agency, 2016. "Minnesota Stormwater Manual," *state.mn.gov*, accessed August 5, 2016, from *http://stormwater.pca.state.mn.us/index.php/Main_Page*

Minnesota Pollution Control Agency, 2018a. "Watershed Pollutant Load Monitoring Overview," *state.mn.gov*, accessed September 10, 2018, from *https://www.pca.state.mn.us/wplmn/overview*

Minnesota Pollution Control Agency, 2018b. *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List*, prepared by the Minnesota Pollution Control Agency, St. Paul, MN.

Minnesota Pollution Control Agency, 2019. *Mississippi Brainerd Watershed Stressor Identification Report: A Study of the Stressors Limiting the Biotic Communities in the Mississippi River Brainerd Watershed*, prepared by the Minnesota Pollution Control Agency, Brainerd, MN.

National Oceanic and Atmospheric Administration, 2018a. "National Centers for Environmental information, Climate at a Glance: US Time Series, Average Temperature," *ncdc.noaa.gov*, accessed on October 25, 2018, from *http://www.ncdc.noaa.gov/cag/*

National Oceanic and Atmospheric Administration, 2018b. "Hydrometeorological Design Studies Center, Precipitation Frequency Data Server," *noaa.gov*, accessed October 15, 2018, from *http://hdsc.nws.noaa.gov/hdsc/pfds/*

Natural Resource Conservation Service, 2009. "Chapter 7 Hydrologic Soil Groups," *Part 30 Hydrology National Engineering Handbook*, prepared by the US Department of Agriculture Natural Resources Conservation Service, Washington, DC.

Norton, A. 2018. *Monitoring Population Trends of White-tailed Deer in Minnesota – 2018,* prepared by the Minnesota Department of Natural Resources, Madelia, MN.

Nürnberg, G. K., 1995. "Quantifying Anoxia in Lakes," *Limnology and Oceanography*, Vol. 40, No. 6, pp. 1100–1111.

Osgood, R. A., 1998. "Lake Mixes and Internal Phosphorus Dynamics," *Archiv fur Hydrobiologie*, Vol. 113, pp. 629–638.

Peake, B., 2018. Personal Communication between B. Peake, Illinois State Water Survey, Champaign, IL, and C. McCutcheon, RESPEC, Rapid City, SD, December 17.

RESPEC, 2019. *DRAFT Mississippi River – Brainerd Watershed Restoration and Protection Strategy Report*, prepared by RESPEC, St. Paul, MN for Minnesota Pollution Control Agency, Brainerd, MN on behalf of Aitkin County Soil and Water Conservation District, Aitkin, MN.

Schupp, D. and B. Wilson, 1993. "Developing Lake Goals for Water Quality and Fisheries," *LakeLine*, December, pp. 18–21.

Shaw, D., 2016. Personal communication between D. Shaw, Minnesota Board of Water and Soil Resources, St. Paul, MN, and B. Wilson, RESPEC, Roseville, MN, October 13.

Tetra Tech, 2018. *Mississippi River – Brainerd Recalibration,* prepared by Tetra Tech, Research Triangle Park, NC, for the Minnesota Pollution Control Agency, St. Paul, MN.

Twarowski, C., N. Czoschke, and T. Anderson, 2007. *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds – Atmospheric Deposition: 2007 Update*, prepared by Barr Engineering Company, Bloomington, MN, for the Minnesota Pollution Control Agency, St. Paul, MN.

University of Minnesota, 2018. "10 classes Minnesota Land Cover Classification and Impervious Surface Area with Landsat and LiDAR: 2013 Update - Version 2," *umn.edu*, retrieved November 2, 2018, from *http://rsl02.cfans.umn.edu/download/statewide_finalmap_2013_2014_v2.zip*

US Environmental Protection Agency, 2001. *Source Water Protection Practices Bulletin Managing Pet and Wildlife Waste to Prevent Contamination of Drinking Water,* prepared by the US Environmental Protection Agency Office of Water, Washington, DC.

US Environmental Protection Agency, 2007. *An Approach for Using Load Duration Curves in the Development of TMDLs*, prepared by the US Environmental Protection Agency Office of Water, Washington, DC.

Walker, Jr., W. W., 1985. *Empirical Methods for Predicting Eutrophication in Impoundments - Report 3, Phase II: Model Refinements*, prepared by the US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Walker, W., 1996. "Simplified Procedures for Eutrophication Assessment and Prediction: User Manual, Instruction Rep. W-96-2, prepared for the U.S. Army Corps of Engineers, Washington, D.C.

Walker, W., 2006. *BATHTUB Version 6.1, Simplified Techniques for Eutrophication Assessment and Prediction*, prepared for Environmental Laboratory, USAE Waterways Experiment Station, Vicksburg, MS.

Wilson, B. and W. W. Walker, 1989. "Development of Lake Assessment Methods Based Upon the Aquatic Ecoregion Concept," *Lake and Reservoir Management*, Vol. 5, No. 2, pp.11–22.

Zeckoski, R. W., B. L. Benham, S. B. Shah, and C. D. Heatwole, 2005. "BSLC: A Tool for Bacteria Source Characterization for Watershed Management," *Applied Engineering in Agriculture*, Vol. 21, No. 5, pp. 879–889.

Appendices

Appendix A: Watershed Maps

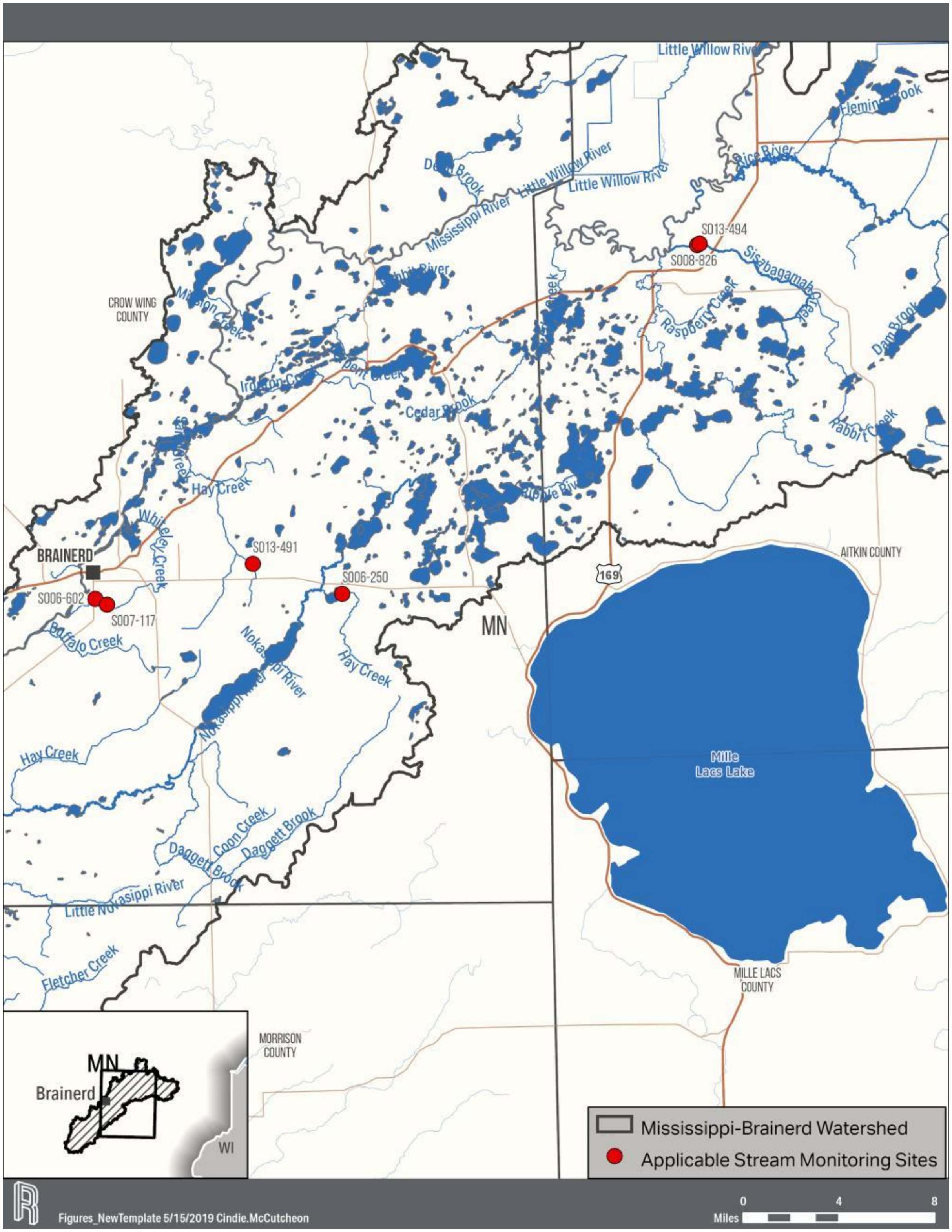


Figure A-1. Mississippi River-Brainerd Monitoring Sites East

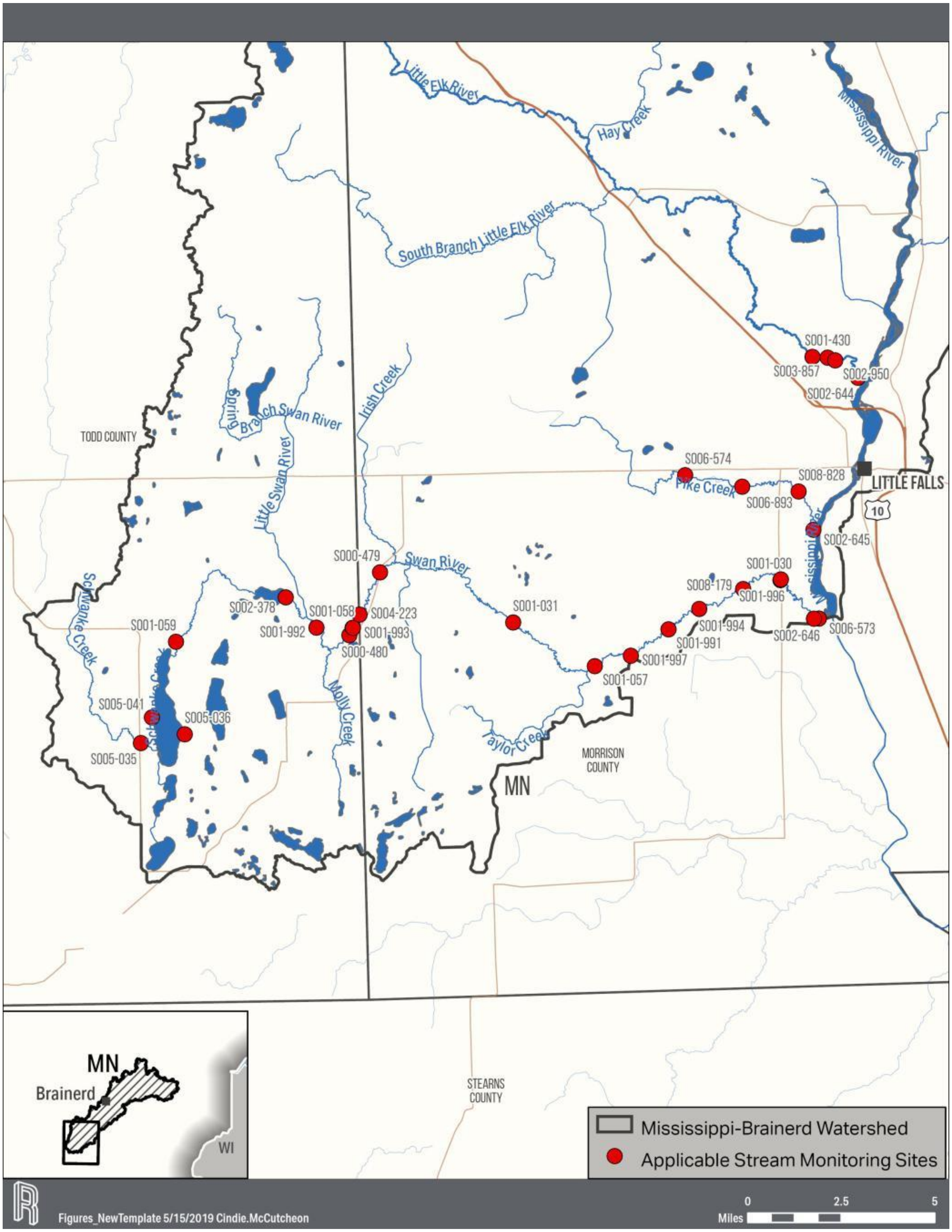


Figure A-2. Mississippi-Brainerd Monitoring Sites West

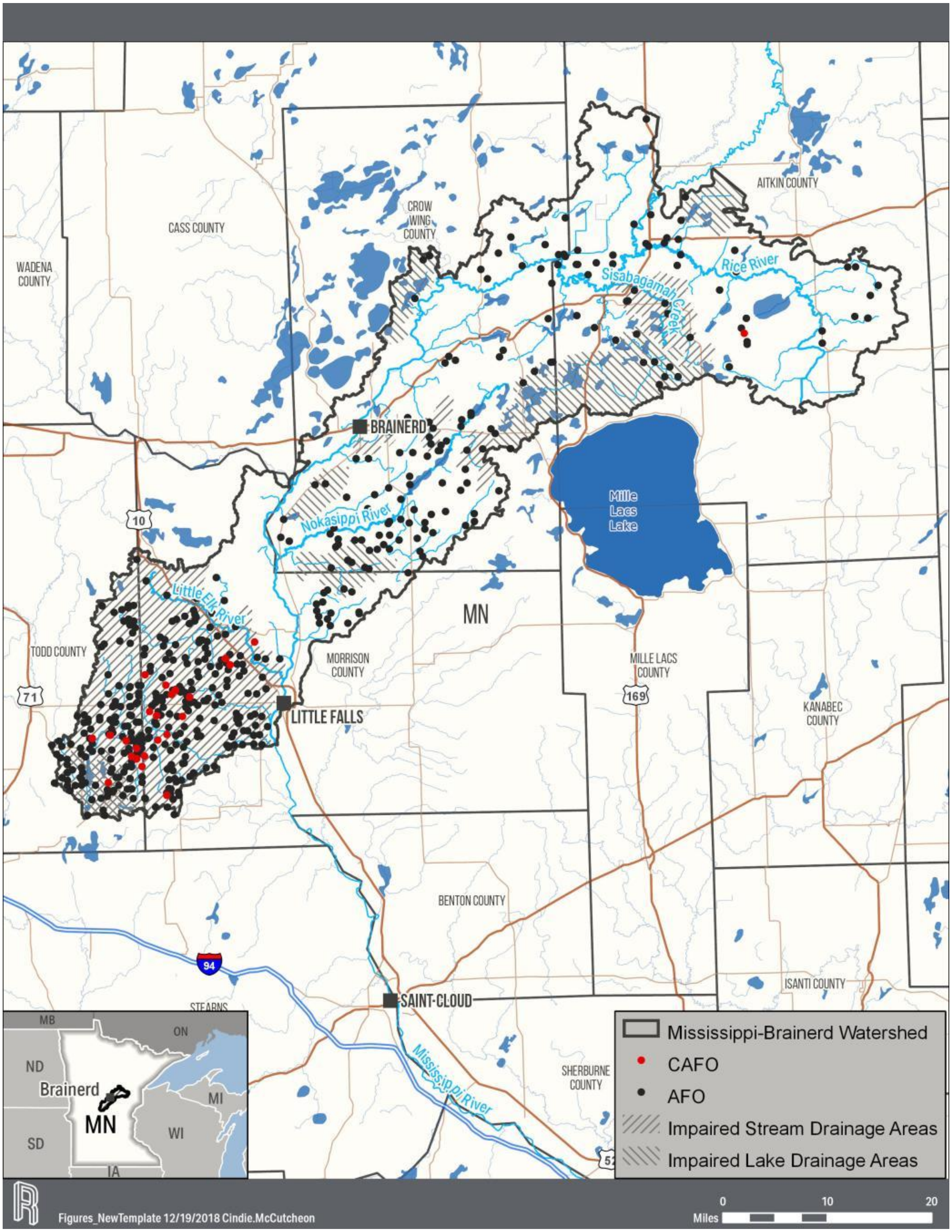


Figure A-3. Mississippi-Brainerd Feedlots

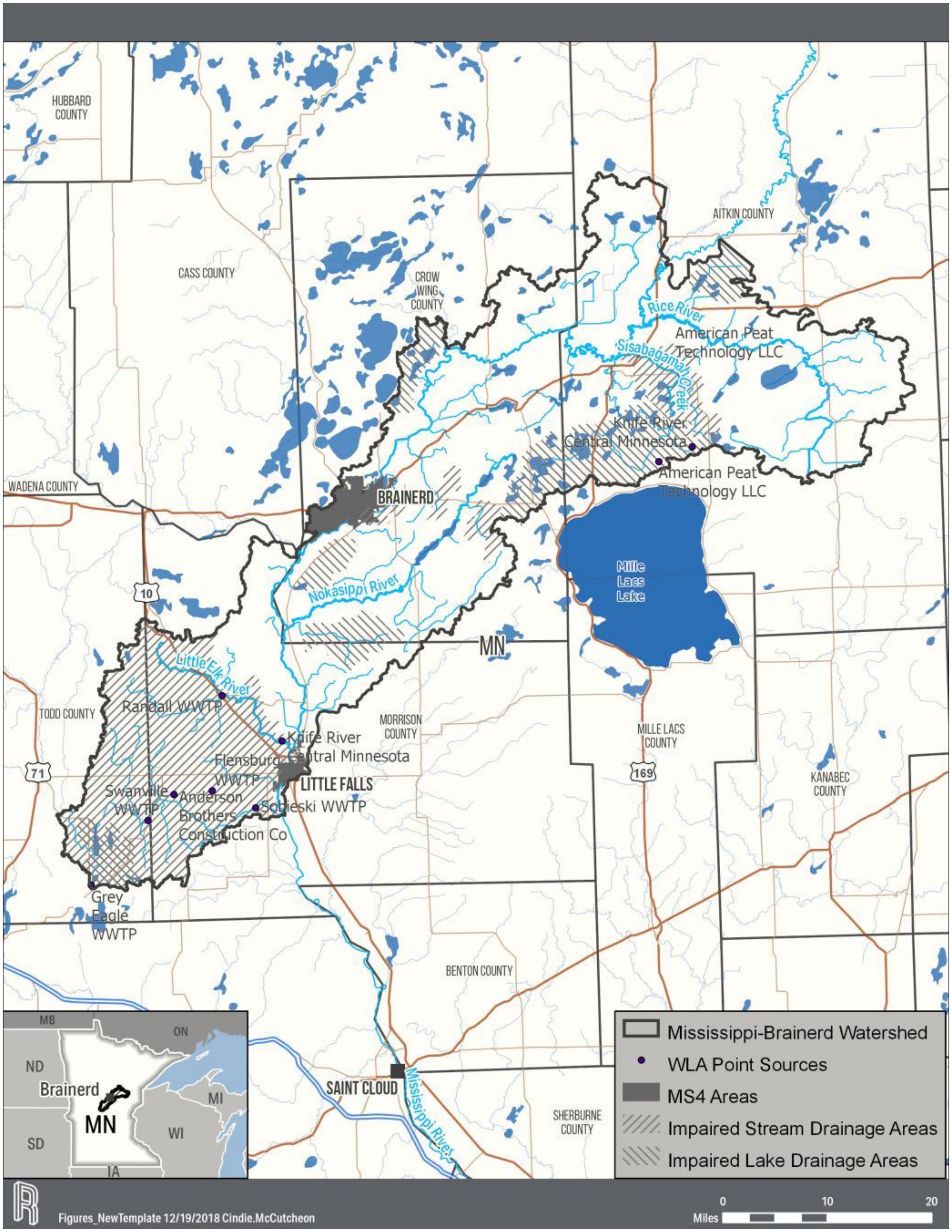


Figure A-4. Mississippi-Brainerd Point Sources

Appendix B: Big Swan (77-0023-00)

Land Cover

Land cover defined by the University of Minnesota [2016] is summarized for the Big Swan Lake Watershed in Table B-1 with the majority of the land cover consisting of row crops (28.7%), forest (20.4%), grassland (18.3%), and open water (11.5%).

Table B-1. Big Swan Lake Watershed Land Cover.

Impairment	Developed (%)	Wetlands (%)	Open Water (%)	Forest (%)	Grassland (%)	Hay/ Pastures (%)	Row Crops (%)
Big Swan	7.2	5.1	11.5	20.4	18.3	8.8	28.7

Physical Characteristics

Big Swan Lake is located 2 miles west of Burtrum, Minnesota, in Todd County, which is the southern portion of Mississippi-Brainerd HUC-8. From a regulatory standpoint, Big Swan Lake is categorized as a deep NCHF ecoregion lake. Select lake morphometric and watershed physical characteristics are listed in Table B-2. Big Swan Lake has one public access area maintained by the DNR that includes parking for approximately 14 boat trailers. Figure B-1 shows aerial imagery of Big Swan Lake, and Figure B-2 shows lake-level data.

Table B-2. Select Lake Morphometric and Watershed Characteristics for Big Swan Lake.

Characteristic	Big Swan Lake	Source
Lake Surface Area (acres)	946.6	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	404	DNR LakeFinder Fish Lake Surveys
Shore Length (miles)	7.77	DNR LakeFinder Fish Lake Surveys
Mean Depth (ft)	18[(a)]	DNR LakeFinder Fish Lake Surveys (a), Calculated (b), or Estimated from Lake Map (c)
Maximum Depth (ft)	45	DNR LakeFinder Fish Lake Surveys
Average Water Clarity (ft)	5.1[(a)]	DNR LakeFinder Fish Lake Surveys (a) or Average Growing Season Secchi Disk Depth (b)
Recorded Water Level Range (ft)	4.26	DNR LakeFinder Water Level
Percent Lake Littoral Surface Area	42.7	Calculated
Number of Islands	0	DNR Lakefinder Map
Public Access Sites	1	DNR LakeFinder Water Access Sites
Drainage Area, Including Lake (acres)	22,265	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	23.5	Calculated, Large in Bold
Wetland Area (acres)	3,432.8	Wetlands Layer
Number of Upland Lakes	14	USGS Topographic Maps
Number of Perennial Inlet Streams	4	NHD Flowlines Fcode 46006
Lake Volume (acre-feet)	14,509.5	Calculated
Maximum Fetch Length (ft)	16,341	Measured Using ArcGIS Imagery
Lake Geometry Ratio (A^0.25/Dmax)*	3.2	Calculated (Shallow > 5.3, Medium 1.6 to 5.3, Deep < 0.9)
Lake Geometry Classification	Medium	
Osgood Index (Dmean/sqrt(A))**	2.8	Calculated (Polymictic < 4, Intermediate 4 to 9, Dimictic > 9)
Osgood Index Category	Polymictic	
Estimated Water Residence Time (days)	374	HSPF Model Application
Shoreland Properties		Imagery

* A is surface area in m2 and Dmax is max depth in m

** A is surface area in km2 and Dmean is mean depth in m

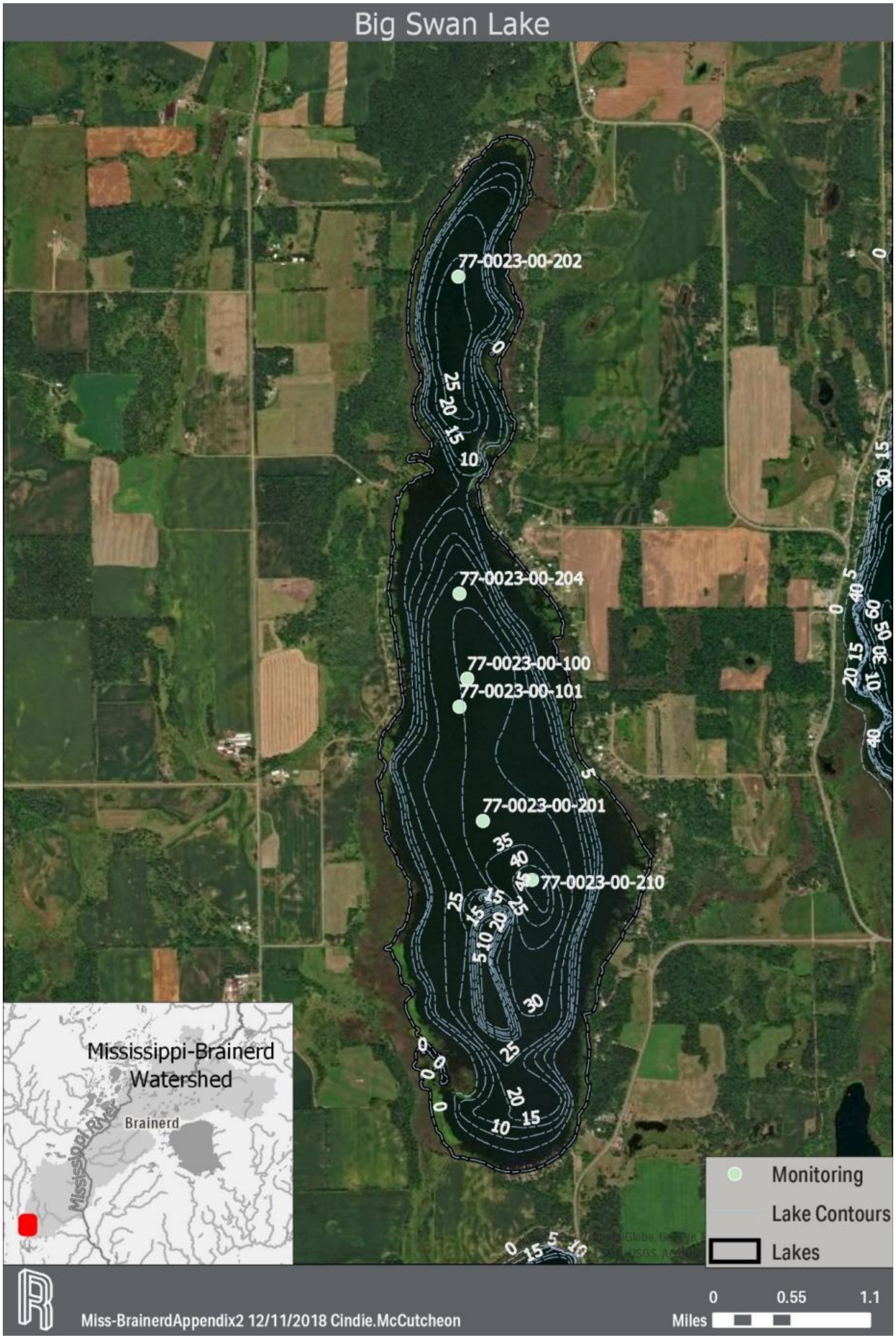


Figure B-1. Big Swan Lake Bathymetry and Aerial Imagery

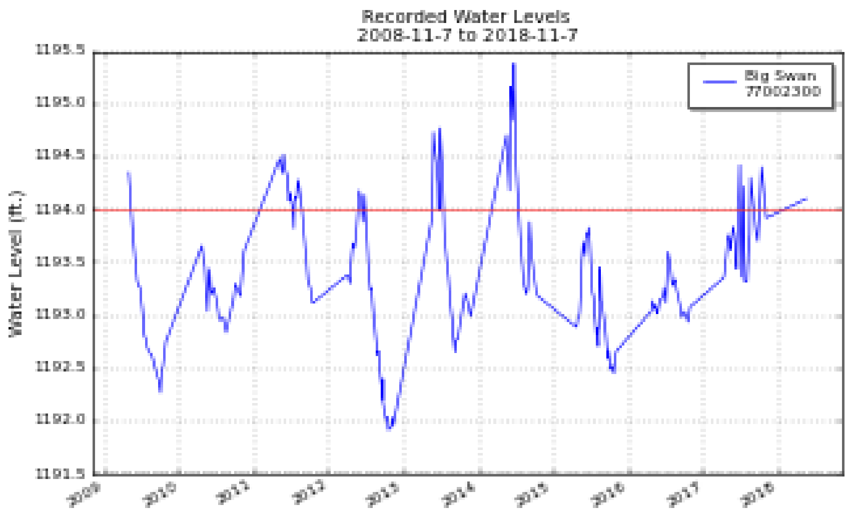


Figure B-2. Big Swan Lake Levels

Water Quality

Annual sample counts of monitoring data are shown in Table B-3 and summarized over the TMDL period (2006 through 2015) in Table B-4 as mean growing season values for TP, Chl-*a*, and Secchi transparency (Secchi). Data collected in 2016 are also shown but were not included for monthly or overall averaging unless no other data were available. Corresponding lake water quality standards are also included. Mean values for TP and Chl-*a* were above the water quality standard, whereas the mean SDD met the water quality standard. These data indicate that Big Swan Lake exceeds the P standard and will require reductions to achieve lake standards. Extreme high values of TP and Chl-*a* were 110 micrograms per liter (µg/L) and 85 µg/L, respectively, while the lowest Secchi reading was 0.5 meter (m). Individual growing season means from data available between 1990 and 2016 are plotted in Figures B-3 and B-4 and show that water quality standards were exceeded most years with available data.

Multiyear growing season mean monthly water quality observations are summarized in Figures B-6 through B-8 for data available from 2006 through 2015. Plots of this mean monthly data indicate a general decline in water quality from June through September. Error bars in annual and monthly P and Secchi plots indicate standard error.

Table B-3. Growing Season TP, Chl-*a*, and Secchi Numbers of Samples Annually.

Lake	Constituent	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[a]	Total
Big Swan	TP	5	8	16							8	4	37
	Chl-*a*	5	8	16							8	4	37
	Secchi	19	35	35	12	22	20	22	26	22	24	40	237

(a) 2016 data not included in total or overall growing season means unless no other data were available

Table B-4. TP, Chl-*a*, and Secchi Growing Season Means (2006–2015).

Parameter	Minimum	Mean	Maximum	Standard Deviation	Lake Standards
TP (µg/L)	16.0	45.3	110.0	26.3	≤40
Chl-*a* (µg/L)	1.0	25.1	85.0	23.8	≤14
Secchi Disk Depth (m)	0.5	2.2	5.9	1.2	≥1.4

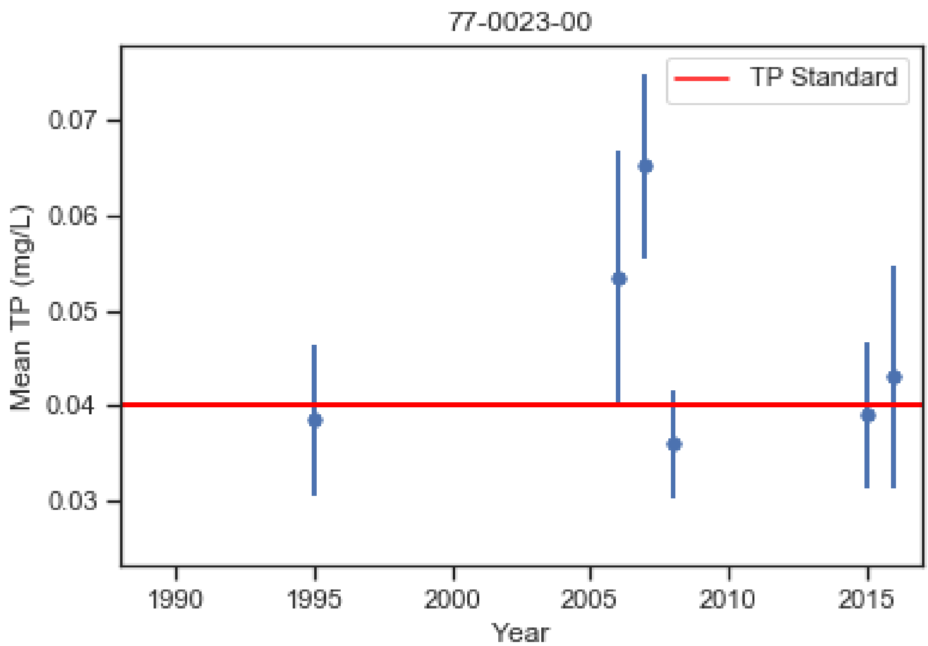


Figure B-3. Big Swan Lake Annual Growing Season Mean TP Concentrations

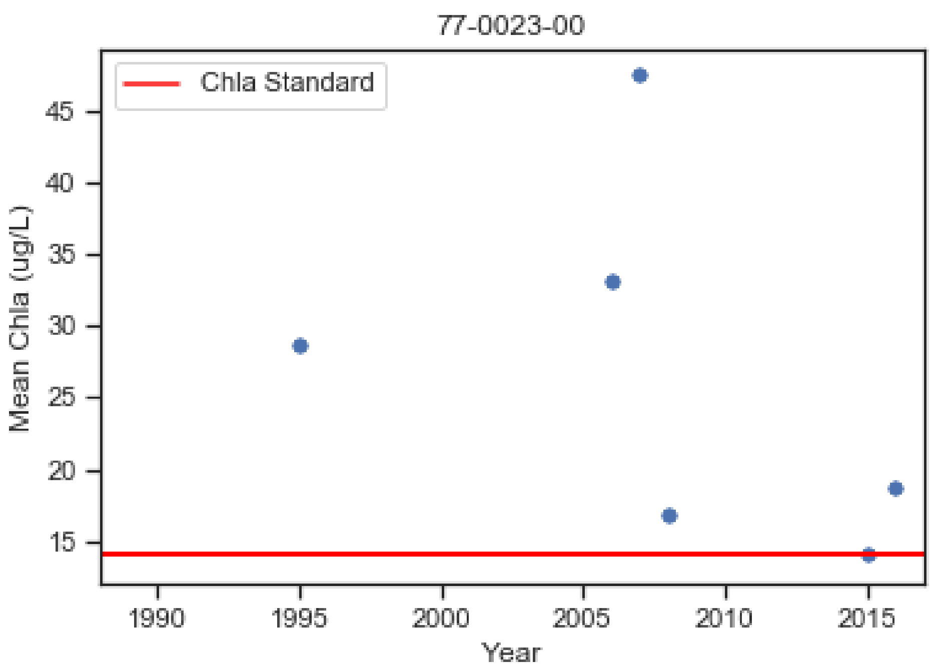


Figure B-4. Big Swan Lake Annual Growing Season Mean Chl-*a* Concentrations

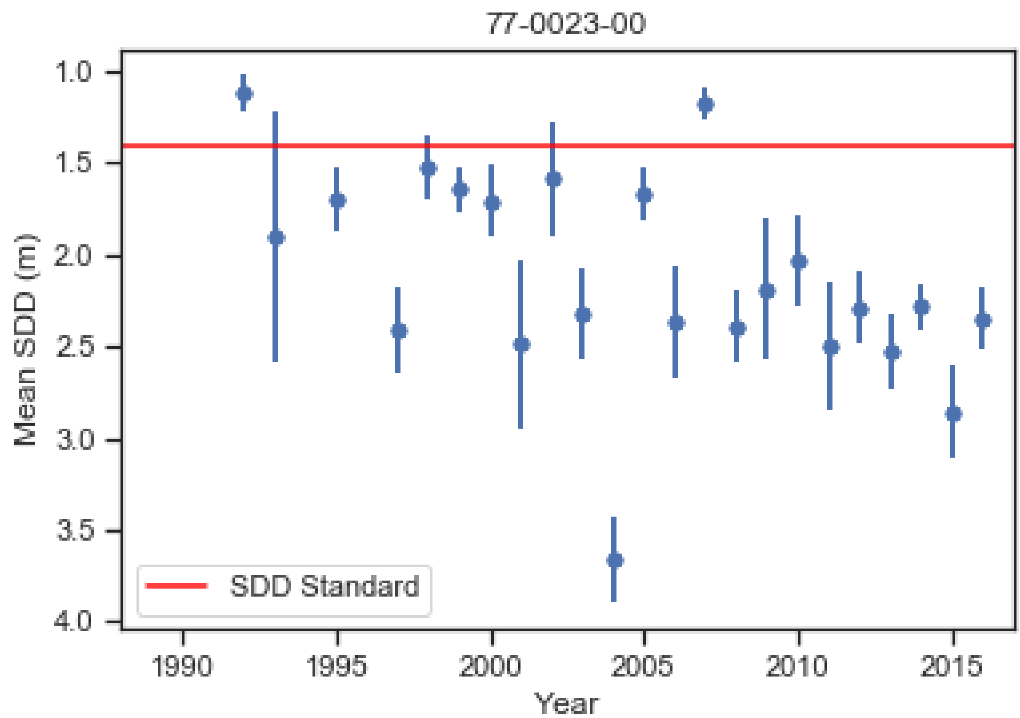


Figure B-5. Big Swan Lake Annual Growing Season Mean Secchi

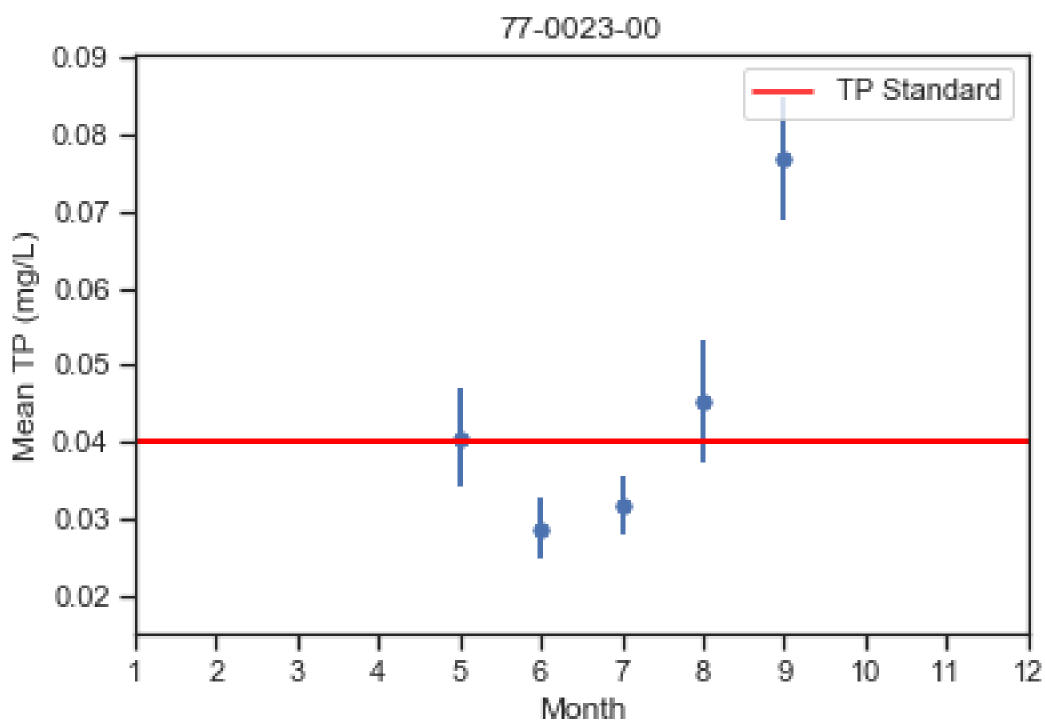


Figure B-6. Big Swan Lake Growing Season Monthly Mean TP (All Available Data 2006–2015)

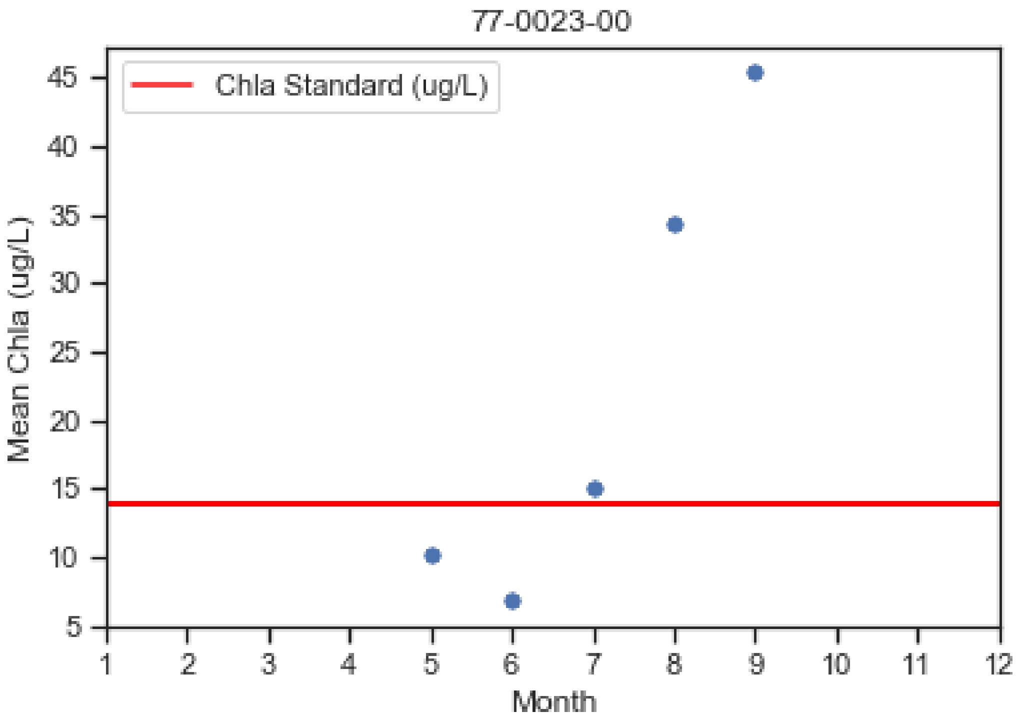


Figure B-7. Big Swan Lake Growing Season Monthly Mean Chl-*a* (All Available Data 2006–2015)

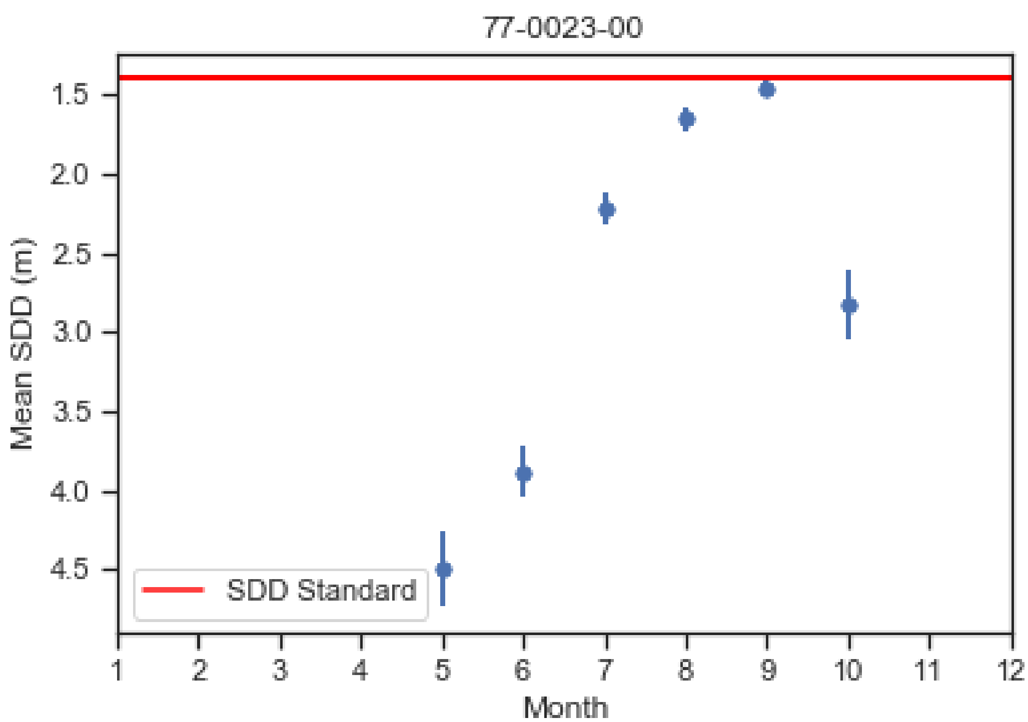


Figure B-8. Big Swan Lake Monthly Growing Season Mean Secchi (All Available Data 2006–2015)

Dissolved Oxygen and Temperature Summary

DO and temperature data monitored by depth were examined in an effort to better define the lake-mixing patterns that affect biological responses and lake P dynamics. Available data for all sites from 2006 through 2016 are plotted in Figures B-9 through B-13 for temperature and DO.

Water temperature profiles indicate well-mixed conditions at site 201 as temperatures are relatively similar from the surface to depth. Temperatures at sites 202 and 210 are more variable as water cools with depth. DO profiles indicate concentration losses with depth during warmer months, indicating that large oxygen depletion rates are occurring. Big Swan Lake exhibited clinograde-like oxygen patterns, with values decreasing at depth (less than 5 mg/L observed on several dates). The DO profiles often show a difference of more than 5 mg/L between the maximum and minimum measured DO concentrations.

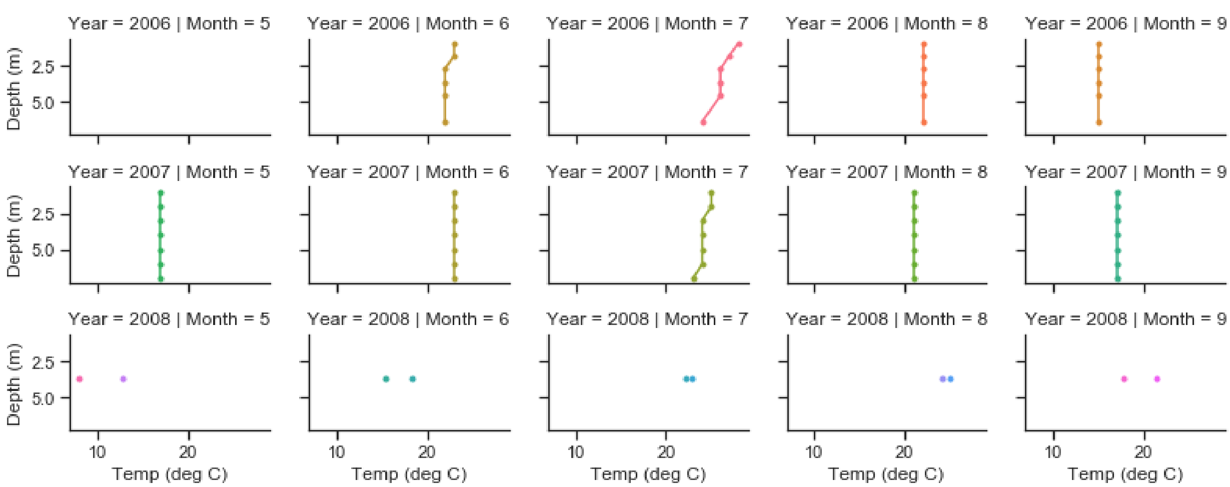


Figure B-9. Big Swan Lake Profiles for Temperature at Site 201

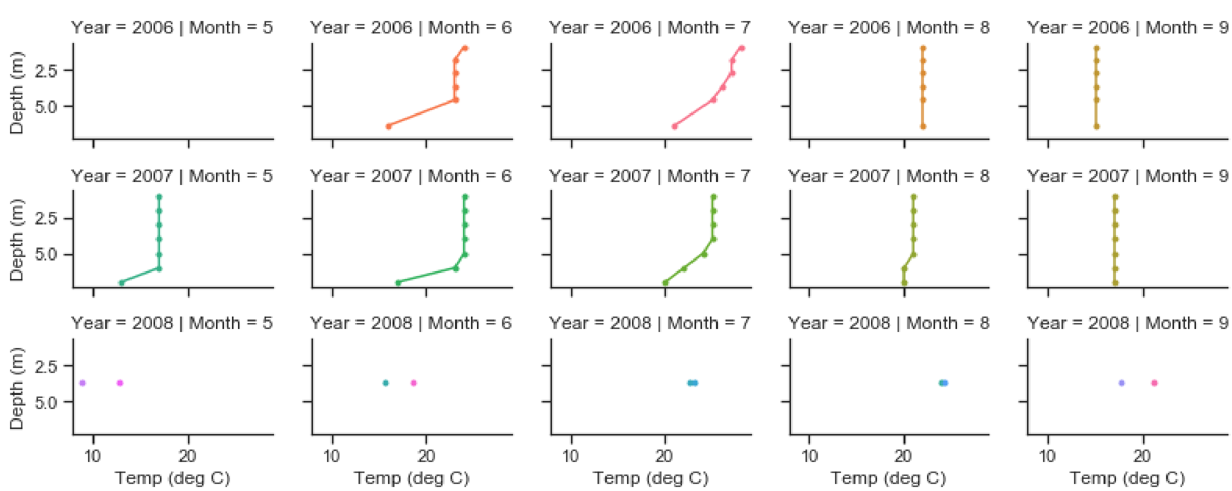


Figure B-10. Big Swan Lake Profiles for Temperature at Site 202

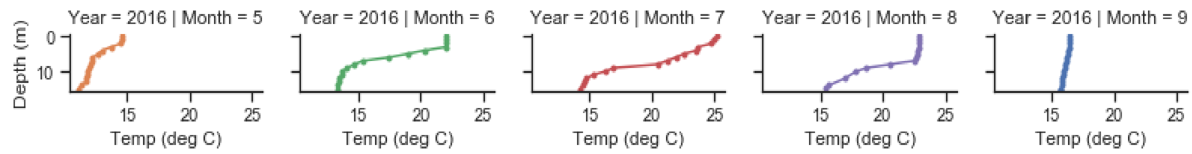


Figure B-11. Big Swan Lake Profiles for Temperature at Site 210

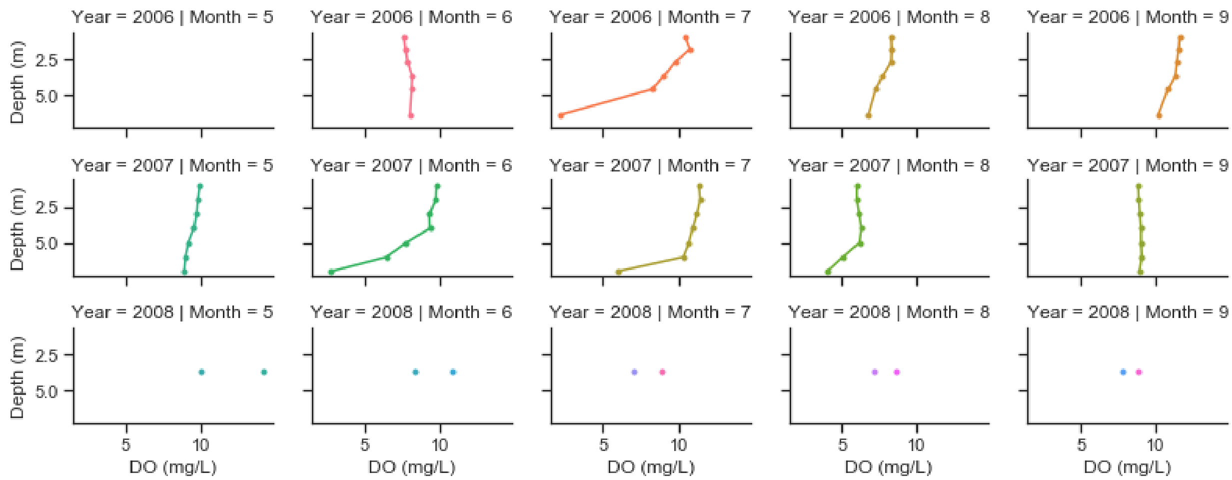


Figure B-12. Big Swan Lake Profiles for DO at Site 201

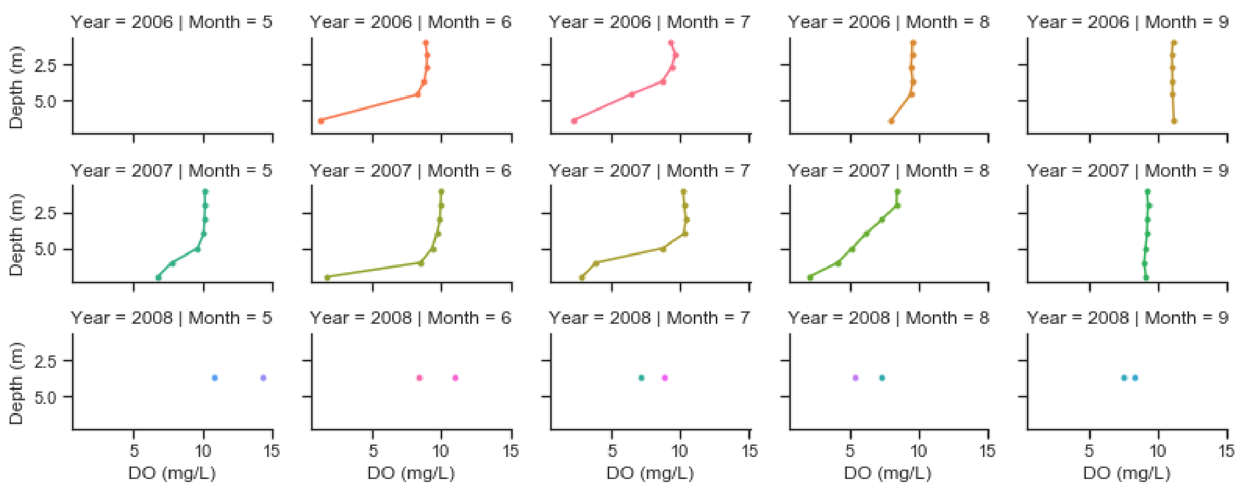


Figure B-13. Big Swan Lake Profiles for DO at Site 202

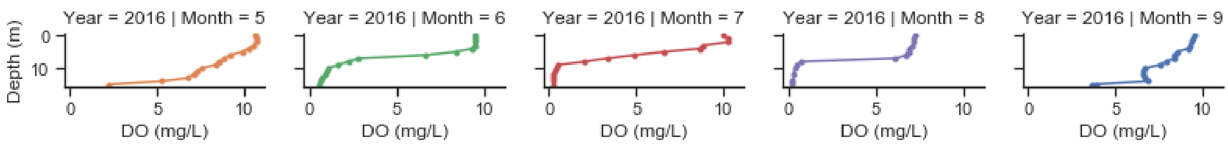


Figure B-14. Big Swan Lake Profiles for DO at Site 210

Aquatic Plants

Qualitative surveys of aquatic plants in Big Swan Lake were performed in 2004, 2008, and 2016 by the DNR. The 2004 survey found 17 species of submersed plants, 1 species of free-floating plants, 2 species of floating-leaf plants, and 4 species of emergent plants. The 2008 survey found 18 species of submersed plants, 2 species of free-floating plants, 3 species of floating-leaf plants, and 6 species of emergent plants. The 2016 survey found 20 species of submersed plants, 3 species of free-floating plants, 3 species of floating-leaf plants, and 8 species of emergent plants. The exotic invasive species curly-leaf pondweed (*Potamogeton Crispus*) was present in 2004 and 2008.

Fisheries

The DNR Fisheries surveyed Big Swan Lake in 2012 and 2016. From these surveys, the DNR Fisheries Lake FIBI Bioassessments noted the presence of intolerant species in the gill nets (Rock Bass) and a relatively large number vegetation dwelling species (8-10 species). The assessments also noted a high proportion of small benthic species sampled during the nearshore (seining and electrofishing) survey. Northern Pike and Walleye dominated the biomass of fish sampled by gill nets. Bluegill, Northern Pike, Bowfin, and Yellow Bullhead were most abundant by biomass in the trap net surveys. The nearshore surveys sampled a diversity of species with 21 species in 2012 and 29 species in 2016. Intolerant species sampled in one or more surveys included: Banded Killifish, Blackchin Shiner, Blacknose Shiner, Iowa Darter, Least Darter, Pugnose Shiner, and Rock Bass. Tolerant species included Black Bullhead, Common Carp, Fathead Minnows, and Green Sunfish [DNR 2017]. Black bullhead and common carp can stir up bottom sediments and increase P contributions to a lake.

Appendix C: Crow Wing (18-0155-00)

Land Cover

Land cover defined by the University of Minnesota [2016] is summarized for the Crow Wing Watershed in Table C-1 with the majority of the land cover consisting of forest (39.1%) and wetlands (29.9%).

Table C-1. Crow Wing Watershed Land Cover.

Impairment	Developed (%)	Wetlands (%)	Open Water (%)	Forest (%)	Grassland (%)	Hay/ Pastures (%)	Row Crops (%)
Crow Wing	8.7	29.9	4.0	39.1	6.8	2.2	9.3

Physical Characteristics

Crow Wing Lake is located five miles northeast of Fort Ripley, Minnesota, in Crow Wing County, which is the central portion of Mississippi-Brainerd HUC-8. From a regulatory standpoint, Crow Wing Lake is categorized as a deep Northern Lakes and Forest (NLF) ecoregion lake. Select lake morphometric and watershed physical characteristics are listed in Table C-2. Crow Wing Lake has one public access area maintained by the DNR that includes parking for approximately eight boat trailers. Figure C-1 shows aerial imagery of Crow Wing Lake, and Figure C-2 shows lake-level data.

Table C-2. Select Lake Morphometric and Watershed Characteristics of Crow Wing Lake.

Characteristic	Crow Wing Lake	Source
Lake Surface Area (acres)	378.9	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	210	DNR LakeFinder Fish Lake Surveys
Shore Length (miles)	3.88	DNR LakeFinder Fish Lake Surveys
Mean Depth (ft)	11[(a)]	DNR LakeFinder Fish Lake Surveys (a), Calculated (b), or Estimated from Lake Map (c)
Maximum Depth (ft)	26	DNR LakeFinder Fish Lake Surveys
Average Water Clarity (ft)	2.8[(a)]	DNR LakeFinder Fish Lake Surveys (a) or Average Growing Season Secchi Disk Depth (b)
Recorded Water Level Range (ft)	3.85	DNR LakeFinder Water Level
Percent Lake Littoral Surface Area	55.4	Calculated
Number of Islands	0	DNR Lakefinder Map
Public Access Sites	1	DNR LakeFinder Water Access Sites
Drainage Area, Including Lake (acres)	10,818	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	28.5	Calculated, Large in Bold
Wetland Area (acres)	1,796.7	Wetlands Layer
Number of Upland Lakes	0	USGS Topographic Maps
Number of Perennial Inlet Streams	0	NHD Flowlines Fcode 46006
Lake Volume (acre-feet)	4,638.1	Calculated
Maximum Fetch Length (ft)	7562	Measured Using ArcGIS Imagery
Lake Geometry Ratio (A^0.25/Dmax)*	4.4	Calculated (Shallow > 5.3, Medium 1.6 to 5.3, Deep < 0.9)
Lake Geometry Classification	Medium	
Osgood Index (Dmean/sqrt(A))**	2.7	Calculated (Polymictic < 4, Intermediate 4 to 9, Dimictic > 9)
Osgood Index Category	Polymictic	
Estimated Water Residence Time (days)	219	HSPF Model Application
Shoreland Properties		Imagery

* A is surface area in m2 and Dmax is max depth in m

** A is surface area in km2 and Dmean is mean depth in m

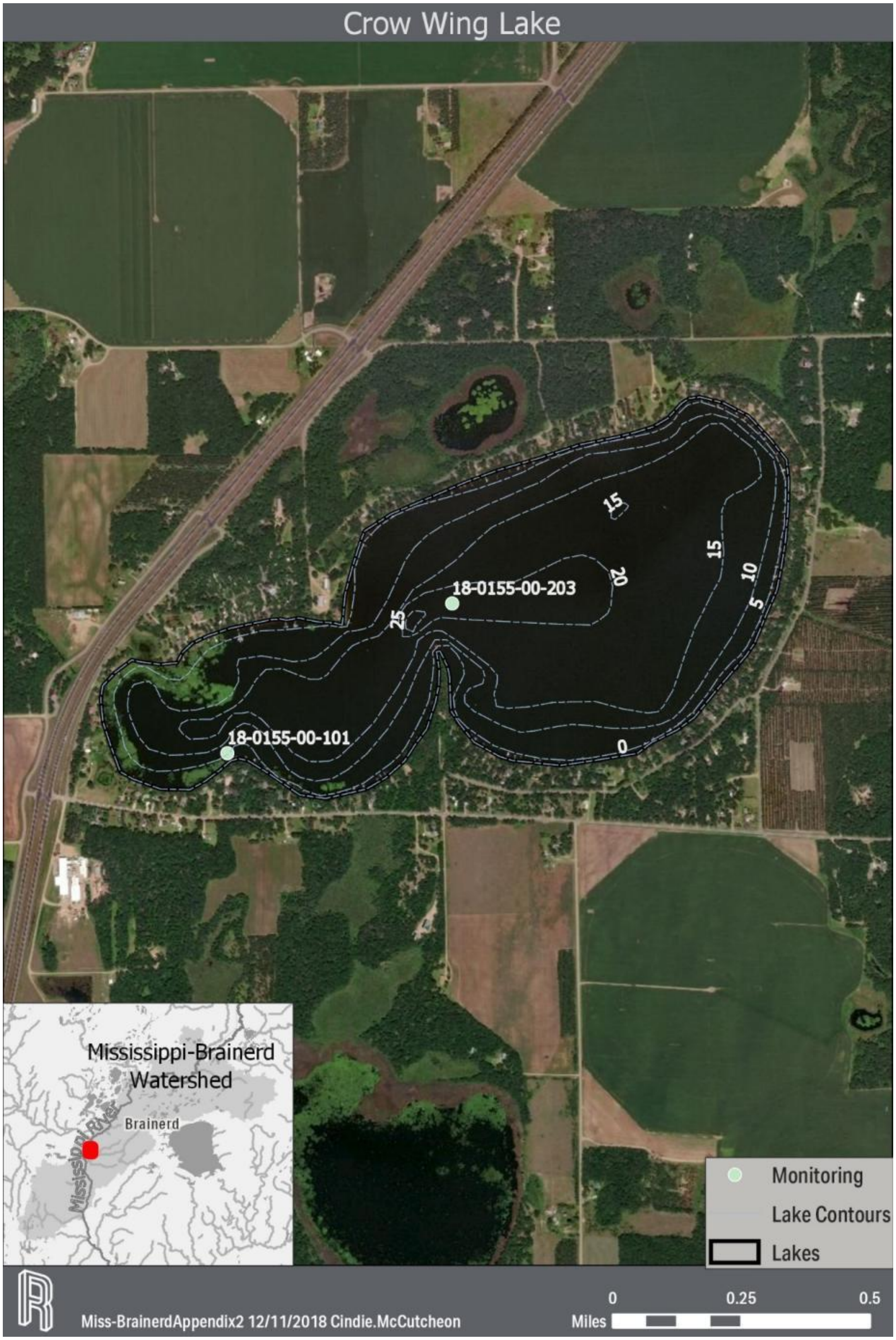


Figure C-1. Crow Wing Lake Bathymetry and Aerial Imagery

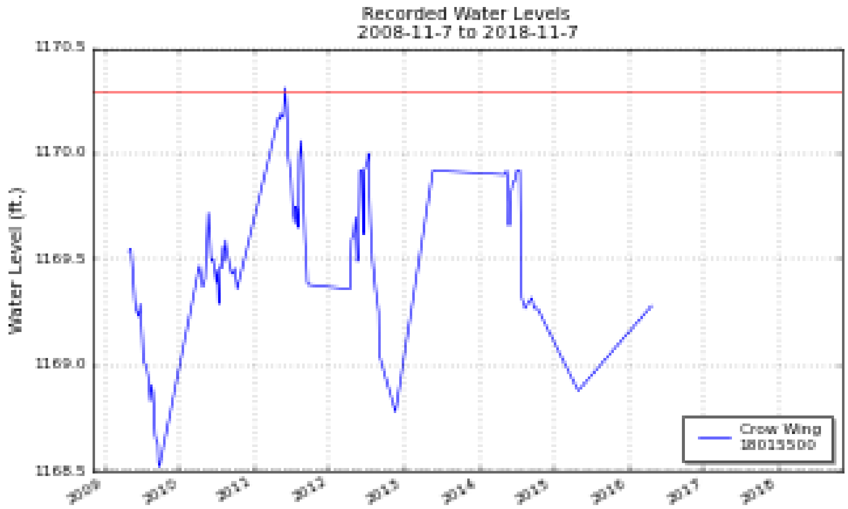


Figure C-2. Crow Wing Lake Levels

Water Quality

Annual sample counts for monitoring data are shown in Table C-3 and summarized over the TMDL period (2006 through 2015) in Table C-4 as mean growing season values for TP, Chl-*a*, and Secchi transparency (Secchi). Data collected in 2016 are also shown but were not included for monthly or overall averaging unless no other data were available. Corresponding lake water quality standards are also included. Mean values for TP and Chl-*a* were above the water quality standard. Similarly, the mean SDD did not meet the water quality standard. These data indicate that Crow Wing Lake exceeds the P standard and will require reductions to achieve lake standards. Extreme high values of TP and Chl-*a* were 207 micrograms per liter (µg/L) and 64 µg/L, respectively, whereas the lowest Secchi reading was 0.7 meter (m). Individual growing season means from data available between 1990 and 2016 are plotted in Figures C-2 to C-4 and show that water quality standards were exceeded most years with available data.

Multiyear growing season mean monthly water quality observations are summarized in Figures C-5 through C-7 for data available from 2006 through 2015. Plots of this mean monthly data indicate a better water quality in May and June and worse water quality in the warmer months of July through September. Error bars in annual and monthly P and Secchi plots indicate standard error.

Table C-3. Growing Season TP, Chl-a, and Secchi Numbers of Samples Annually.

Lake	Constituent	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[(a)]	Total
Crow Wing	TP		8	6						5		4	19
	Chl-*a*		8	6				1		5		4	20
	Secchi		11	9	3	2	3	9	5	24	26	32	92

(a) 2016 Data Not Included in Total or Overall Growing Season Means Unless No Other Data Were Available

Table C-4. TP, Chl-a, and Secchi Growing Season Means (2006–2015).

Parameter	Minimum	Mean	Maximum	Standard Deviation	Lake Standards
TP (µg/L)	18.0	37.7	80.0	19.1	≤30
Chl-*a* (µg/L)	4.0	22.4	64.0	17.0	≤9
Secchi Disk Depth (m)	0.7	1.6	3.5	0.6	≥2

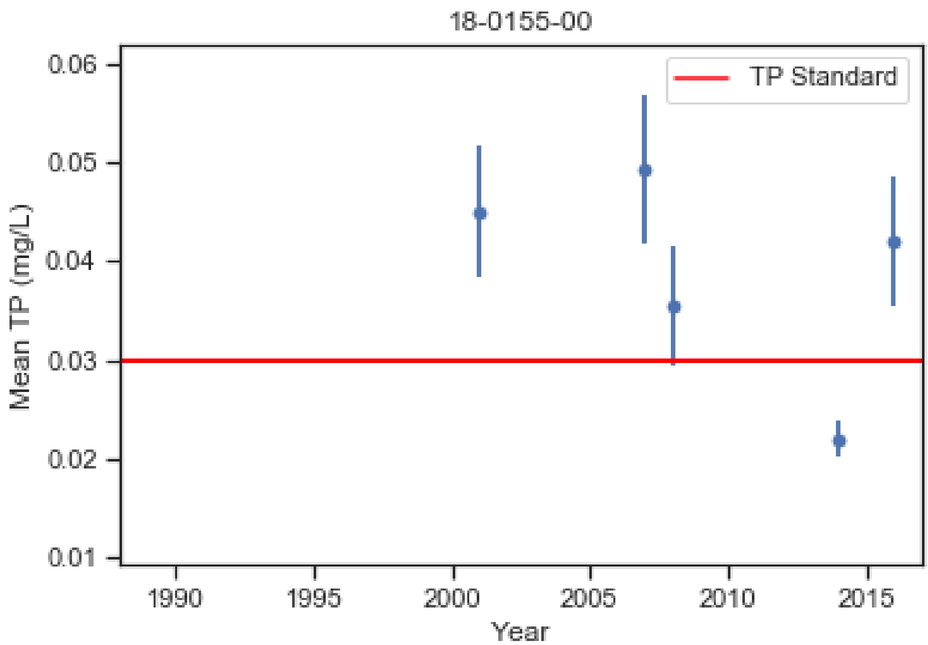


Figure C-3. Crow Wing Lake Annual Growing Season Mean TP Concentrations

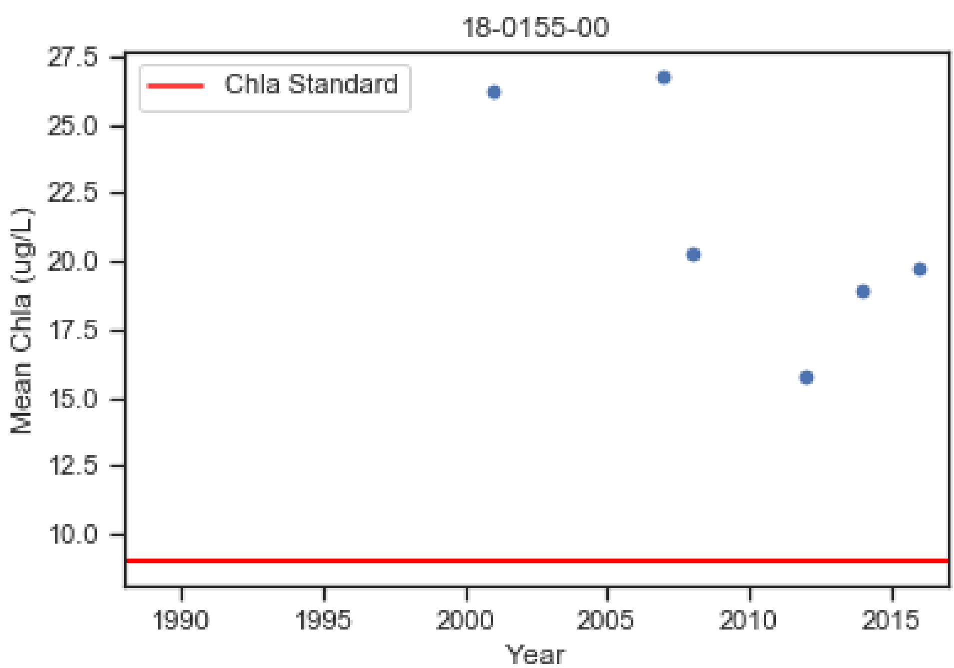


Figure C-4. Crow Wing Lake Annual Growing Season Mean Chl-a Concentrations

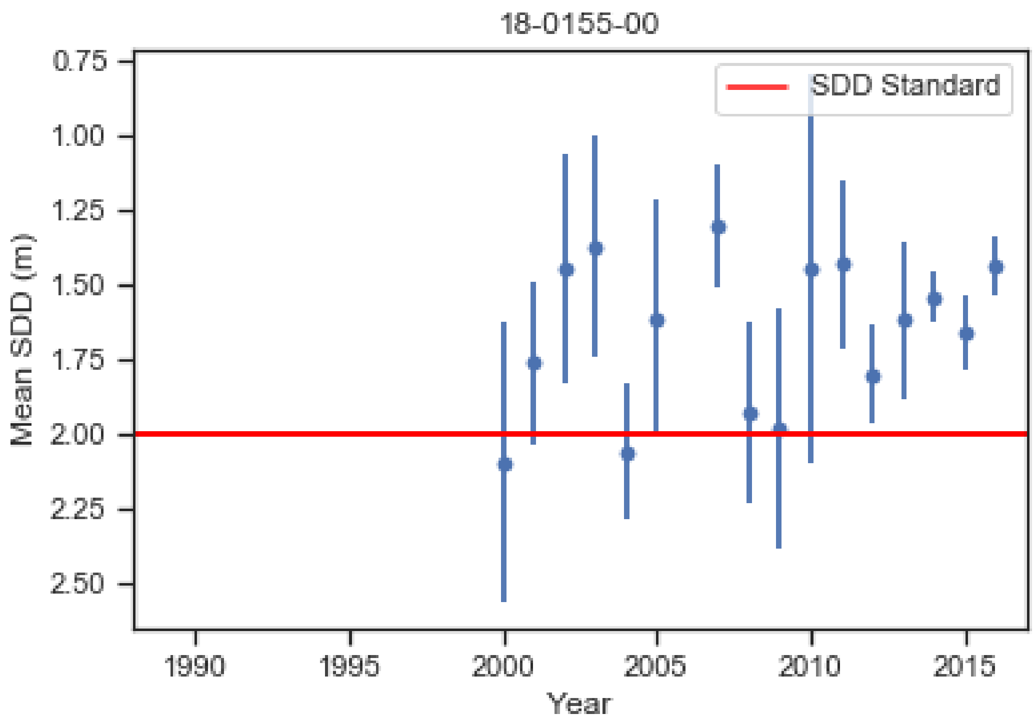


Figure C-5. Crow Wing Lake Annual Growing Season Mean Secchi

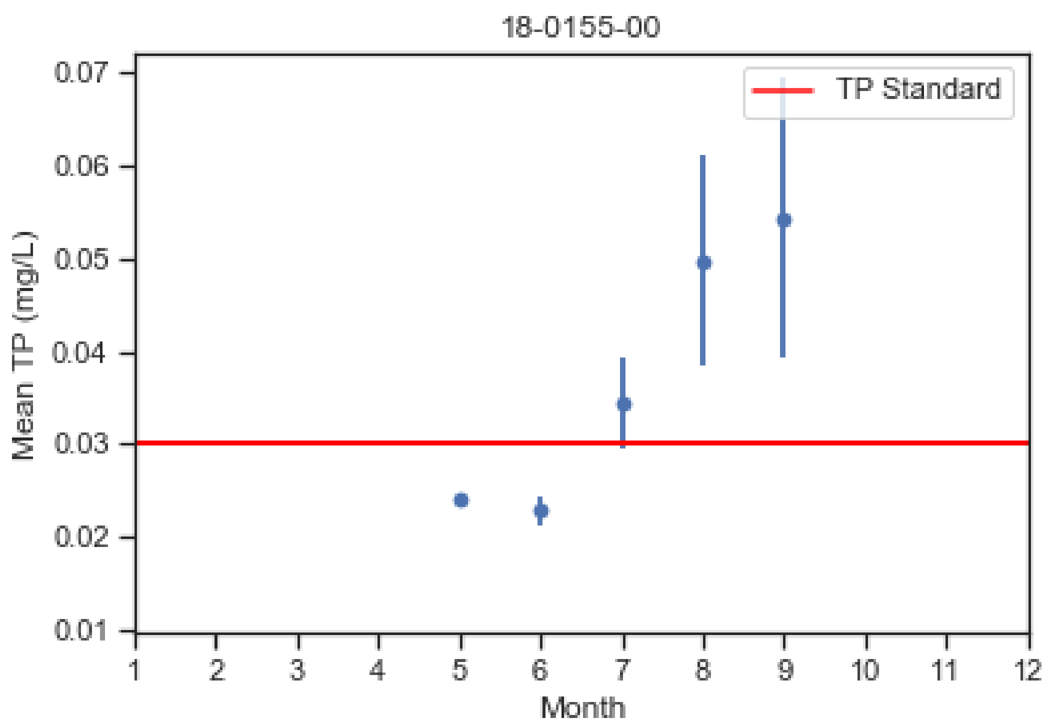


Figure C-6. Crow Wing Lake Growing Season Monthly Mean TP (All Available Data 2006–2015)

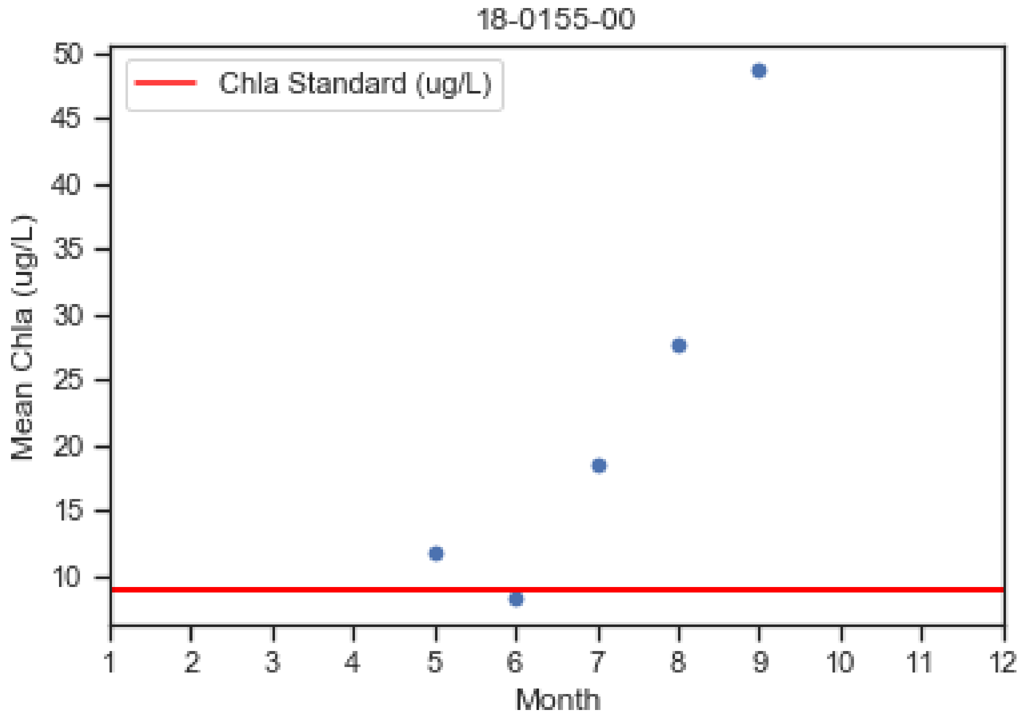


Figure C-7. Crow Wing Lake Growing Season Monthly Mean Chl-a (All Available Data 2006–2015)

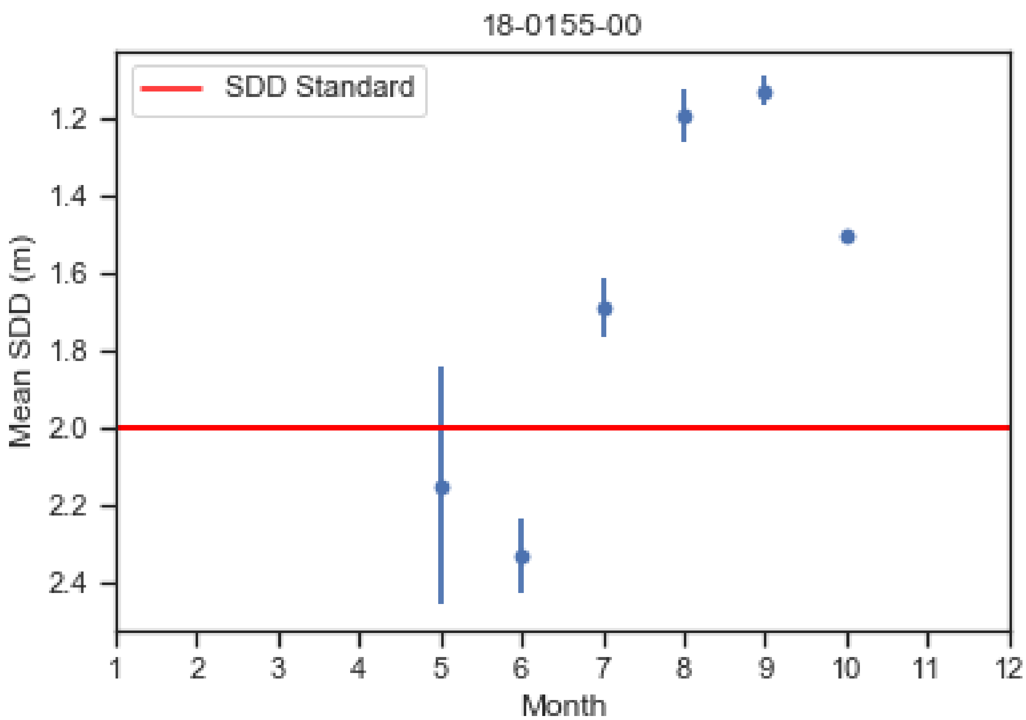


Figure C-8. Crow Wing Lake Monthly Growing Season Mean Secchi Mean Secchi (All Available Data 2006–2015)

Dissolved Oxygen and Temperature Summary

DO and temperature data monitored by depth were examined in an effort to better define the lake-mixing patterns that affect biological responses and lake P dynamics. Available data for all sites from 2006 through 2016 are plotted in Figures C-8 and C-9 for temperature and DO.

Water temperature profiles indicate cooling with depth at site 203, and DO profiles indicate concentration losses with depth from May through August, indicating that large oxygen depletion rates are occurring. Crow Wing Lake exhibited clinograde-like oxygen patterns, with values decreasing at depth (zero mg/L observed on several dates). When oxygen concentrations approach zero along lake bottoms, internal P loading from sediments is expected. The DO profiles often show a difference of more than 5 mg/L between the maximum and minimum measured DO concentrations.

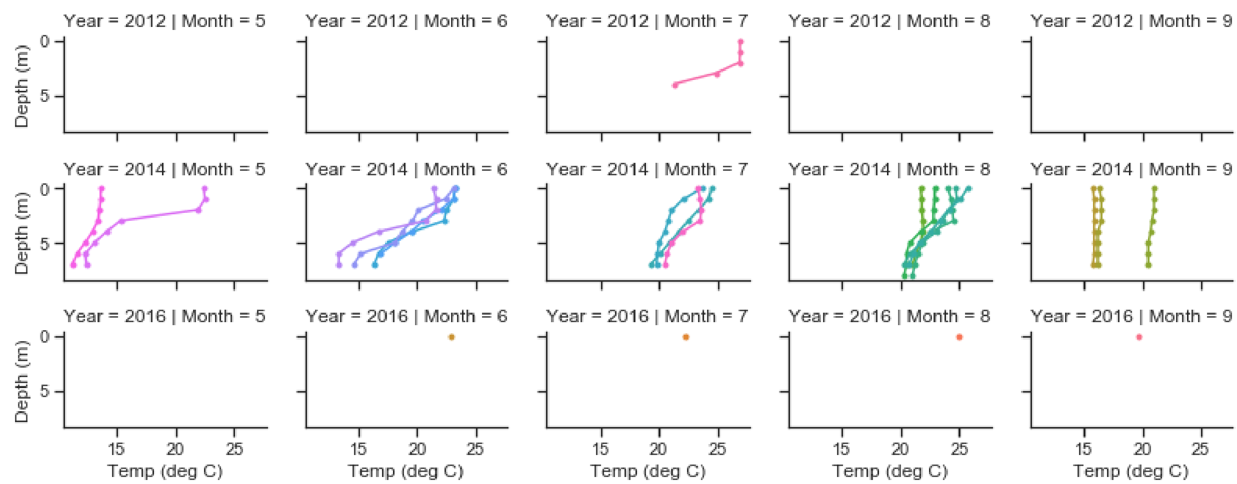


Figure C-9. Crow Wing Lake Profiles for Temperature at Site 203

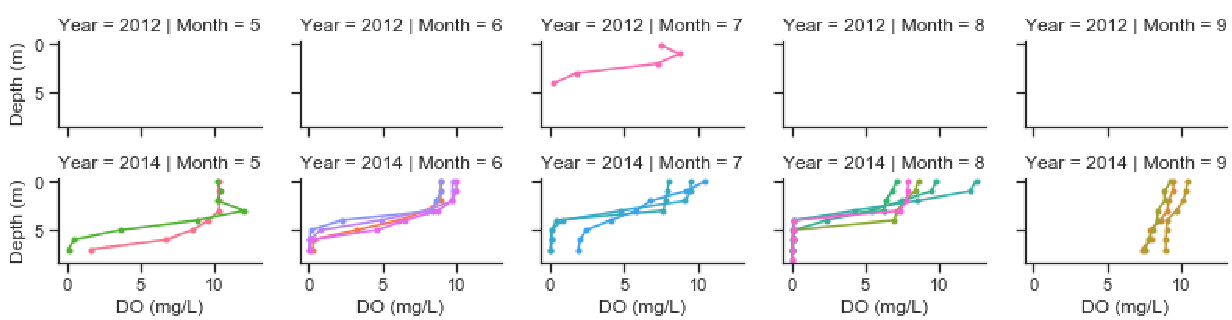


Figure C-10. Crow Wing Lake Profiles for DO at Site 203

Aquatic Plants

Two qualitative surveys of aquatic plants in Crow Wing Lake were performed on 2007 by the DNR. The survey done in May found 12 species of submersed plants, 1 specie of free-floating plants, 1 species of floating-leaf plants, and 1 species of emergent plants. The survey done in July found 13 species of submersed plants, 1 species of free-floating plants, 2 species of floating-leaf plants, and 4 species of emergent plants. The exotic invasive species curly-leaf pondweed (*Potamogeton Crispus*) was present during both surveys.

Fisheries

The DNR Fisheries surveyed Crow Wing Lake in 2010 and 2016. From these surveys, the DNR Fisheries Lake FIBI Bioassessments noted that there were a low number of intolerant species sampled (2) and a high number of omnivore species (5-6). The trap net composition also negatively influenced the score with relatively biomass of omnivore species and low biomass of insectivore species. Yellow Bullhead were most abundant by biomass in the 2010 trap net survey and second most abundant after White Sucker in the 2016 survey. The gill net surveys had different assemblages. Northern Pike, Walleye, and Yellow Bullhead dominated the gill net biomass in 2010; Black Crappie, Walleye, Yellow Bullhead, Northern Pike, and White Sucker accounted for most of the biomass in 2016. The fish species sampled by each nearshore survey also differed with Sunfish species and Bluntnose Minnow most abundant in 2010 and Spottail Shiner, Yellow Perch, and Bluegill most abundant in 2016. The only intolerant species sampled were Banded Killifish and Iowa Darter, both sampled in low numbers during each survey. Tolerant species included low numbers of Black Bullhead, Fathead Minnows, and Common Carp [DNR 2017]. These tolerant species can stir up bottom sediments and increase P contributions to a lake.

Appendix D: Elm Island (01-0123-00)

Land Cover

Land cover defined by the University of Minnesota [2016] is summarized for the Elm Island Watershed in Table D-1 with the majority of the land cover consisting of forest (38.8%), wetlands (26.8%), and open water (16.8%).

Table D-1. Elm Island Watershed Land Cover.

Impairment	Developed (%)	Wetlands (%)	Open Water (%)	Forest (%)	Grassland (%)	Hay/ Pastures (%)	Row Crops (%)
Elm Island	5.3	26.8	16.8	38.8	5.5	4.7	2.0

Physical Characteristics

Elm Island Lake is located 7 miles southeast of Aitkin, Minnesota, in Aitkin County, the northern portion of Mississippi-Brainerd HUC-8. From a regulatory standpoint, Big Swan Lake is categorized as a deep NLF ecoregion lake. Select lake morphometric and watershed physical characteristics are listed in Table D-2. Elm Island Lake has one public access area maintained by the DNR that includes parking for approximately eight boat trailers. Figure D-1 shows aerial imagery of Elm Island Lake, and Figure D-2 shows lake-level data.

Table D-2. Select Lake Morphometric and Watershed Physical Characteristics for Elm Island Lake.

Characteristic	Elm Island Lake	Source
Lake Surface Area (acres)	519.5	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	389	DNR LakeFinder Fish Lake Surveys
Shore Length (miles)	7.92	DNR LakeFinder Fish Lake Surveys
Mean Depth (ft)	9[(a)]	DNR LakeFinder Fish Lake Surveys (a), Calculated (b), or Estimated from Lake Map (c)
Maximum Depth (ft)	25	DNR LakeFinder Fish Lake Surveys
Average Water Clarity (ft)	5.5[(a)]	DNR LakeFinder Fish Lake Surveys (a) or Average Growing Season Secchi Disk Depth (b)
Recorded Water Level Range (ft)	3.37	DNR LakeFinder Water Level
Percent Lake Littoral Surface Area	74.9	Calculated
Number of Islands	2	DNR Lakefinder Map
Public Access Sites	1	DNR LakeFinder Water Access Sites
Drainage Area, Including Lake (acres)	61713	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	**118.8**	Calculated, Large in Bold
Wetland Area (acres)	18,350.5	Wetlands Layer
Number of Upland Lakes	45	USGS Topographic Maps
Number of Perennial Inlet Streams	1	NHD Flowlines Fcode 46006
Lake Volume (acre-feet)	5,087.6	Calculated
Maximum Fetch Length (ft)	7,638	Measured Using ArcGIS Imagery
Lake Geometry Ratio (A^0.25/Dmax)*	5.0	Calculated (Shallow > 5.3, Medium 1.6 to 5.3, Deep < 0.9)
Lake Geometry Classification	Medium	
Osgood Index (Dmean/sqrt(A))**	1.9	Calculated (Polymictic < 4, Intermediate 4 to 9, Dimictic > 9)
Osgood Index Category	Polymictic	
Estimated Water Residence Time (days)	55	HSPF Model Application
Shoreland Properties		Imagery

* A is surface area in m2 and Dmax is max depth in m

** A is surface area in km2 and Dmean is mean depth in m

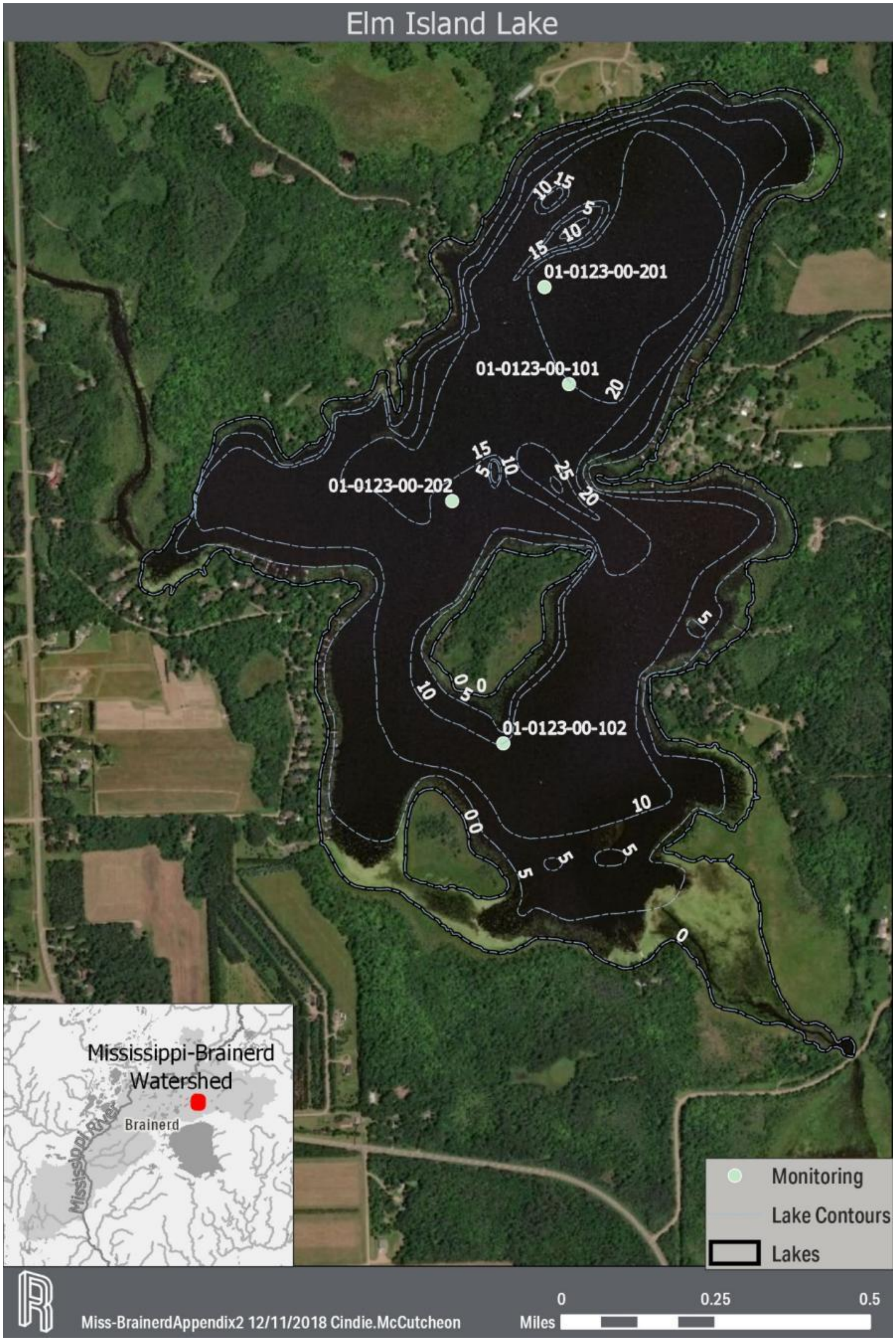


Figure D-1. Elm Island Lake Bathymetry and Aerial Imagery

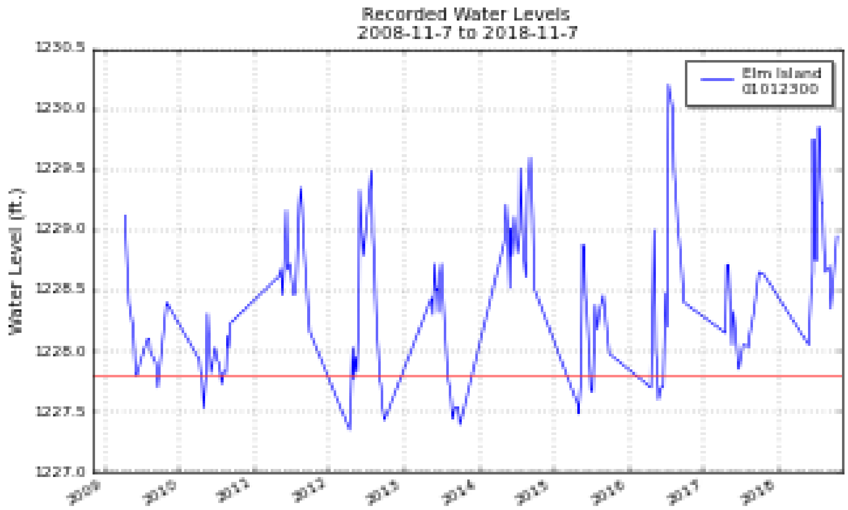


Figure D-2. Elm Island Lake Levels

Water Quality

Annual sample counts for monitoring data are shown in Table D-3 and summarized over the TMDL period (2006 through 2015) in Table D-4 as mean growing season values for TP, Chl-*a*, and Secchi transparency (Secchi). Data collected in 2016 are also shown but were not included for monthly or overall averaging unless no other data were available. Corresponding lake water quality standards are also included. Mean values for TP and Chl-*a* were above the water quality standard. Similarly, the mean SDD did not meet the water quality standard. These data indicate that Elm Island Lake exceeds the P standard and will require reductions to achieve lake standards. Extreme high values of TP and Chl-*a* were 71 µg/L and 65 µg/L, respectively, whereas the lowest Secchi reading was 0.5 m. Individual growing season means from data available between 1990 and 2016 are plotted in Figures D-2 through D-4 and show that means from all years exceeded the water quality standards.

Multiyear growing season mean monthly water quality observations are summarized in Figures D-5 through D-7 for data available from 2006 through 2015. Plots of this mean monthly data indicate a general decline in water quality from June through September. Error bars in annual and monthly P and Secchi plots indicate standard error.

Table D-3. Growing Season TP, Chl-*a*, and Secchi Numbers of Samples Annually.

Lake	Constituent	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[a]	Total
Elm Island	TP		8									5	8
	Chl-*a*		8									5	8
	Secchi	11	14	6	12	8	14	11	8	13	12	9	109

(a) 2016 data not included in total or overall growing season means unless no other data were available

Table D-4. TP, Chl-*a*, and Secchi Growing Season Means (2006–2015).

Parameter	Minimum	Mean	Maximum	Standard Deviation	Lake Standards
TP (µg/L)	44.0	59.1	71.0	10.1	≤30
Chl-*a* (µg/L)	12.8	32.8	65.8	15.0	≤9
Secchi Disk Depth (m)	0.5	1.2	2.0	0.3	≥2

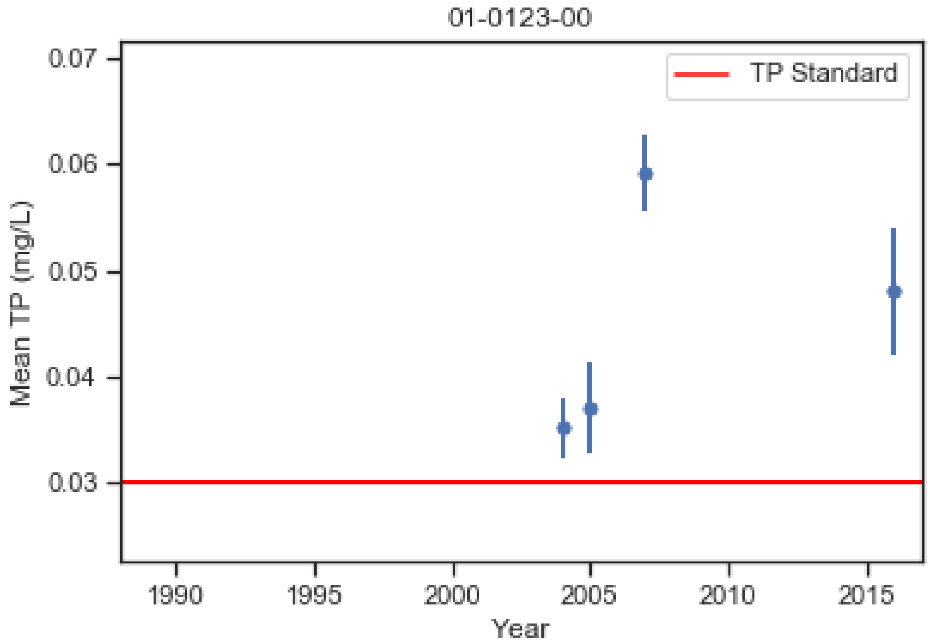


Figure D-3. Elm Island Lake Annual Growing Season Mean TP Concentrations

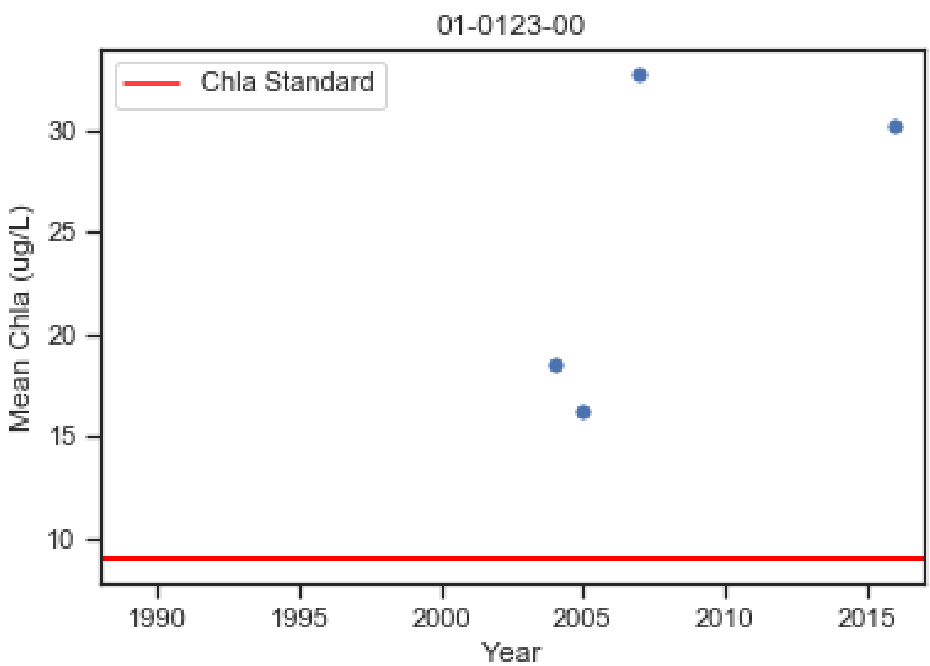


Figure D-4. Elm Island Lake Annual Growing Season Mean Chl-a Concentrations

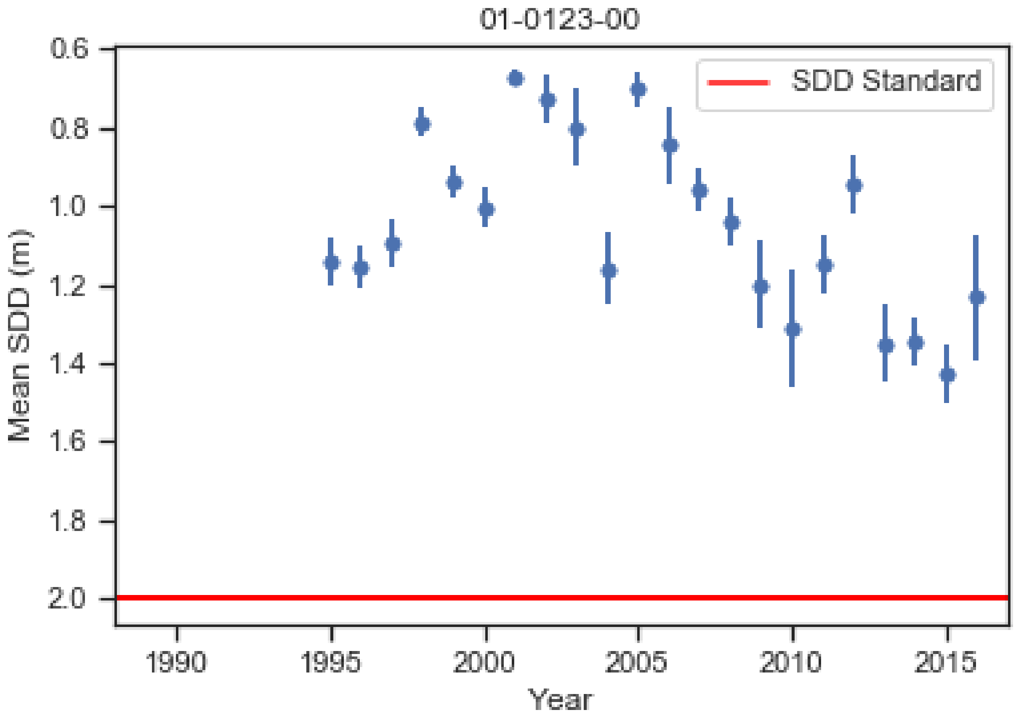


Figure D-5. Elm Island Lake Annual Growing Season Mean Secchi

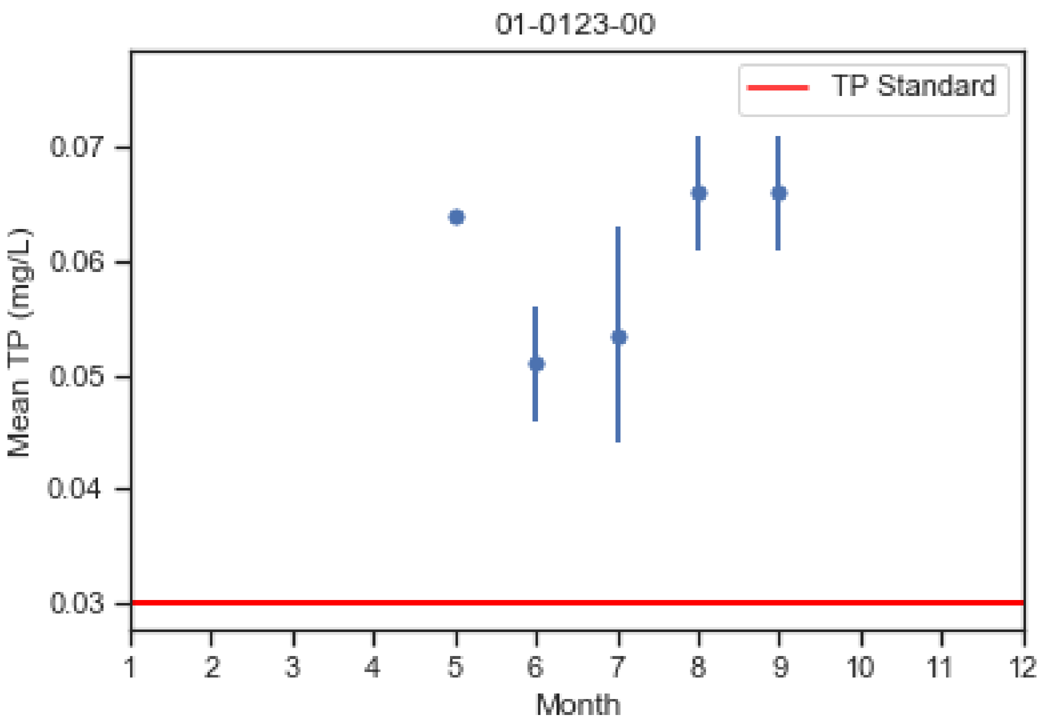


Figure D-6. Elm Island Lake Growing Season Monthly Mean TP (All Available Data 2006–2015)

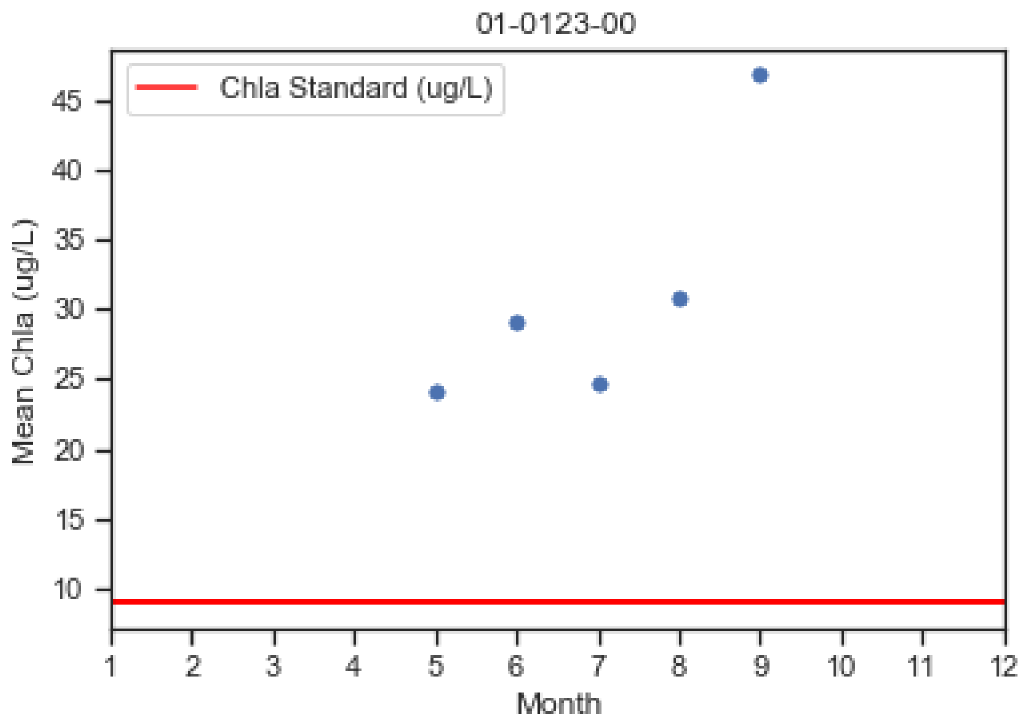


Figure D-7. Elm Island Lake Growing Season Monthly Mean Chl-*a* (All Available Data 2006–2015)

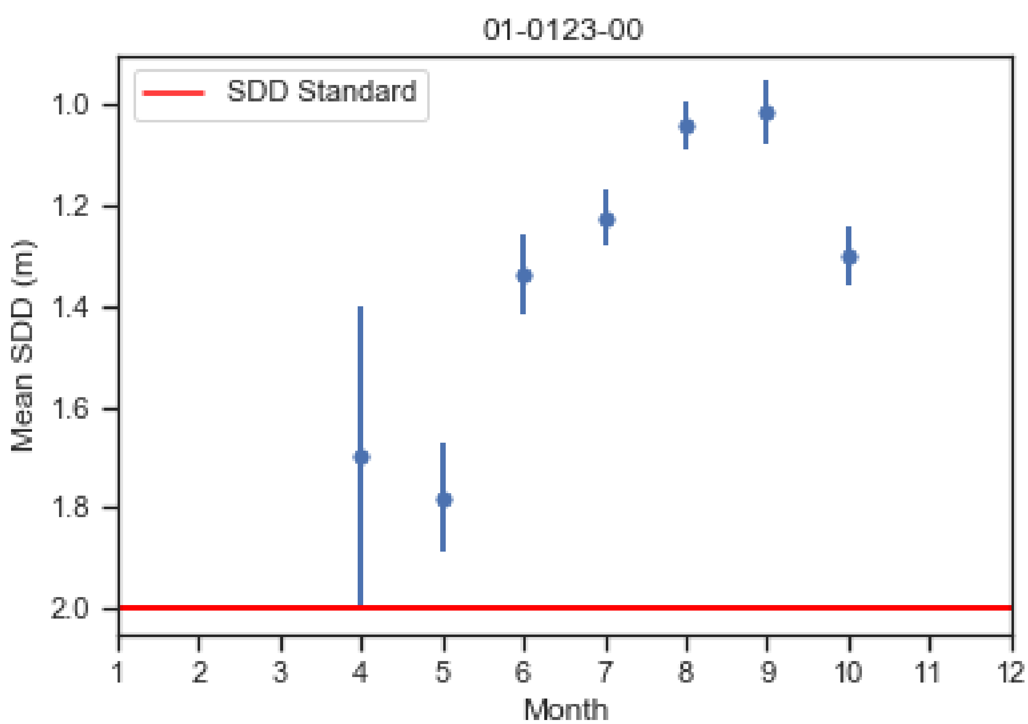


Figure D-8. Elm Island Lake Monthly Growing Season Mean Secchi (All Available Data 2006–2015)

Dissolved Oxygen and Temperature Summary

DO and temperature data monitored by depth were examined in an effort to better define the lake-mixing patterns that affect biological responses and lake P dynamics. Available data from all sites from 2006 through 2016 are plotted in Figures D-8 through D-11 for temperature and DO.

Water temperature profiles indicate cooling with depth at sites 201 and 202 between June and August. DO profiles indicate concentration losses with depth during warmer months, indicating that large oxygen depletion rates are occurring. Elm Island Lake exhibited clinograde-like oxygen patterns, with values decreasing at depth (zero mg/L observed on several dates). When oxygen concentrations approach zero along lake bottoms, internal P loading from sediments is expected. The DO profiles often show a difference of more than 5 mg/L between the maximum and minimum measured DO concentrations.

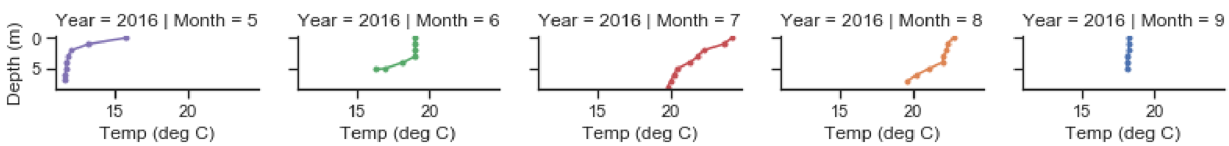


Figure D-9. Elm Island Lake Profiles for Temperature at Site 201

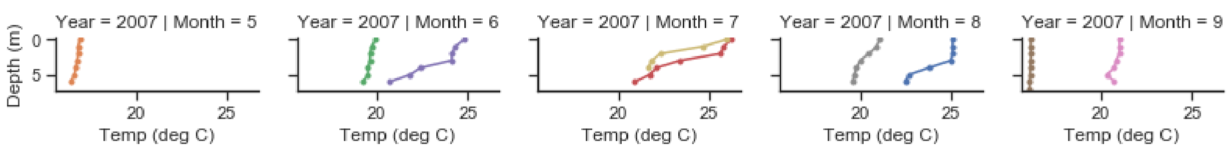


Figure D-10. Elm Island Lake Profiles for Temperature at Site 202

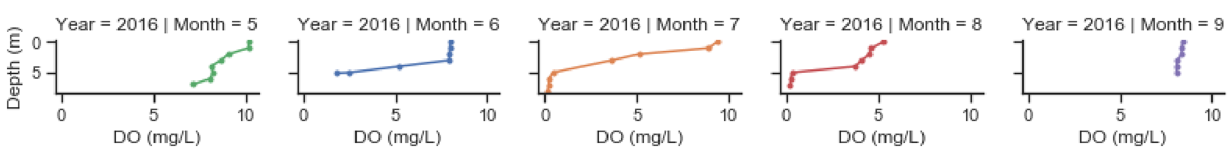


Figure D-11. Elm Island Lake Profiles for DO at Site 201

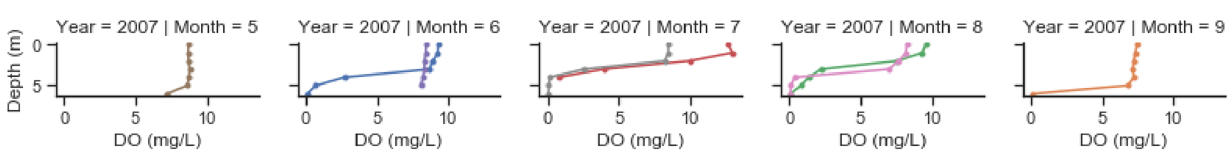


Figure D-12. Elm Island Lake Profiles for DO at Site 202

Aquatic Plants

A qualitative survey of aquatic plants in Elm Island Lake was performed in 2013 by the DNR. This survey found 13 species of submersed plants, 1 species of free-floating plants, 3 species of floating-leaf plants, and 5 species of emergent plants. The exotic invasive species curly-leaf pondweed (*Potamogeton Crispus*) was present during this survey.

Fisheries

The DNR Fisheries surveyed Elm Island Lake in 2013 and 2016. From these surveys, the DNR Fisheries Lake FIBI Bioassessments noted that there was a low number of intolerant species sampled and by the composition of species sampled by the trap nets. The trap nets had a relatively high biomass of tolerant species (Black Bullhead) and a low biomass of insectivore species. Northern Pike were the most abundant species by biomass in gill nets, and the metric measuring top carnivore biomass in the gill nets had a positive influence on the scores. Few fish were sampled in the 2013 nearshore survey (primarily Largemouth Bass and Yellow Perch). In 2016, Yellow Perch, Black Crappie, and Bluegill were most commonly sampled with small catches of two intolerant species (Logperch and Rock Bass) [DNR 2017]. Black bullhead can stir up bottom sediments and increase P contributions to a lake.

Appendix E: Fawn (18-0240-00)

Land Cover

Land cover defined by the University of Minnesota [2016] is summarized for the Fawn Watershed in Table E-1 with the majority of the land cover consisting of wetlands (34.7%), forest (26.7%), and open water (21.2%).

Table E-1. Fawn Watershed Land Cover.

Impairment	Developed (%)	Wetlands (%)	Open Water (%)	Forest (%)	Grassland (%)	Hay/ Pastures (%)	Row Crops (%)
Fawn	4.2	34.7	21.2	26.7	5.6	0.1	7.6

Physical Characteristics

Fawn Lake is located 3.3 miles northwest of Riverton, Minnesota, in Crow Wing County in the central portion of the Mississippi-Brainerd HUC-8. Fawn Lake was categorized as a shallow NLF ecoregion lake for this TMDL because of its high percent of littoral area. Select lake morphometric and watershed physical characteristics are listed in Table E-2. Fawn Lake has one public access maintained by Crow Wing County that includes parking for approximately three boat trailers. Figure E-1 shows aerial imagery of Fawn Lake. Two lake levels at Fawn Lake of 1201.75 feet (ft) and 1201.74 ft were recorded in December of 2004. A lake level of 1199.53 ft was also recorded in 1961.

Table E-2. Select Lake and Watershed Physical Characteristics for Fawn Lake.

Characteristic	Fawn Lake	Source
Lake Surface Area (acres)	120.7	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	108	DNR LakeFinder Fish Lake Surveys
Shore Length (miles)	1.71	DNR LakeFinder Fish Lake Surveys
Mean Depth (ft)	10[(c)]	DNR LakeFinder Fish Lake Surveys (a), Calculated (b), or Estimated from Lake Map (c)
Maximum Depth (ft)	24	DNR LakeFinder Fish Lake Surveys
Average Water Clarity (ft)	2.3[(b)]	DNR LakeFinder Fish Lake Surveys (a) or Average Growing Season Secchi Disk Depth (b)
Recorded Water Level Range (ft)	2.2	DNR LakeFinder Water Level
Percent Lake Littoral Surface Area	89.5	Calculated
Number of Islands	0	DNR LakeFinder Map
Public Access Sites	1	DNR LakeFinder Water Access Sites
Drainage Area, Including Lake (acres)	2,512	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	20.8	Calculated, Large in Bold
Wetland Area (acres)	260.4	Wetlands Layer
Number of Upland Lakes	2	USGS Topographic Maps
Number of Perennial Inlet Streams	1	NHD Flowlines Fcode 46006
Lake Volume (acre-ft)	1,206.8	Calculated
Maximum Fetch Length (ft)	3,246	Measured Using ArcGIS Imagery
Lake Geometry Ratio (A^0.25/Dmax), A is surface area in m2 and Dmax is max depth in meters (m)	3.6	Calculated (Shallow>5.3, Medium1.6–5.3, Deep<0.9)
Lake Geometry Classification	Medium	
Osgood Index (Dmean/sqrt[A]), A is surface area in km2 and Dmean is mean depth in m	4.4	Calculated (Polymictic<4, Intermediate4–9,Dimictic>9)
Osgood Index Category	Intermediate	
Estimated Water Residence Time (days)	226	HSPFModel Application
Shore Land Properties		Imagery

Figure E-1. Fawn Lake Aerial Imagery

Water Quality

Monitoring data annual sample counts are shown in Table E-3 and are summarized for 2016 in Table E-4 as mean growing season values for TP, Chl-*a*, and Secchi transparency (Secchi). Corresponding lake water quality standards are also included. Data were not collected during the TMDL period (2006 through 2015). Mean values for TP and Chl-*a* are above the water quality standard. Similarly, the mean SDD did not meet the water quality standard. These data indicate that Fawn Lake exceeds the P standard and will require reductions to achieve lake standards. Extreme high values of TP and Chl-*a* were 341 micrograms per liter (µg/L) and 65 µg/L, respectively, while the lowest Secchi reading was 0.6 m. Individual growing season means from data available between 1990 and 2016 are plotted in Figures E-2 through E-4 and show that water quality standards were exceeded in 2016, the only year with available data.

Multiyear growing season mean monthly water quality observations are summarized in Figures E-5 through E-7 for 2016, the only year with available data. Plots of this mean monthly data indicate poor water quality throughout the summer. Error bars in annual and monthly P and Secchi plots indicate standard error.

Table E-3. Growing Season TP, Chl-*a*, and Secchi Number of Samples Annually.

Lake	Constituent	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[(a)]	Total
Fawn	TP											4	4[(b)]
	Chl-*a*											4	4[(b)]
	Secchi											11	11[(b)]

(a) 2016 Data Not Included in Total or Overall Growing Season Means Unless No Other Data Were Available

(b) Only 2016 Samples Available for Total

Table E-4. Total P, Chl-*a*, and Secchi Growing Season Means (2016).

Parameter	Minimum	Mean	Maximum	Standard Deviation	Lake Standards
TP (µg/L)	43.0	54.7	65.0	9.7	≤30
Chl-*a* (µg/L)	29.4	42.6	65.0	16.4	≤9
Secchi disk depth (m)	0.6	0.7	0.9	0.1	≥2

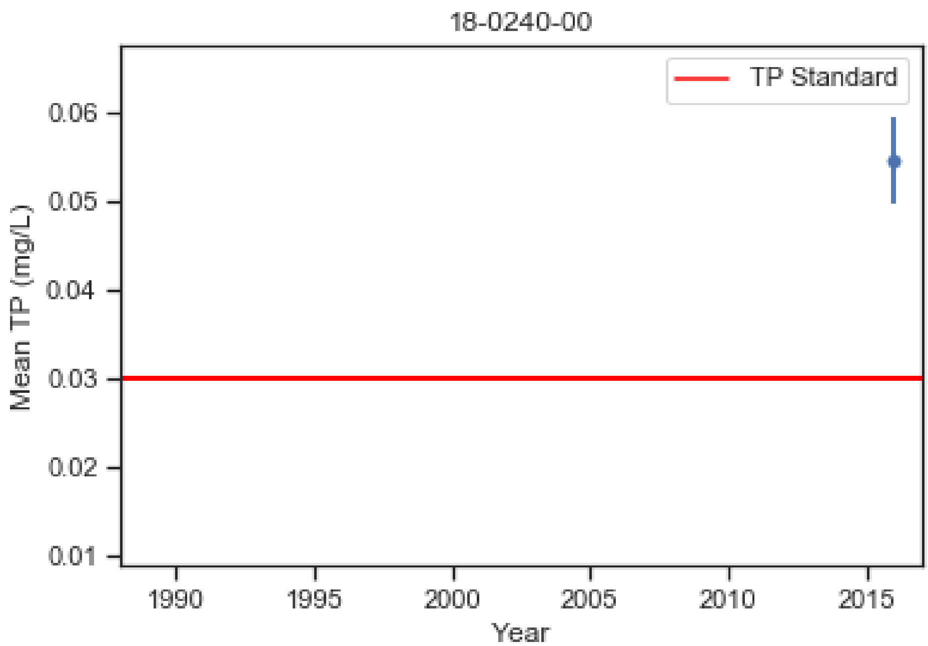


Figure E-2. Fawn Lake Annual Growing Season Mean TP Concentrations

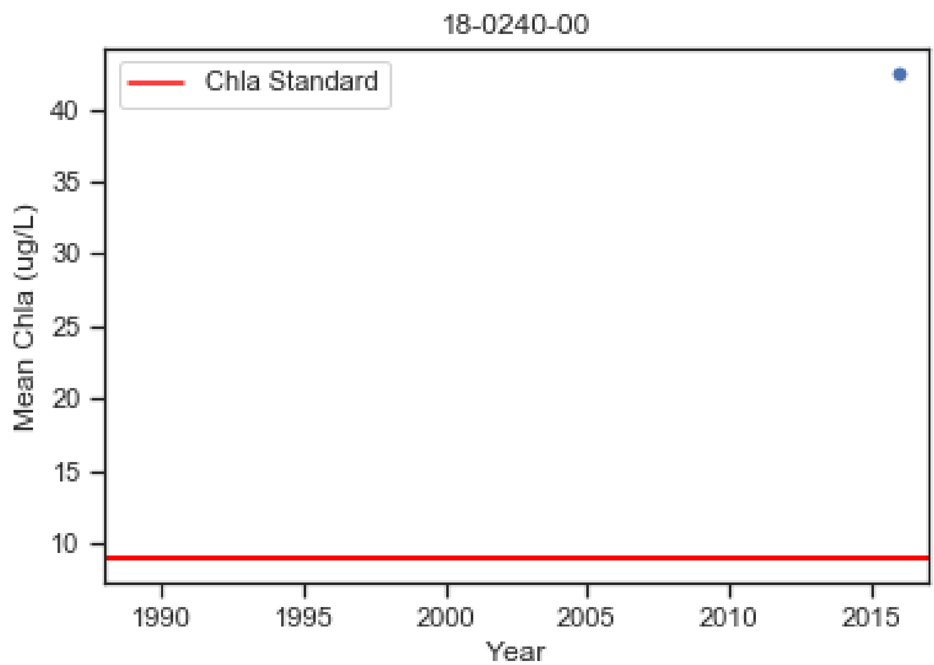


Figure E-3. Fawn Lake Annual Growing Season Mean Chl-*a* Concentrations

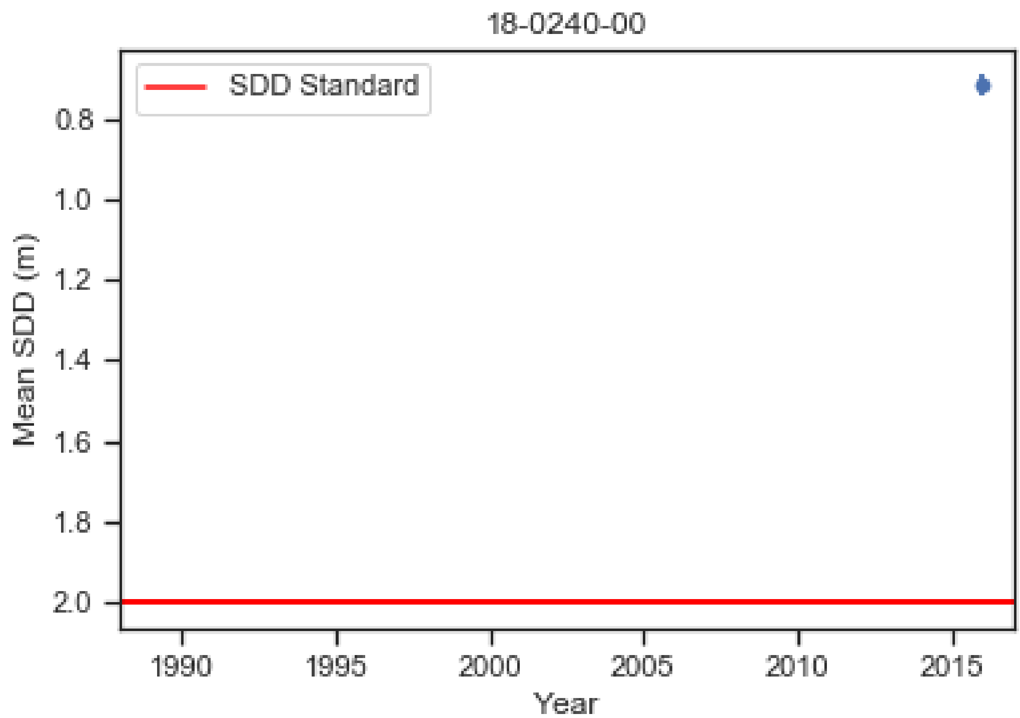


Figure E-4. Fawn Lake Annual Growing Season Mean Secchi

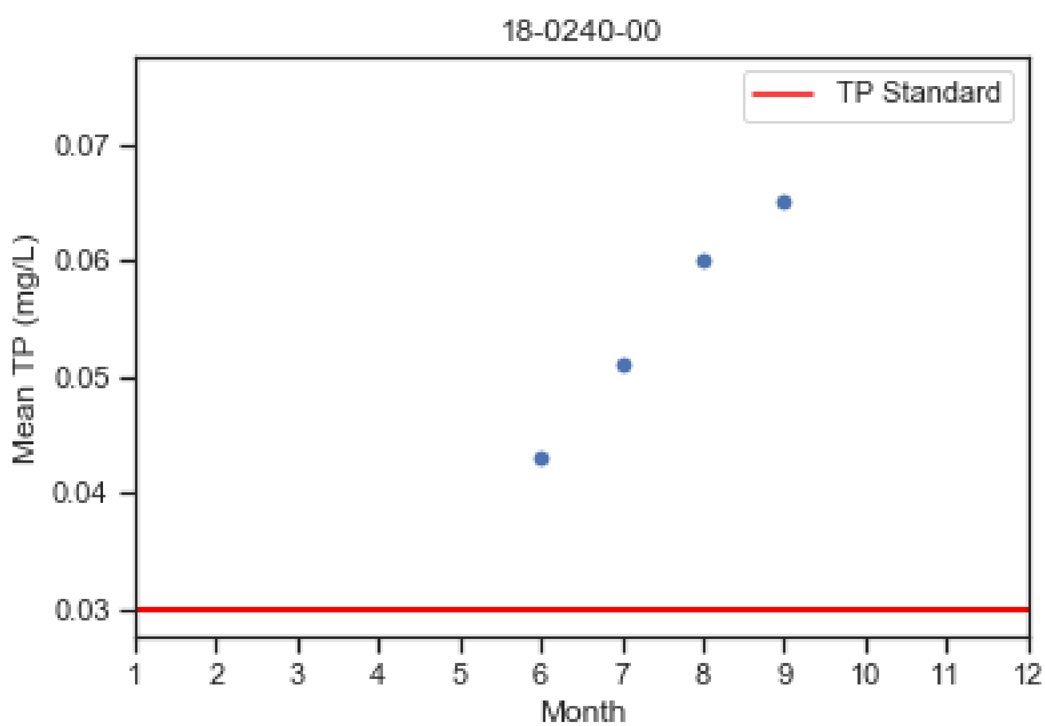


Figure E-5. Fawn Lake Growing Season Monthly Mean TP (2016)

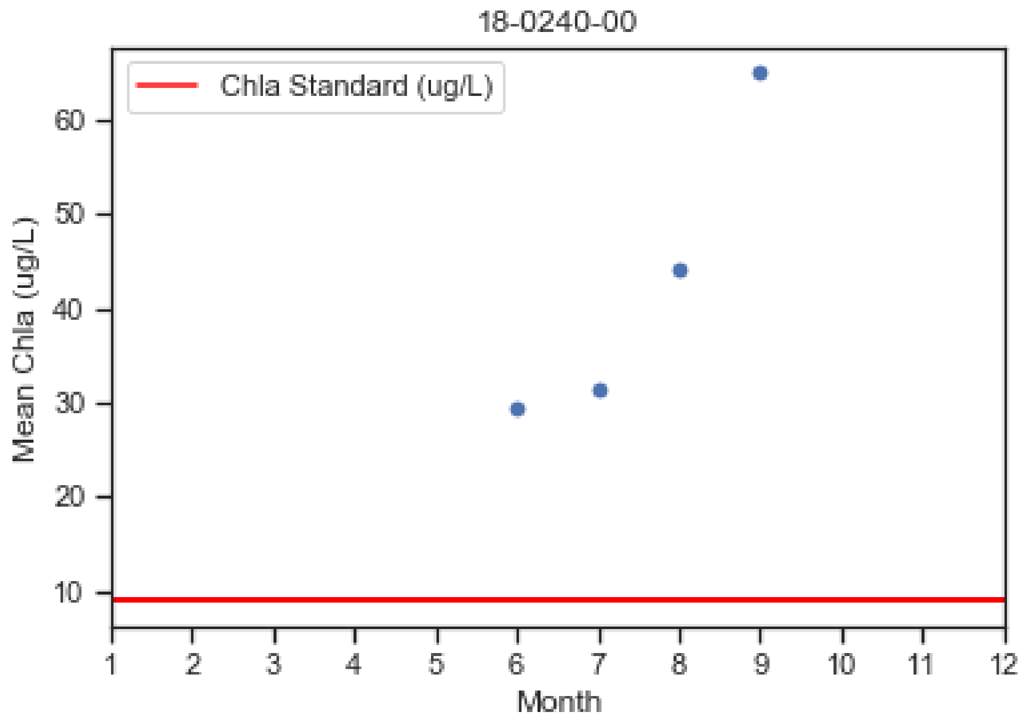


Figure E-6. Fawn Lake Growing Season Monthly Mean Chl-*a* (2016)

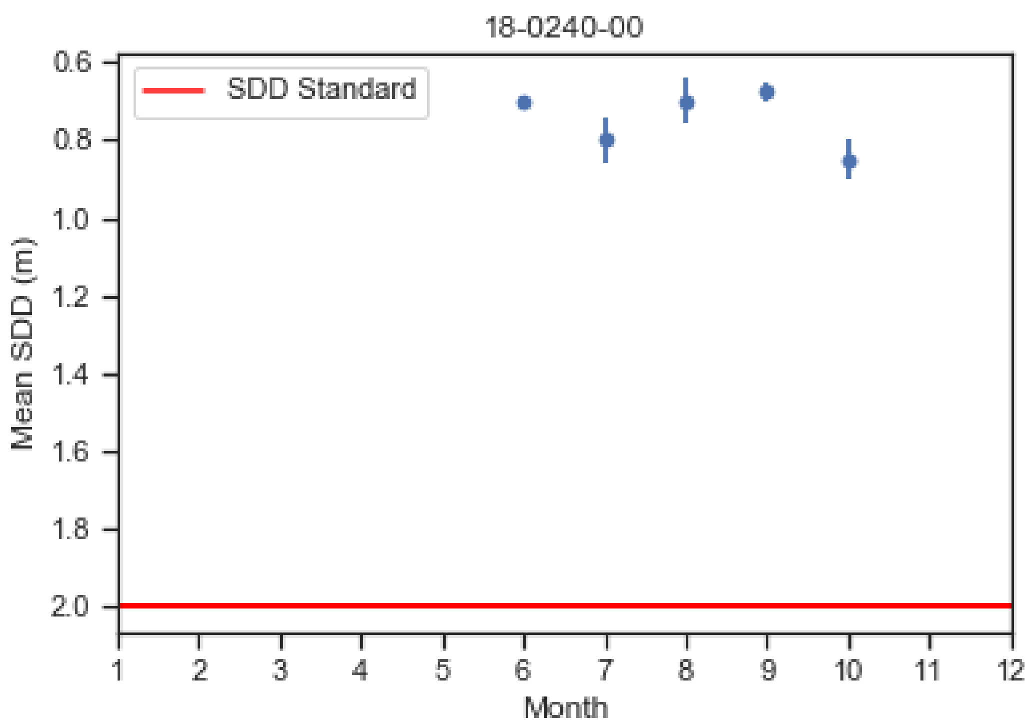


Figure E-7. Fawn Lake Monthly Growing Season Mean Secchi (2016)

Dissolved Oxygen and Temperature Summary

DO and temperature data monitored by depth were examined in an effort to better define lake-mixing patterns affecting biological responses and lake P dynamics. Available data from all sites from 2006 through 2016 are plotted in Figures E-8 through E-9 for temperature and DO.

Water temperature profiles indicate cooling with depth at site 101 between June and August. DO profiles indicate concentration losses with depth from June through September, indicating large oxygen depletion rates are occurring. Fawn Lake exhibited clinograde-like oxygen patterns with values decreasing with depth with values of zero milligrams per liter (mg/L) observed on several dates. When oxygen concentrations approach zero along lake bottoms, internal P loading from sediments is expected. The DO profiles often show a difference of more than 5 mg/L between the maximum and minimum measured DO concentrations.

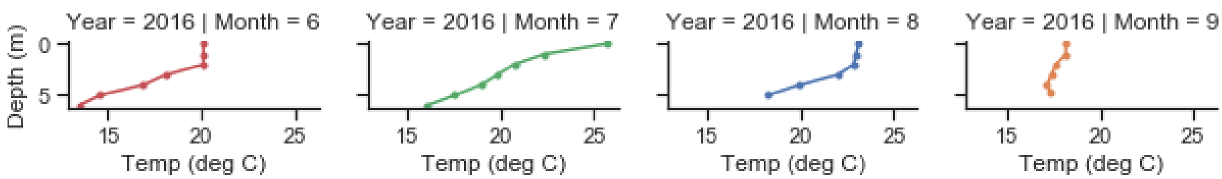


Figure E-8. Fawn Lake Profiles for Temperature at Site 101

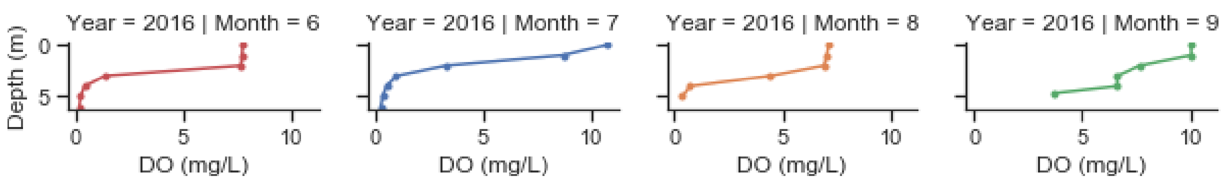


Figure E-9. Fawn Lake Profiles for DO at Site 101

Aquatic Plants

A qualitative survey of aquatic plants in Fawn Lake was performed on July 19, 1995 by the DNR. This survey found 13 species of submersed plants, 2 species of free-floating plants, 3 species of floating-leaf plants, 6 species of emergent plants, and 13 species of shoreland (wetland) plants. The exotic invasive species curly-leaf pondweed (*Potamogeton Crispus*) was not present during the 1995 survey.

Fisheries

The DNR Fisheries surveyed Fawn Lake in 1985. The survey noted the presence of black bullhead with a standard gill net catch rate of 69 catch per unit effort (CPUE) and a standard trap net catch rate of 4.5 CPUE. The status of the fishery on Minnesota Lakefinder noted that test netting indicated a very high population of black bullhead, that northern pike were abundant with a rapid growth rate, that bowfin, largemouth bass, and yellow perch, and walleyes were present but in low numbers, and that bluegills were abundant but have a slow rate of growth. Black bullhead can stir up bottom sediments and increase P contributions to a lake.

Appendix F: Fleming (01-0105-00)

Land Cover

Land cover defined by the University of Minnesota [2016] is summarized for the Fleming Watershed in Table F-1, with the majority of the land cover consisting of forest (40.9%), wetlands (22.8%), open water (14.7%), and hay/pastures (10.1%).

Table F-1. Fleming Watershed Land Cover.

Impairment	Developed (%)	Wetlands (%)	Open Water (%)	Forest (%)	Grassland (%)	Hay/ Pastures (%)	Row Crops (%)
Fleming	4.3	22.8	14.7	40.9	3.6	10.1	3.3

Physical Characteristics

Fleming Lake is located 6 miles south of Palisade, Minnesota, in Aitkin County in the northern portion of the Mississippi-Brainerd HUC-8. From a regulatory standpoint, Fleming Lake is categorized as a shallow NLF ecoregion lake. Select lake morphometric and watershed physical characteristics are listed in Table F-2. Fleming Lake has one public access maintained by DNR that includes parking for approximately 20 boat trailers. Figure F-1 shows aerial imagery of Fleming Lake. Figure F-2 shows lake level data from Fleming Lake.

Table F-2. Select Lake and Watershed Physical Characteristics for Fleming Lake.

Characteristic	Fleming Lake	Source
Lake Surface Area (acres)	318.8	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	314	DNR LakeFinder Fish Lake Surveys
Shore Length (miles)	3.62	DNR LakeFinder Fish Lake Surveys
Mean Depth (feet [ft])	6[(a)]	DNR LakeFinder Fish Lake Surveys (a), Calculated (b), or Estimated from Lake Map (c)
Maximum Depth (ft)	15	DNR LakeFinder Fish Lake Surveys
Average Water Clarity (ft)	2.8[(a)]	DNR LakeFinder Fish Lake Surveys (a) or Average Growing Season Secchi Disk Depth (b)
Recorded Water Level Range (ft)	3.64	DNR LakeFinder Water Level
Percent Lake Littoral Surface Area	98.6	Calculated
Number of Islands	0	DNR LakeFinder Map
Public Access Sites	1	DNR LakeFinder Water Access Sites
Drainage Area, Including Lake (acres)	4,630	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	14.5	Calculated, Large in Bold
Wetland Area (acres)	1,776.4	Wetlands Layer
Number of Upland Lakes	3	USGS Topographic Maps
Number of Perennial Inlet Streams	0	NHD Flowlines Fcode 46006
Lake Volume (acre-ft)	2,569.6	Calculated
Maximum Fetch Length (ft)	6,345	Measured Using ArcGIS Imagery
Lake Geometry Ratio (A^0.25/Dmax), A is surface area in m2 and Dmax is max depth in meters (m)	7.4	Calculated (Shallow>5.3, Medium1.6–5.3, Deep<0.9)
Lake Geometry Classification	Shallow	
Osgood Index (Dmean/sqrt[A]), A is surface area in km2 and Dmean is mean depth in m	1.6	Calculated (Polymictic<4, Intermediate4–9,Dimictic>9)
Osgood Index Category	Polymictic	
Estimated Water Residence Time (days)	342	HSPF Model Application
Shore Land Properties		Imagery

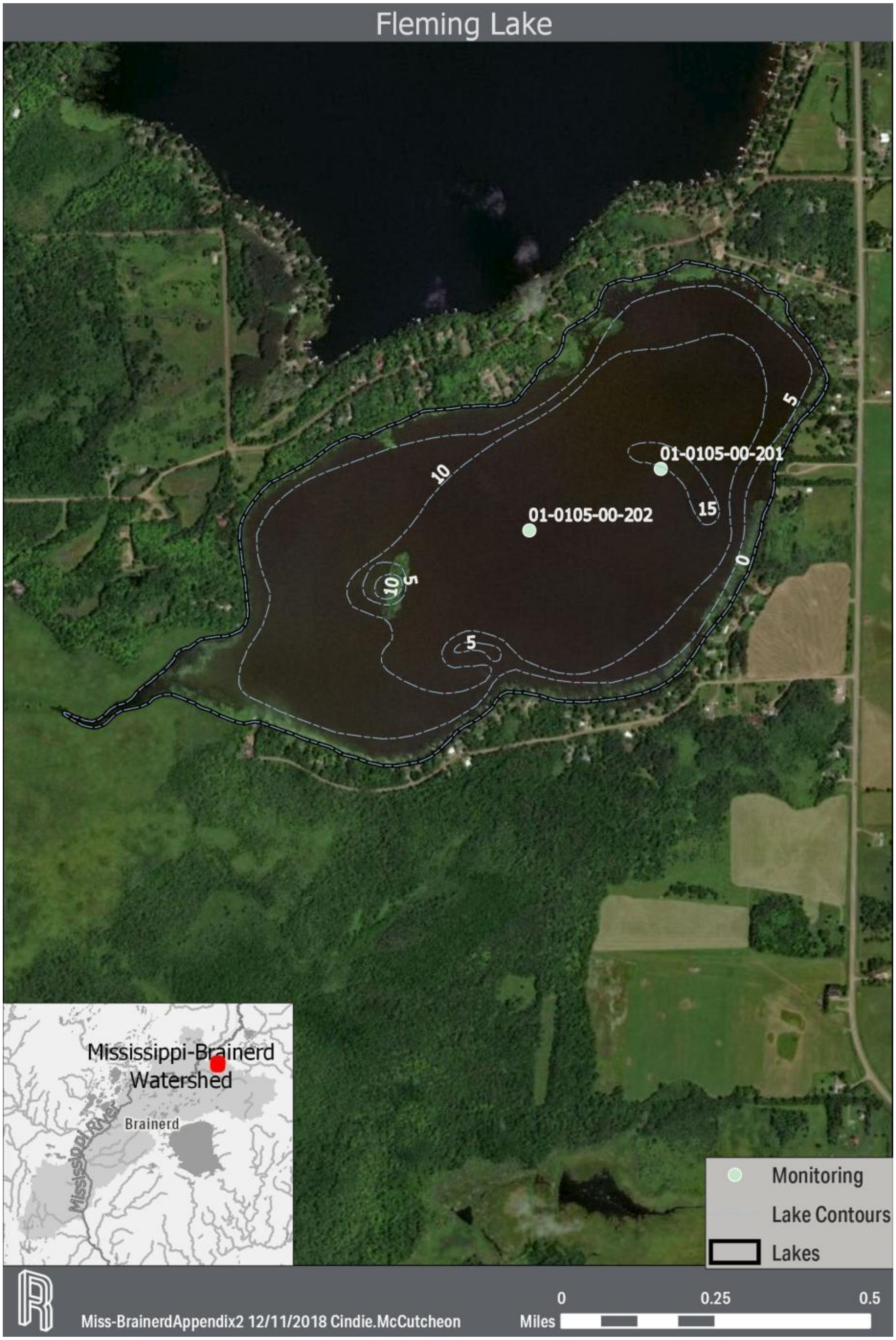


Figure F-1. Fleming Lake Bathymetry and Aerial Imagery

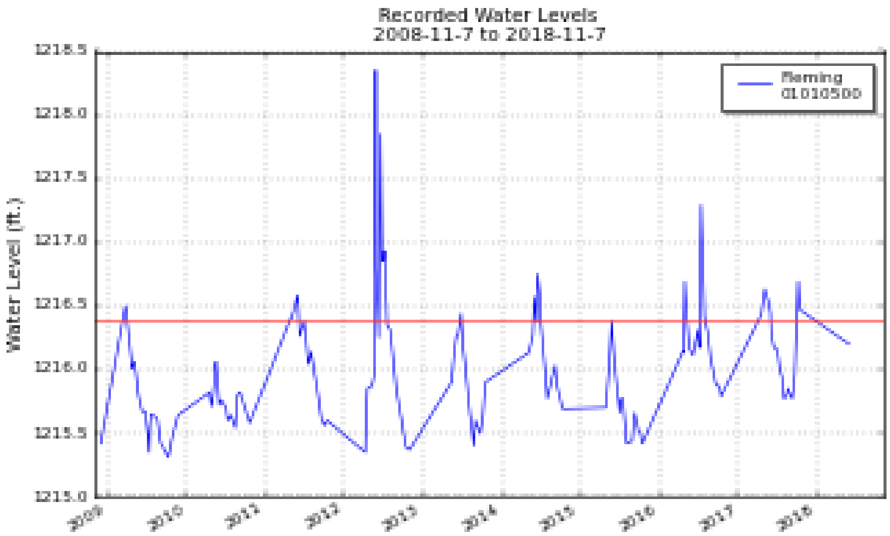


Figure F-2. **Fleming Lake Levels**

Water Quality

Monitoring data annual sample counts are shown in Table F-3 and are summarized over the TMDL period (2006 through 2015) in Table F-4 as mean growing season values for total TP, Chl-*a*, and Secchi transparency (Secchi). Data collected in 2016 are also shown but were not included for monthly or overall averaging unless no other data were available. Corresponding lake water quality standards are also included. Mean values for TP and Chl-*a* are above the water quality standard. Similarly, the mean SDD did not meet the water quality standard. These data indicate that Fleming Lake exceeds the P standard and will require reductions to achieve lake standards. Extreme high values of TP and Chl-*a* were 50.9 micrograms per liter (µg/L) and 31 µg/L, respectively, while the lowest Secchi reading was 0.6 m. Individual growing season means from data available between 1990 and 2016 are plotted in Figures F-3 to F-5 and show that water quality standards were exceeded every year with data.

Multiyear growing season mean monthly water quality observations are summarized in Figures F-6 through F-8 for data available from 2006 through 2015. Plots of this mean monthly data indicate a general decline in water quality from June through September. Error bars in annual and monthly P and Secchi plots indicate standard error.

Table F-3. Growing Season TP, Chl-a, and Secchi Number of Samples Annually.

Lake	Constituent	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[(a)]	Total
Fleming	TP		9	7			1				5	4	22
	Chl-*a*		9	7							5	5	21
	Secchi	7	9	12	7	5	11		7	7	5	4	70

(a) 2016 data not included in total or overall growing season means unless no other data were available.

Table F-4. TP, Chl-*a*, and Secchi Growing Season Means (2006–2015).

Parameter	Minimum	Mean	Maximum	Standard Deviation	Lake Standards
TP (µg/L)	21.0	53.0	83.0	19.3	≤30
Chl-*a* (µg/L)	4.4	33.2	60.7	18.6	≤9
Secchi disk depth (m)	0.6	1.1	2.0	0.4	≥2

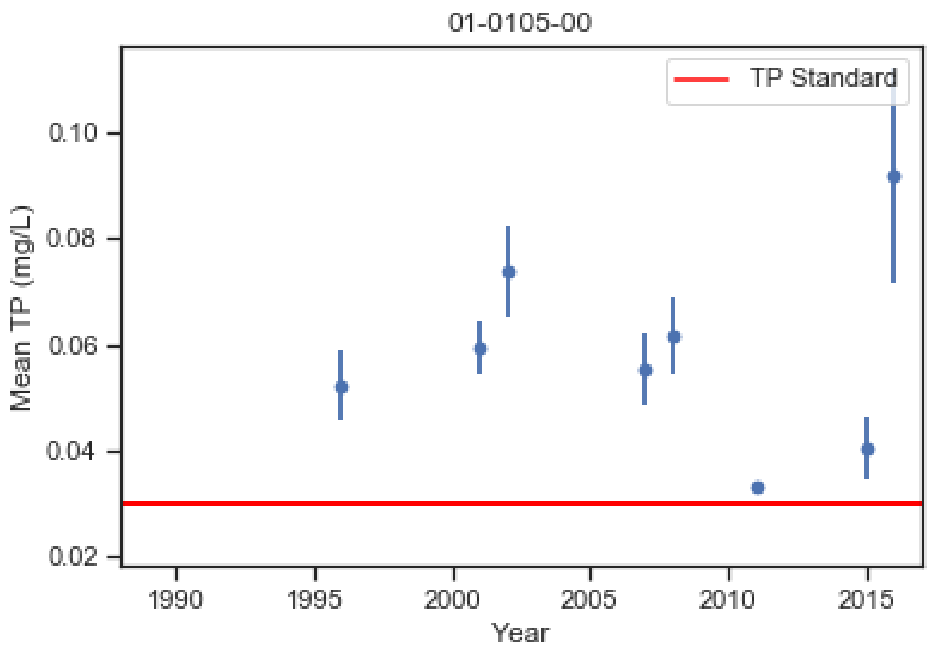


Figure F-3. Fleming Lake Annual Growing Season Mean TP Concentrations

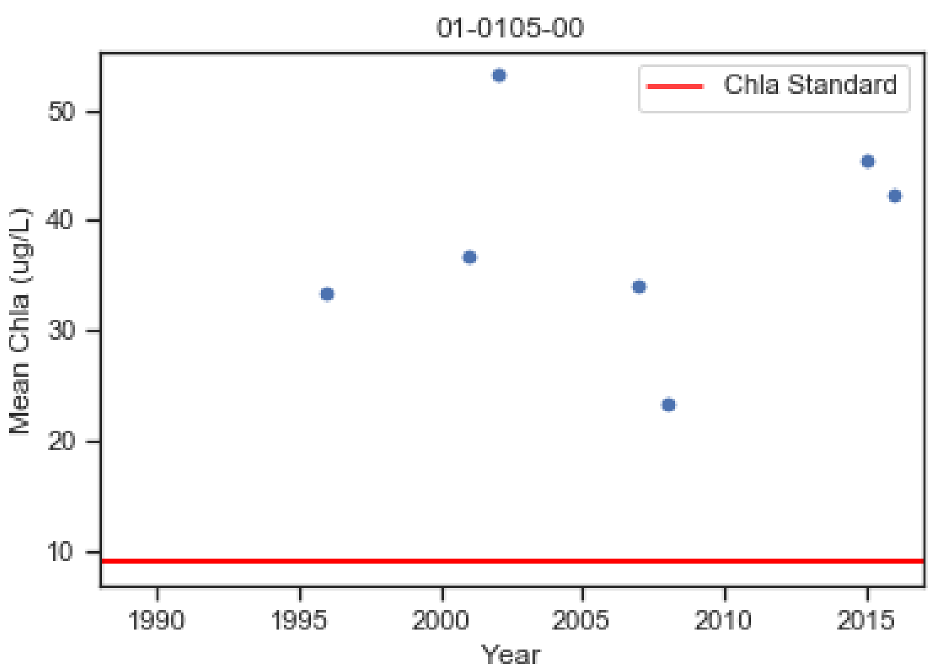


Figure F-4. Fleming Lake Annual Growing Season Mean Chl-*a* concentrations.

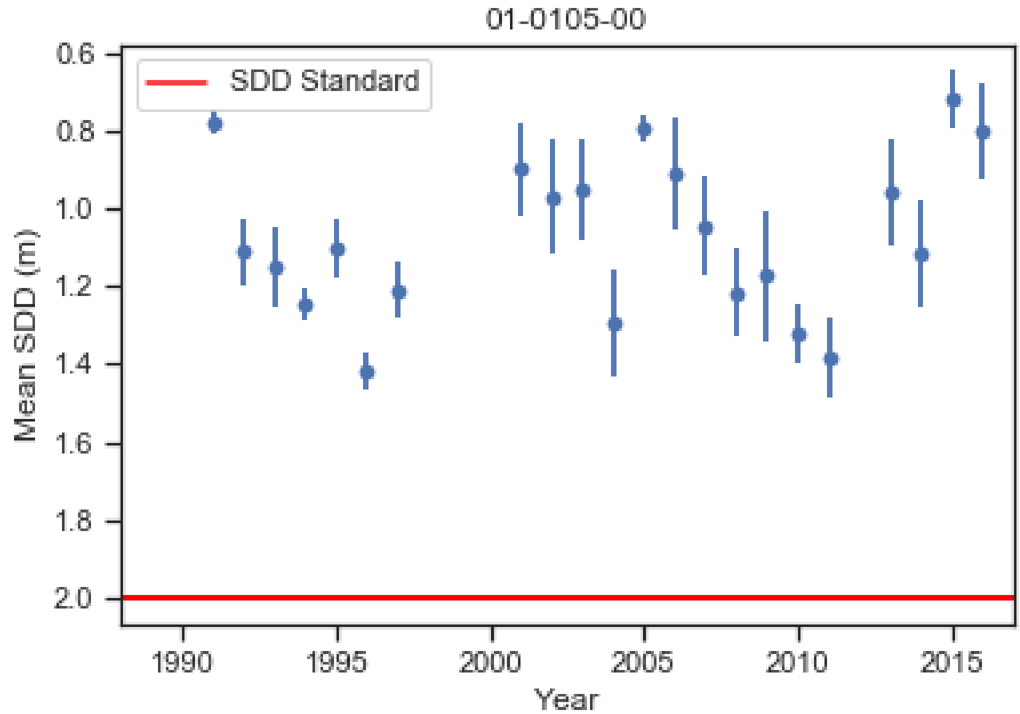


Figure F-5. Fleming Lake Annual Growing Season Mean Secchi Transparency.

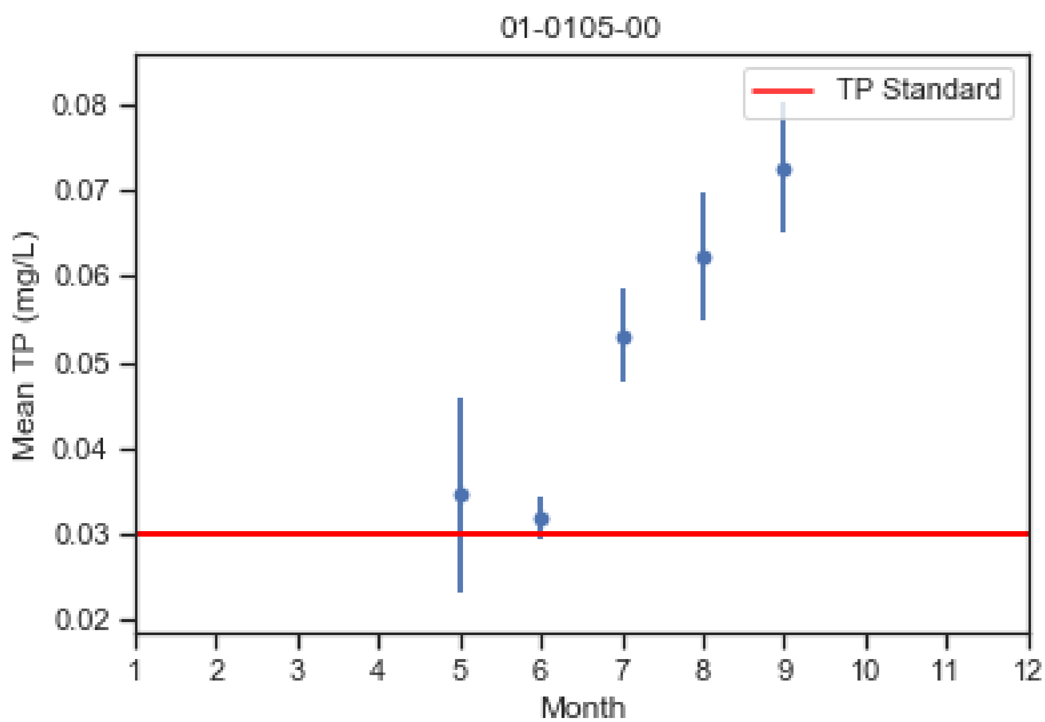
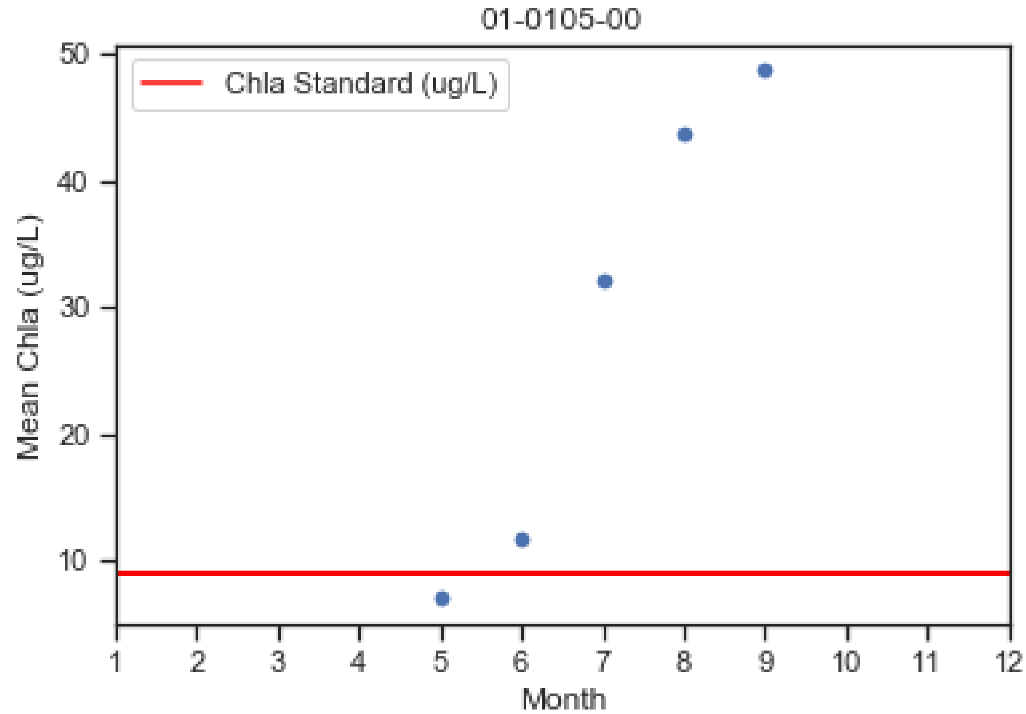


Figure F-6. Fleming Lake Growing Season Monthly Mean Total Phosphorus (All Available Data 2006–2015)

Figure F-7. Fleming Lake Growing Season Monthly Mean Chl-*a* (All Available Data 2006–2015)



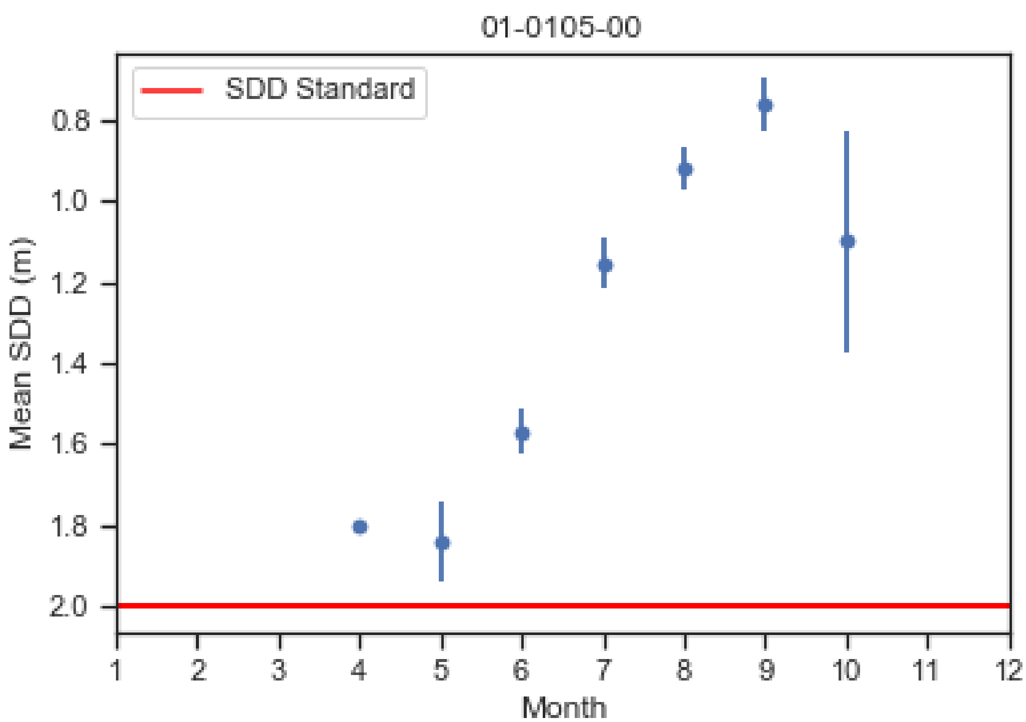


Figure F-8. Fleming Lake Monthly Growing Season Mean Secchi (All Available Data 2006–2015)

Dissolved Oxygen and Temperature Summary

DO and temperature data monitored by depth were examined in an effort to better define lake-mixing patterns affecting biological responses and lake P dynamics. Available data from all sites from 2006 through 2016 are plotted in Figures F-9 through F-10 for temperature and DO.

Water temperature profiles indicate temperature drops slightly with decreasing depth most years in May, June, and August at site 201, and the temperature drops more dramatically with decreasing depth in July. DO profiles indicate concentration losses with depth during warmer months, indicating large oxygen depletion rates are occurring. Fleming Lake exhibited clinograde-like oxygen patterns with values decreasing with depth with values of zero milligrams per liter (mg/L) observed on several dates. When oxygen concentrations approach zero along lake bottoms, internal P loading from sediments is expected. The DO profiles often show a difference of more than 5 mg/L between the maximum and minimum measured DO concentrations.

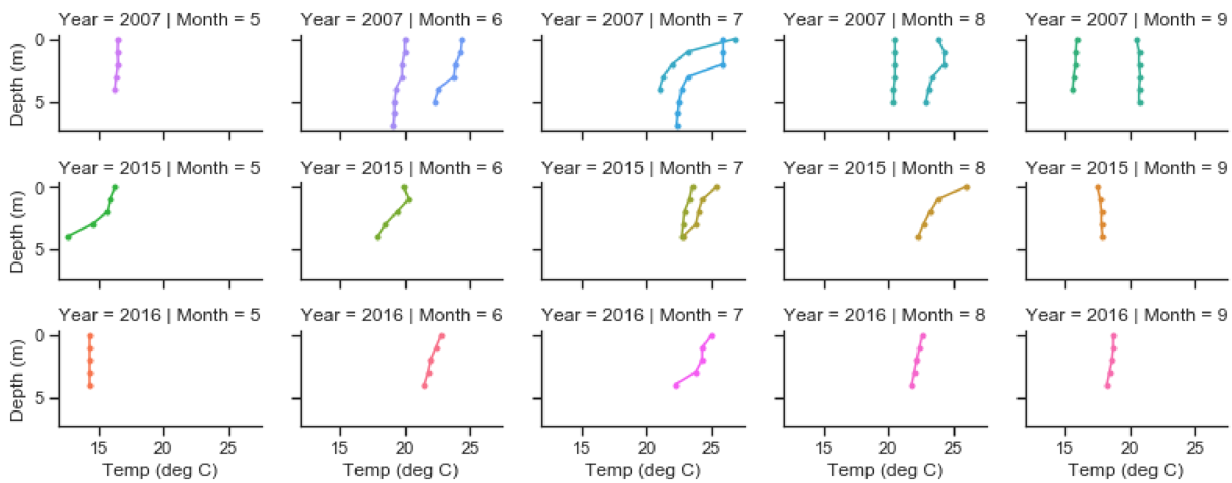


Figure F-9. Fleming Lake Profiles for Temperature at Site 201

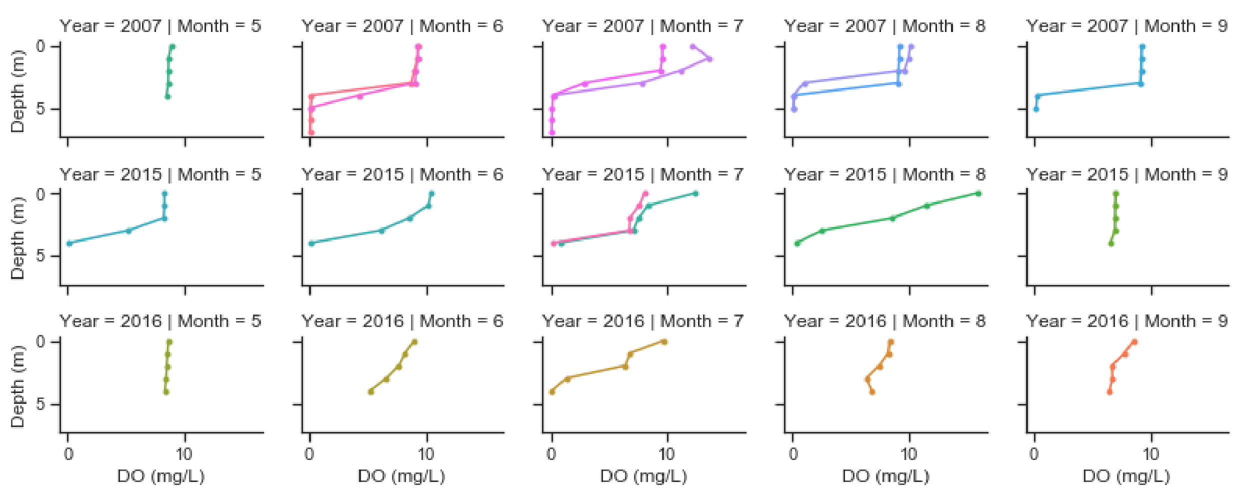


Figure F-10. Fleming Lake Profiles for DO at Site 201

Aquatic Plants

A qualitative survey of aquatic plants in Fleming Lake was performed on September 8, 1995, by the DNR. This survey found 9 species of submersed plants, 3 species of free-floating plants, 6 species of floating-leaf plants, 8 species of emergent plants, and 13 species of shoreland (wetland) plants. The exotic invasive species curly-leaf pondweed (*Potamogeton Crispus*) was not present.

The DNR Fisheries surveyed Fleming Lake in 2017. From this survey, the DNR Fisheries Lake FIBI Bioassessments noted that there was a lack of any intolerant species in the survey and the relatively low proportion of top carnivores sampled in the gill nets. Yellow perch dominated the gill net catch. Bowfin, Bluegill, Black Crappie, and Northern Pike accounted for most of the trap net biomass. Overall few species were sampled during the nearshore survey, which is common for lakes scored with FIBI Tool 5. The primary species sampled in the nearshore survey were Bluegill and Yellow Perch. The survey noted the presence of black bullhead with a standard gill net catch rate of 6.17 CPUE, which is toward the lower end of the normal range (1.9 to 57.5). Black bullhead can stir up bottom sediments and increase P contributions to a lake.

Appendix G: Gun (01-0099-00)

Land Cover

Land cover defined by the University of Minnesota [2016] is summarized for the Gun Watershed in Table G-1, with the majority of the land cover consisting of wetlands (55.5%), forest (14.4%), and hay/pastures (12.3%).

Table G-1. Gun Watershed Land Cover.

Impairment	Developed (%)	Wetlands (%)	Open Water (%)	Forest (%)	Grassland (%)	Hay/ Pastures (%)	Row Crops (%)
Gun	4.6	55.5	8.6	14.4	1.0	12.3	3.5

Physical Characteristics

Gun Lake is located 5 miles southwest of Palisade, Minnesota, in Aitkin County in the northern portion of the Mississippi-Brainerd HUC-8. From a regulatory standpoint, Gun Lake is categorized as a deep NLF ecoregion lake. Select lake morphometric and watershed physical characteristics are listed in Table G-2. Gun Lake has one public access maintained by the DNR that includes parking for approximately eight boat trailers. Figure G-1 shows aerial imagery of Gun Lake. Figure G-2 shows lake level data from Gun Lake.

Table G-2. Select Lake and Watershed Physical Characteristics for Gun Lake.

Characteristic	Gun Lake	Source
Lake Surface Area (acres)	711.9	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	292	DNR LakeFinder Fish Lake Surveys
Shore Length (miles)	8.68	DNR LakeFinder Fish Lake Surveys
Mean Depth (feet [ft])	18[(a)]	DNR LakeFinder Fish Lake Surveys (a), Calculated (b), or Estimated from Lake Map (c)
Maximum Depth (ft)	44	DNR LakeFinder Fish Lake Surveys
Average Water Clarity (ft)	6[(a)]	DNR LakeFinder Fish Lake Surveys (a) or Average Growing Season Secchi Disk Depth (b)
Recorded Water Level Range (ft)	2.12	DNR LakeFinder Water Level
Percent Lake Littoral Surface Area	41.0	Calculated
Number of Islands	3	DNR LakeFinder Map
Public Access Sites	1	DNR LakeFinder Water Access Sites
Drainage Area, Including Lake (acres)	9,537	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	13.4	Calculated, Large in Bold
Wetland Area (acres)	5,105.9	Wetlands Layer
Number of Upland Lakes	1	USGS Topographic Maps
Number of Perennial Inlet Streams	1	NHD Flowlines Fcode 46006
Lake Volume (acre-ft)	8,719.8	Calculated
Maximum Fetch Length (ft)	11,132	Measured Using ArcGIS Imagery
Lake Geometry Ratio (A^0.25/Dmax), A is surface area in m^2 and Dmax is max depth in meters (m)	3.1	Calculated (Shallow>5.3, Medium1.6–5.3, Deep<0.9)
Lake Geometry Classification	Medium	
Osgood Index (Dmean/sqrt[A]), A is surface area in km^2 and Dmean is mean depth in m	3.2	Calculated (Polymictic<4, Intermediate4–9,Dimictic>9)
Osgood Index Category	Polymictic	
Estimated Water Residence Time (days)	529	HSPF Model Application
Shore Land Properties		Imagery

Figure G-1. Gun Lake Aerial Imagery and Lake Bathymetry

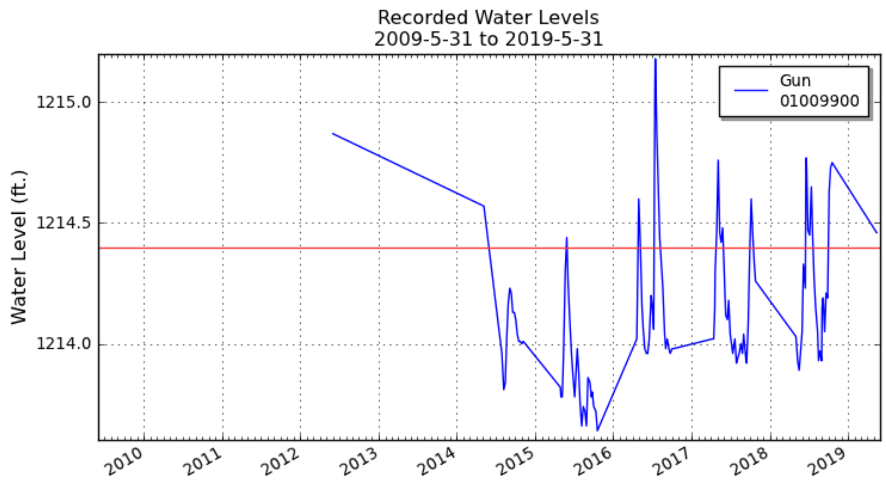


Figure G-2. Gun Lake Levels

Water Quality

Monitoring data annual sample counts are shown in Table G-3 and are summarized over the TMDL period (2006 through 2015) in Table G-4 as mean growing season values for TP, Chl-*a*, and Secchi transparency (Secchi). Data collected in 2016 are also shown but were not included for monthly or overall averaging unless no other data were available. Corresponding lake water quality standards are also included. Mean values for TP and Chl-*a* are slightly above the water quality standard, while the mean SDD is at the water quality standard. These data indicate that Gun Lake exceeds the P standard and will require reductions to achieve lake standards. Extreme high values of TP and Chl-*a* were 85 µg/L and 31 µg/L, respectively, while the lowest Secchi reading was 1.1 m. Individual growing season means from data available between 1990 and 2016 are plotted in Figures G-3 and G-5 and show that water quality standards were exceeded about half of the years with available data.

Multiyear growing season mean monthly water quality observations are summarized in Figures G-6 through G-8 for data available from 2006 through 2015. Plots of this mean monthly data indicate that the worst water quality occurred in August and September. Error bars in annual and monthly P and Secchi plots indicate standard error.

Table G-3. Growing Season TP, Chl-*a*, and Secchi Number of Samples Annually.

Lake	Constituent	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[a]	Total
Gun	TP	6	6	4	9	7							32
	Chl-*a*	6	6	4	9	7							32
	Secchi	5	6	4	9	7							31

(a) 2016 data not included in total or overall growing season means unless no other data were available

Table G-4. TP, Chl-*a*, and Secchi Growing Season Means (2006–2015).

Parameter	Minimum	Mean	Maximum	Standard Deviation	Lake Standards
TP (µg/L)	14.0	29.8	78.0	13.7	≤30
Chl-*a* (µg/L)	2.0	9.6	31.3	6.2	≤9
Secchi disk depth (m)	1.1	2.0	3.1	0.5	≥2

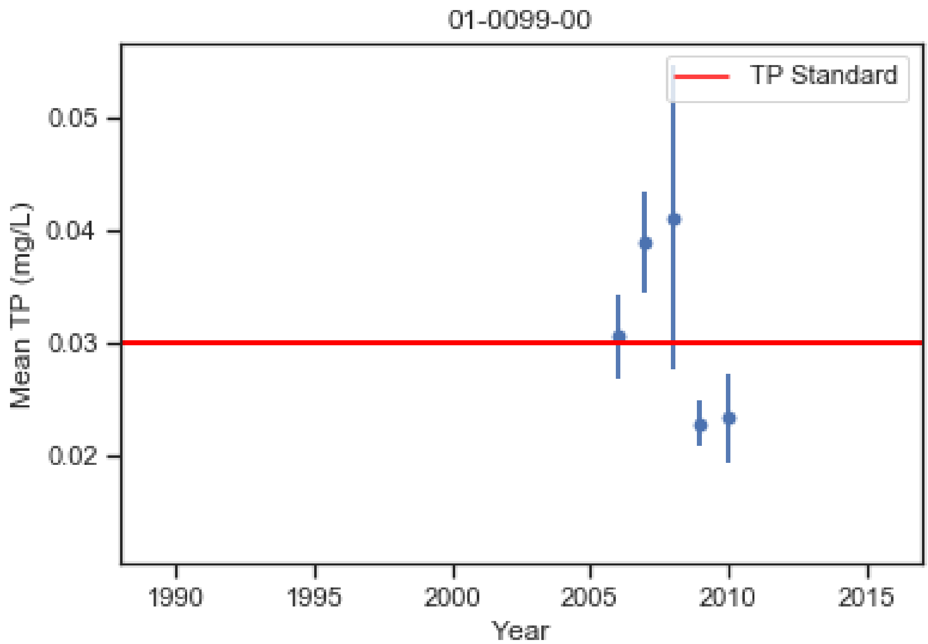


Figure G-3. Gun Lake Annual Growing Season Mean TP Concentrations

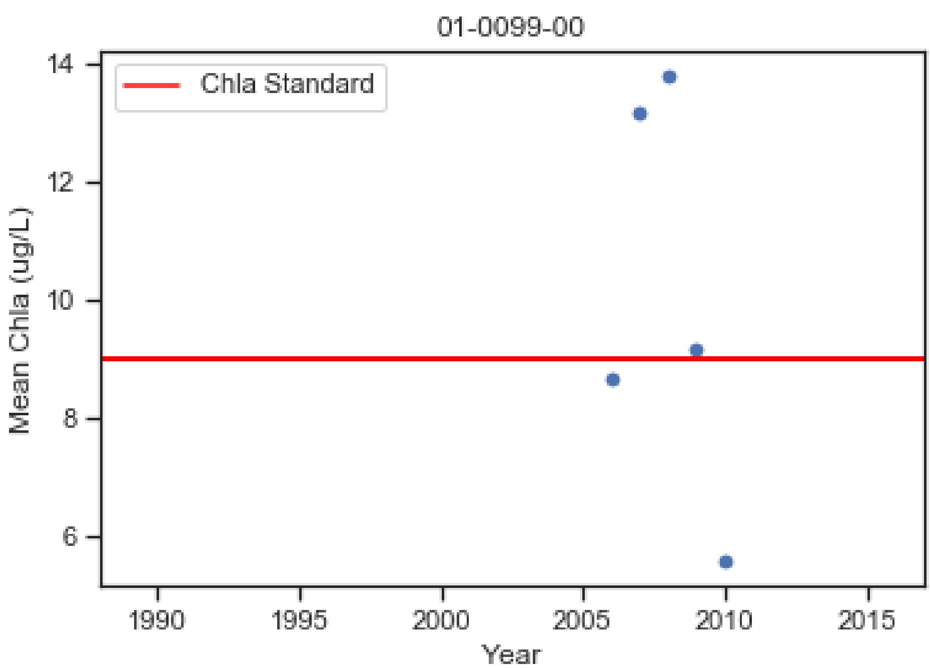


Figure G-4. Gun Lake Annual Growing Season Mean Chl-*a* Concentrations

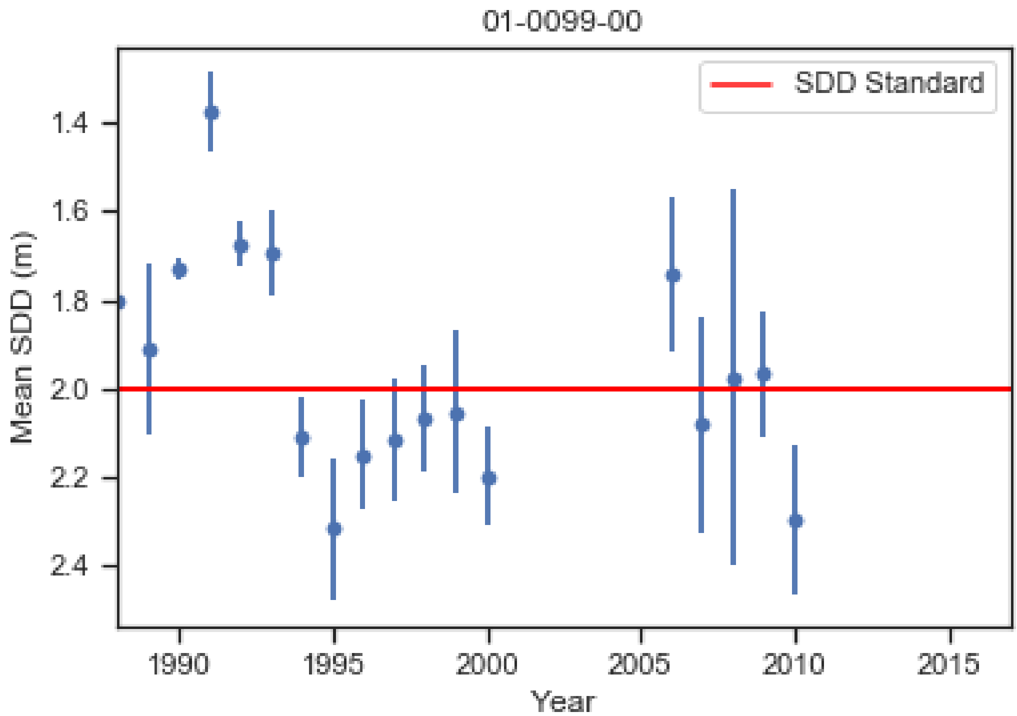


Figure G-5. Gun Lake Annual Growing Season Mean Secchi

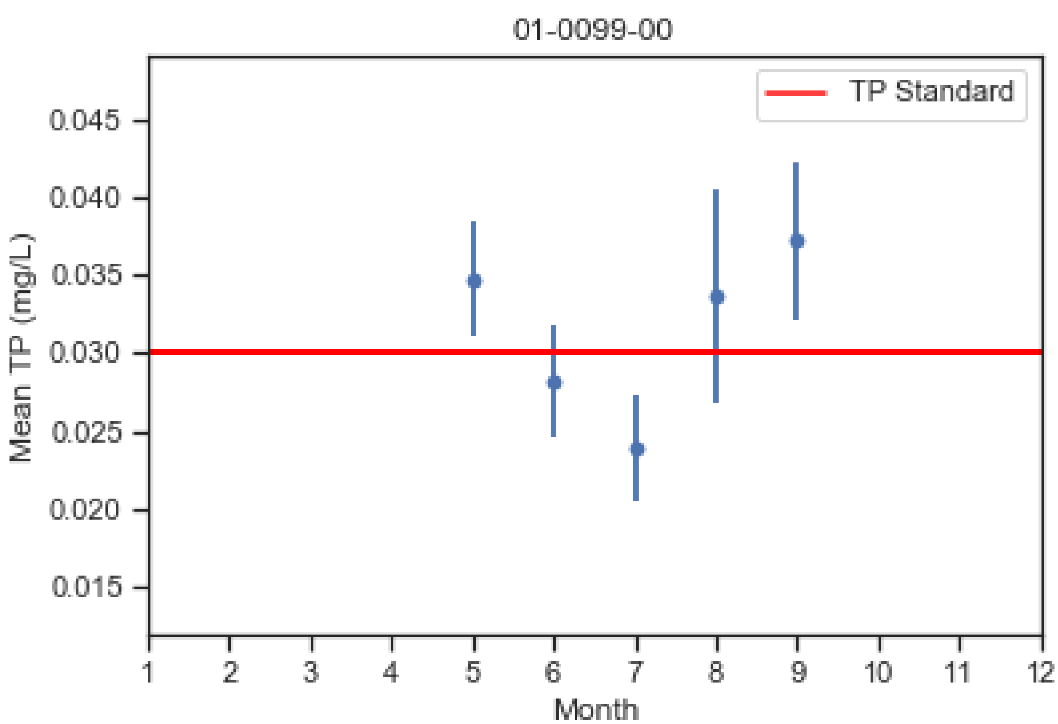


Figure G-6. Gun Lake Growing Season Monthly Mean TP (All Available Data 2006–2015)

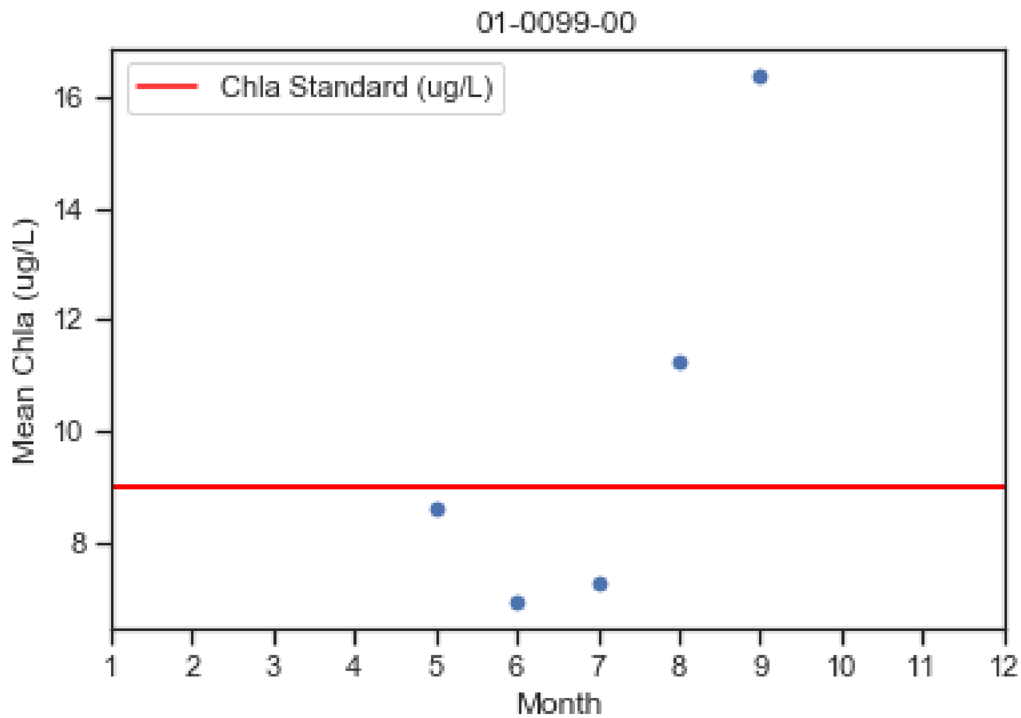


Figure G-7. **Gun Lake Growing Season Monthly Mean Chl-*a* (All Available Data 2006–2015)**

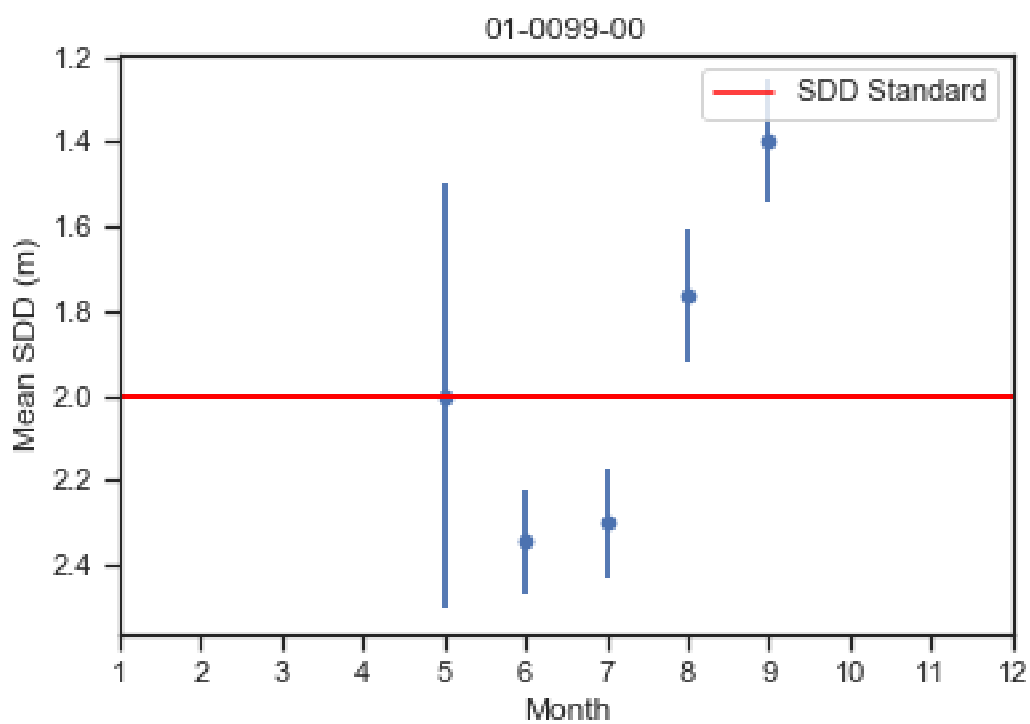


Figure G-8. **Gun Lake Monthly Growing Season Mean Secchi (All Available Data 2006–2015)**

Dissolved Oxygen and Temperature Summary

DO and temperature data monitored by depth were examined in an effort to better define lake-mixing patterns affecting biological responses and lake P dynamics. Available data from all sites from 2006 through 2016 are plotted in Figures G-9 and G-10 for temperature and DO.

Water temperature profiles indicate a decrease in temperature with depth at site 205 during June, July, and August. DO profiles indicate large concentration losses with depth during June, July, and August, indicating large oxygen depletion rates are occurring. Gun Lake exhibited clinograde-like oxygen patterns with values decreasing with depth with values of zero milligrams per liter (mg/L) observed on several dates. When oxygen concentrations approach zero along lake bottoms, internal P loading from sediments is expected. The DO profiles often show a difference of more than 5 mg/L between the maximum and minimum measured DO concentrations.

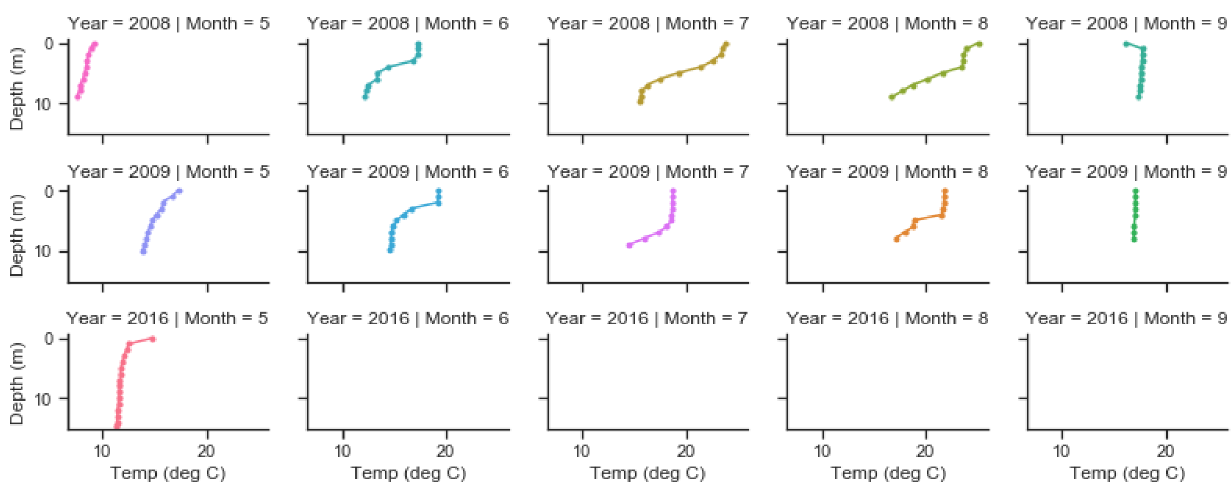


Figure G-9. Gun Lake Profiles for Temperature at Site 205

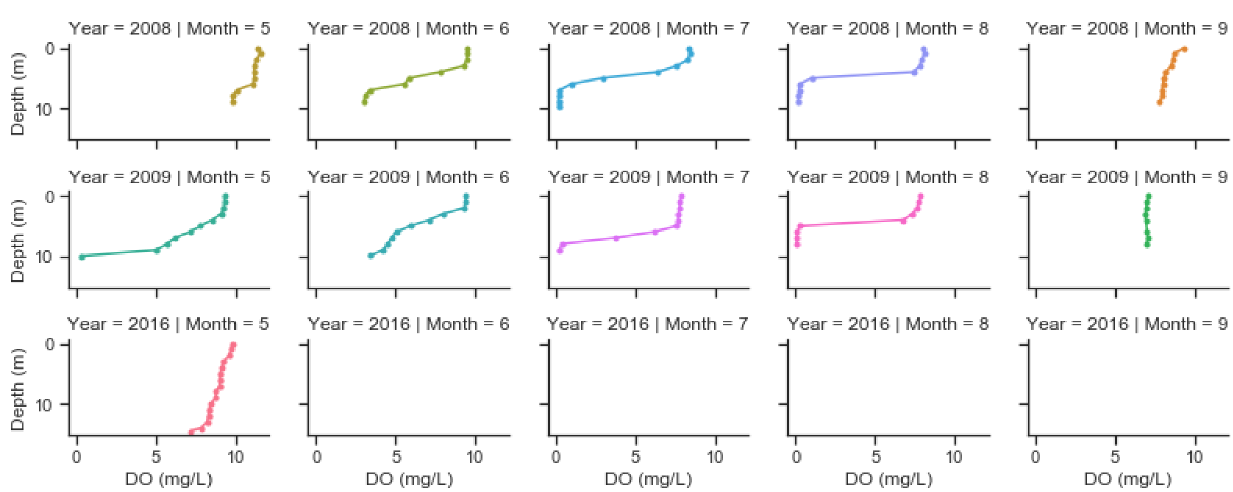


Figure G-10. Gun Lake Profiles for Dissolved Oxygen at Site 205

Aquatic Plants

A qualitative survey of aquatic plants in Gun Lake was performed on July 17, 1996, by the DNR. This survey found 15 species of submersed plants, 1 species of free-floating plants, 5 species of floating-leaf plants, 9 species of emergent plants, and 1 species of shoreland (wetland) plants. The exotic invasive species curly-leaf pondweed (*Potamogeton Crispus*) was present.

Fisheries

The DNR Fisheries surveyed Gun Lake in 2013 and 2016. From these surveys, the DNR Fisheries Lake FIBI Bioassessments noted that the fish assemblages were slightly different between the surveys, with one notable difference being the addition of an intolerant species in the gill net catch of the 2016 survey (Rock Bass). Consistent between both surveys was the very low catch of tolerant species (Black Bullhead) which positively influenced the FIBI score. A relatively low number of intolerant species sampled in the 2013 survey, the low proportion of intolerants sampled in the nearshore survey of2016, and low abundance by biomass of insectivores in the trap net catches in both 2013 and 20016 most negatively impacted the FIBI score. Northern Pike were the most abundant species by biomass in gill nets. Bowfin and Northern Pike were the most abundant species by biomass in trap nets. Both nearshore surveys sampled small numbers of intolerant species (Blackchin Shiner, Blacknose Shiner, Iowa Darter, and Rock Bass) [DNR 2017]. Both the 2013 survey and 2016 survey noted the presence of black bullhead with CPUE values below the normal range. Black bullheads can stir up bottom sediments and increase P contributions to a lake.

Appendix H: Lower Mission (18-0243-00)

Land Cover

Land cover defined by the University of Minnesota [2016] is summarized for the Lower Mission Watershed in Table H-1, with the majority of the land cover consisting of forest (40.5%), wetlands (25.2%), and open water (21.8%).

Table H-1. Lower Mission Watershed Land Cover.

Impairment	Developed (%)	Wetlands (%)	Open Water (%)	Forest (%)	Grassland (%)	Hay/ Pastures (%)	Row Crops (%)
Lower Mission	5.8	25.2	21.8	40.5	4.1	0.4	2.3

Physical Characteristics

Lower Mission Lake is located 8 miles northwest of Crosby, Minnesota, in Crow Wing County in the central portion of the Mississippi-Brainerd HUC-8. From a regulatory standpoint, Lower Mission Lake is categorized as a deep NLF ecoregion lake. Select lake morphometric and watershed physical characteristics are listed in Table H-2. Lower Mission Lake has one public access maintained by the DNR that includes parking for approximately eight boat trailers. Figure H-1 shows aerial imagery of Lower Mission Lake. Figure H-2 shows lake level data from Lower Mission Lake.

Table H-2. Select Lake and Watershed Physical Characteristics for Lower Mission Lake.

Characteristic	Lower Mission Lake	Source
Lake Surface Area (acres)	732.2	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	452	DNR LakeFinder Fish Lake Surveys
Shore Length (miles)	6.33	DNR LakeFinder Fish Lake Surveys
Mean Depth (feet [ft])	11.5[(b)]	DNR LakeFinder Fish Lake Surveys (a), Calculated (b), or Estimated from Lake Map (c)
Maximum Depth (ft)	27	DNR LakeFinder Fish Lake Surveys
Average Water Clarity (ft)	11.5[(a)]	DNR LakeFinder Fish Lake Surveys (a) or Average Growing Season Secchi Disk Depth (SDD) (b)
Recorded Water Level Range (ft)	2.76	DNR LakeFinder Water Level
Percent Lake Littoral Surface Area	61.7	Calculated
Number of Islands	0	DNR Lakefinder Map
Public Access Sites	1	DNR LakeFinder Water Access Sites
Drainage Area, Including Lake (acres)	11,594	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	15.8	Calculated, Large in Bold
Wetland Area (acres)	1,235.5	Wetlands Layer
Number of Upland Lakes	12	USGS Topographic Maps
Number of Perennial Inlet Streams	1	NHD Flowlines Fcode 46006
Lake Volume (acre-ft)	8,437.5	Calculated
Maximum Fetch Length (ft)	11,242	Measured Using ArcGIS Imagery
Lake Geometry Ratio (A^0.25/Dmax), A is surface area in m^2 and Dmax is max depth in meters (m)	5.0	Calculated (Shallow>5.3, Medium1.6–5.3, Deep<0.9)
Lake Geometry Classification	Medium	
Osgood Index (Dmean/sqrt[A]), A is surface area in km^2 and Dmean is mean depth in m	2.0	Calculated (Polymictic<4, Intermediate4–9, Dimictic>9)
Osgood Index Category	Polymictic	
Estimated Water Residence Time (days)	605	Hydrological Simulation Program–FORTRAN Model Application
Shore Land Properties		Imagery

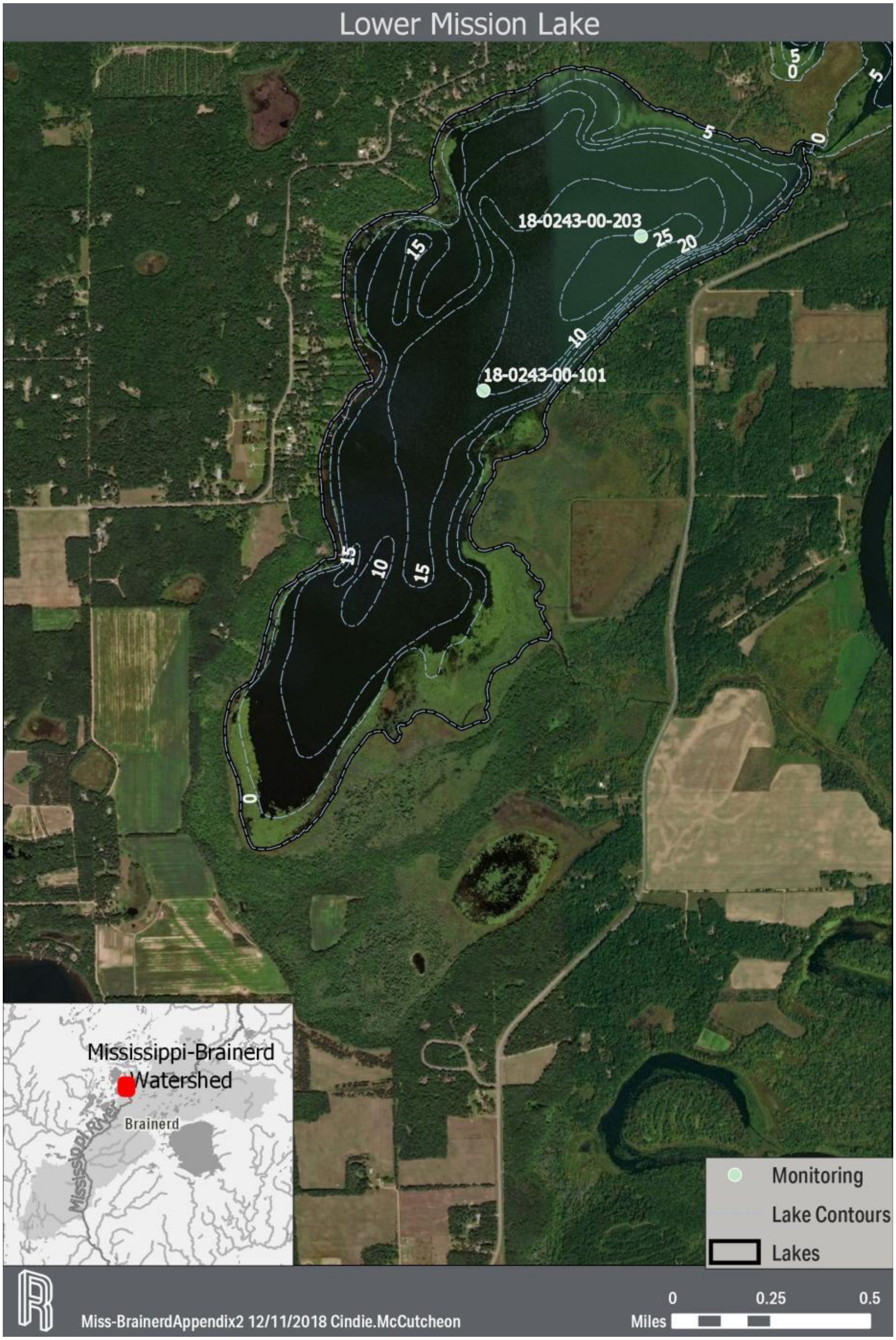


Figure H-1. Lower Mission Lake Bathymetry and Aerial Imagery

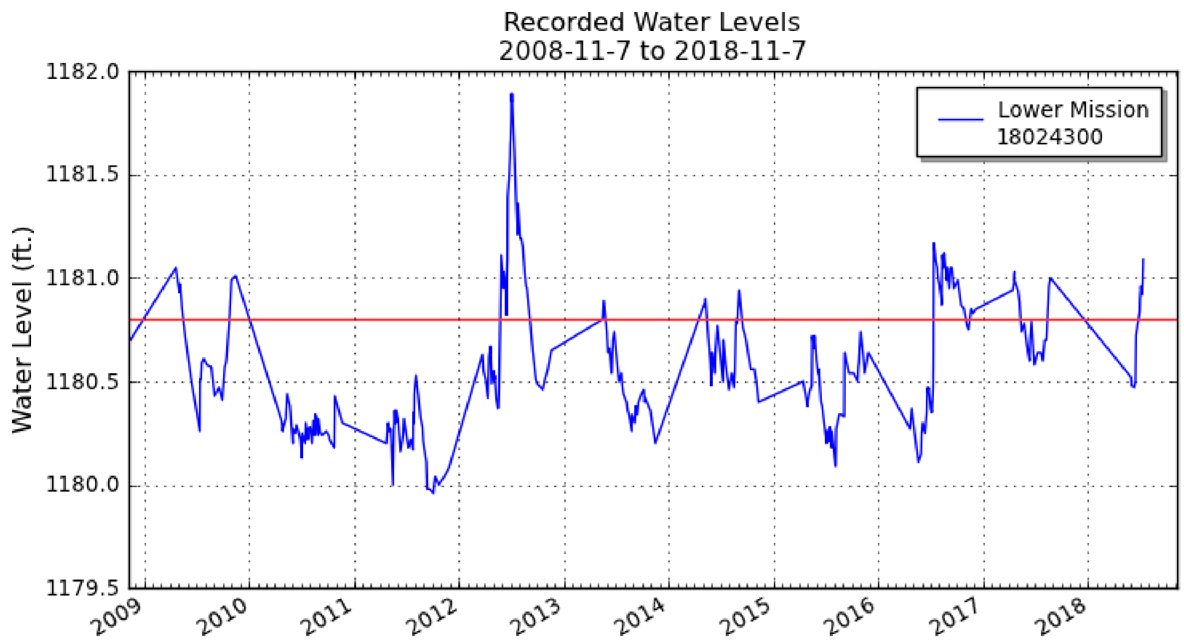


Figure H-2. Lower Mission Lake Levels

Water Quality

Monitoring data annual sample counts are shown in Table H-3 and are summarized over the TMDL period (2006 through 2015) in Table H-4 as mean growing season values for TP, Chl-*a*, and Secchi transparency (Secchi). Data collected in 2016 are also shown but were not included for monthly or overall averaging unless no other data were available. Corresponding lake water quality standards are also included. Mean values for TP and Chl-*a* are above the water quality standard, while the mean SDD meets the water quality standard. These data indicate that Lower Mission Lake exceeds the P standard and will require reductions to achieve lake standards. Extreme high values of TP and Chl-*a* were 105 µg/L and 79 µg/L, respectively, while the lowest Secchi reading was 0.5 m. Individual growing season means from data available from 1990 through 2016 are plotted in Figures H-3 to H-5 and show that TP and Chl-*a* water quality standards were exceeded most years with available data.

Multiyear growing season mean monthly water quality observations are summarized in Figures H-6 through H-8 for data available from 2006 through 2015. Plots of this mean monthly data indicate a general decline in water quality from June through August. Error bars in annual and monthly P and Secchi plots indicate standard error.

Table H-3. Growing Season TP, Chl-*a*, and Secchi Number of Samples Annually.

Lake	Constituent	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[a]	Total
Lower Mission	TP	3		4	4	4				3			18
	Chl-*a*	3		4	4	4				3			18
	Secchi	16	6	8	11	9	14	8	8	8	6	7	94

Table H-4. TP, Chl-*a*, and Secchi Growing Season Means (2006–2015).

Parameter	Minimum	Mean	Maximum	Standard Deviation	Lake Standards
TP (µg/L)	14.0	46.5	105.0	27.8	≤30
Chl-*a* (µg/L)	3.0	18.8	79.0	17.8	≤9
SDD (m)	0.5	2.2	7.0	1.3	≥2

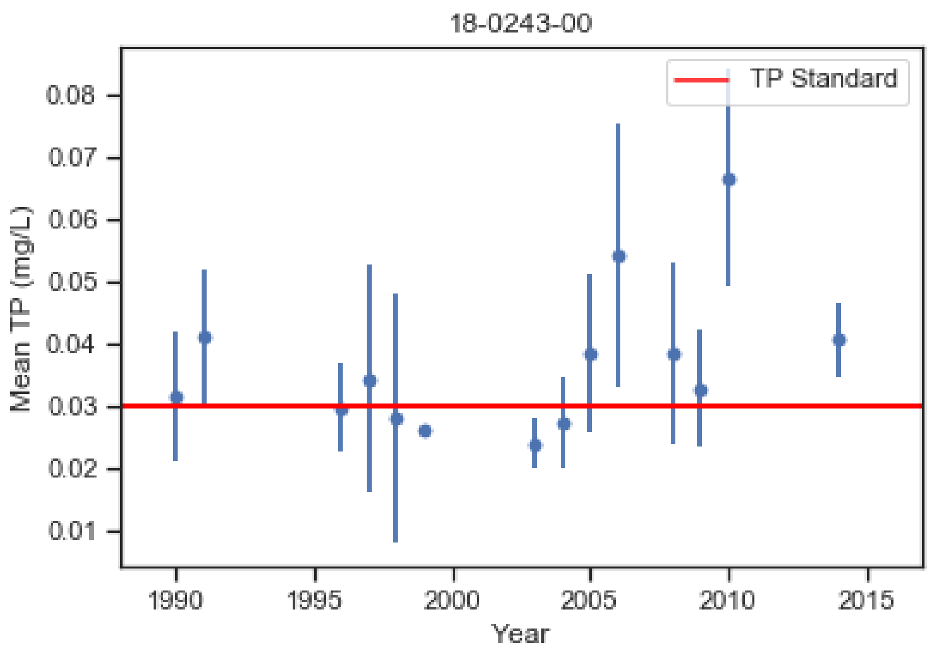


Figure H-3. Lower Mission Lake Annual Growing Season Mean TP Concentrations

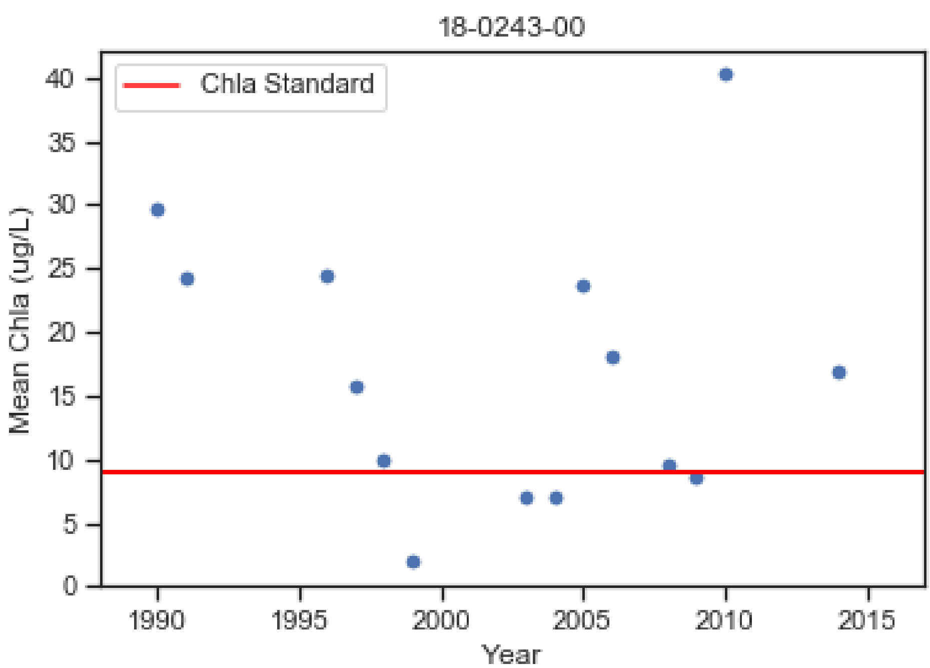


Figure H-4. Lower Mission Lake Annual Growing Season Mean Chl-*a* Concentrations

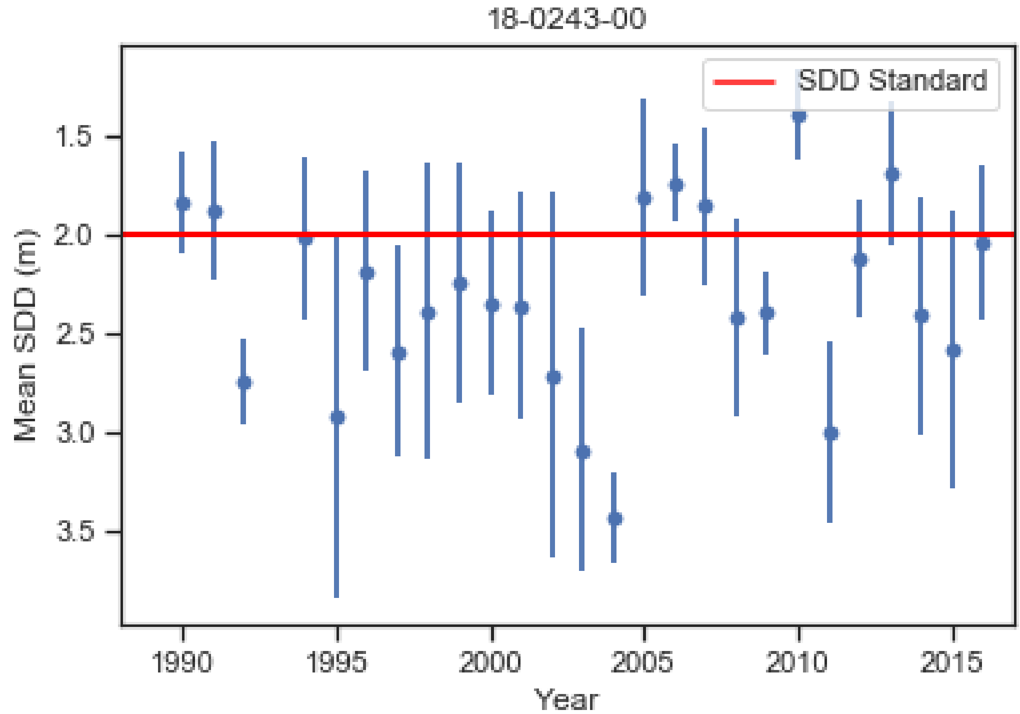


Figure H-5. Lower Mission Lake Annual Growing Season Mean Secchi

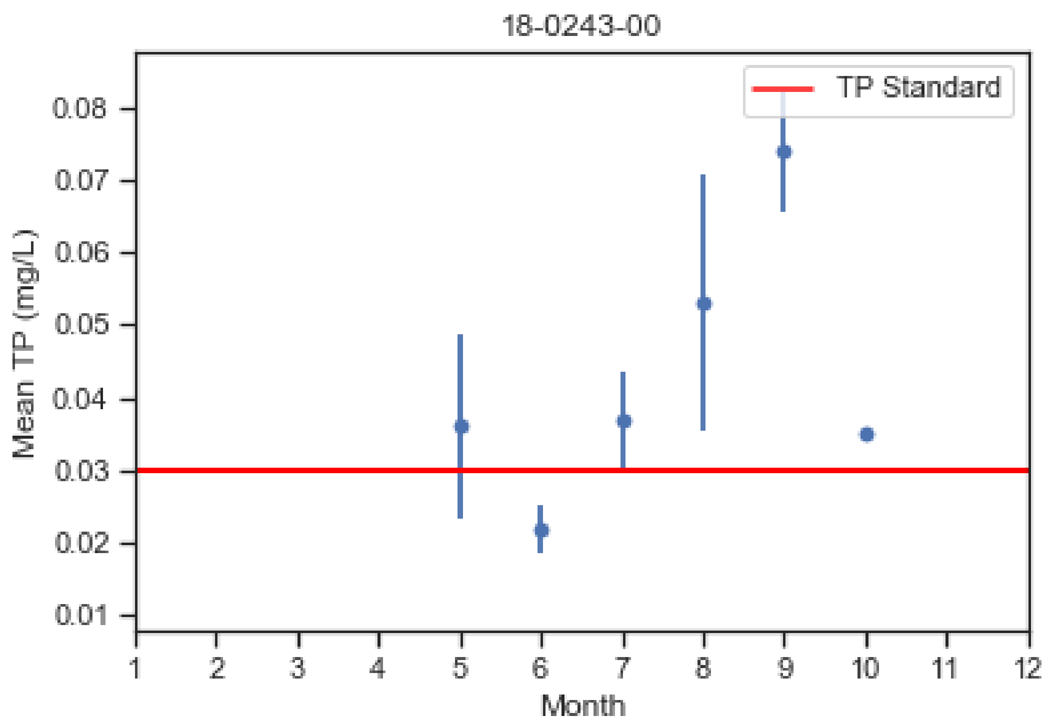


Figure H-6. Lower Mission Lake Growing Season Monthly Mean TP (All Available Data 2006–2015)

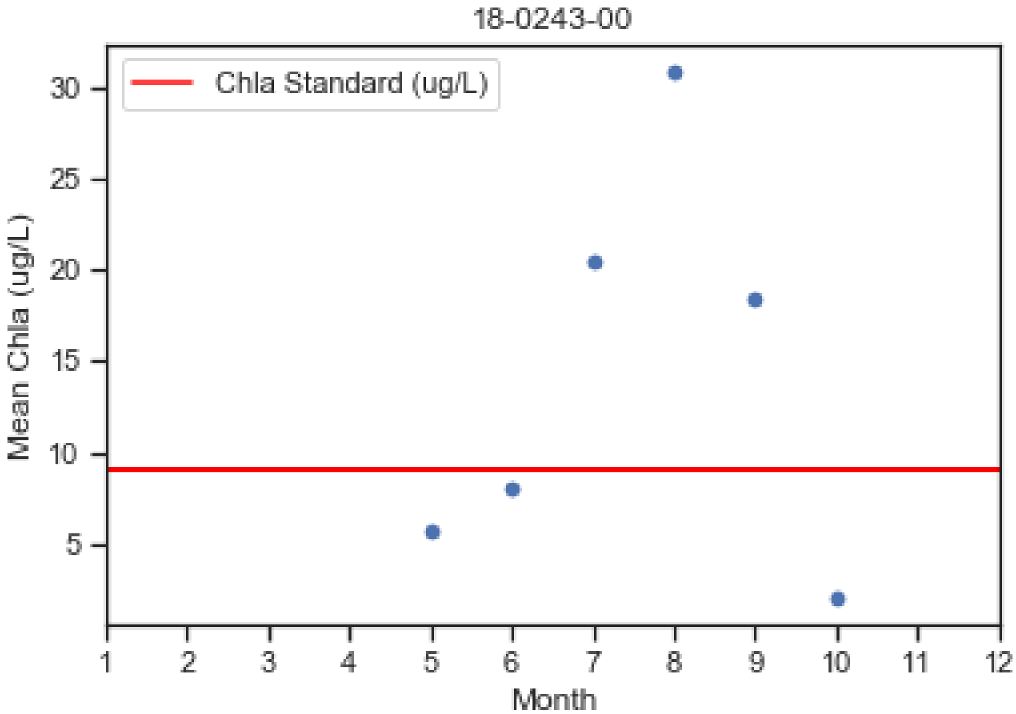


Figure H-7. Lower Mission Lake Growing Season Monthly Mean Chl-*a* (All Available Data 2006–2015)

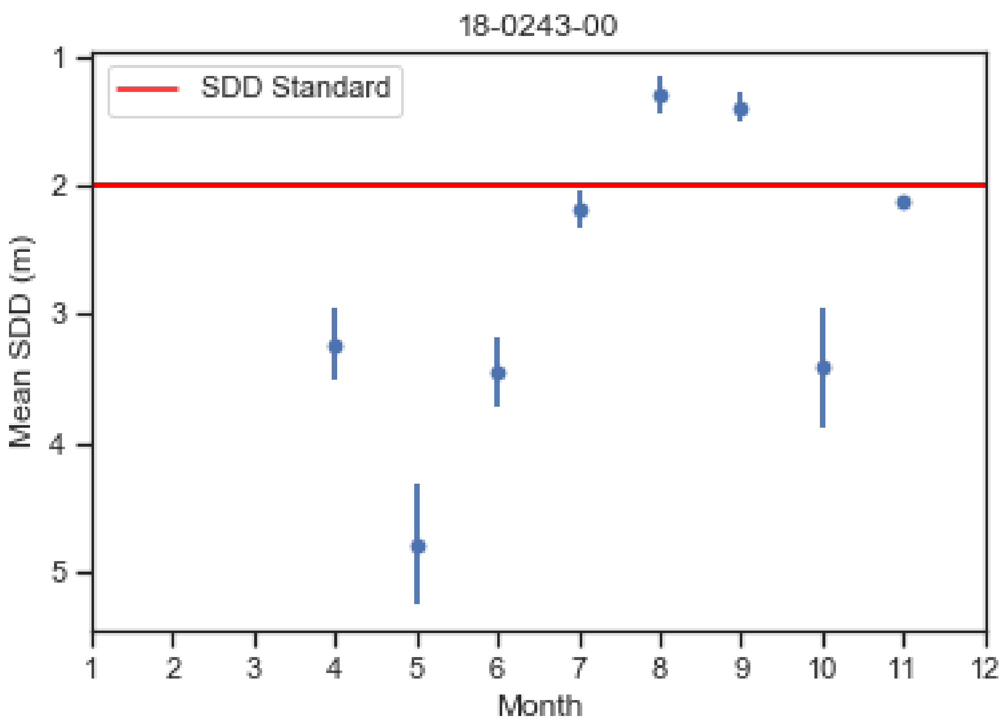


Figure H-8. Lower Mission Lake Monthly Growing Season Mean Secchi (All Available Data 2006–2015)

Dissolved Oxygen and Temperature Summary

DO and temperature data monitored by depth were examined in an effort to better define lake-mixing patterns affecting biological responses and lake P dynamics. Available data from all sites from 2006 through 2016 are plotted in Figures H-9 and H-10 for temperature and DO.

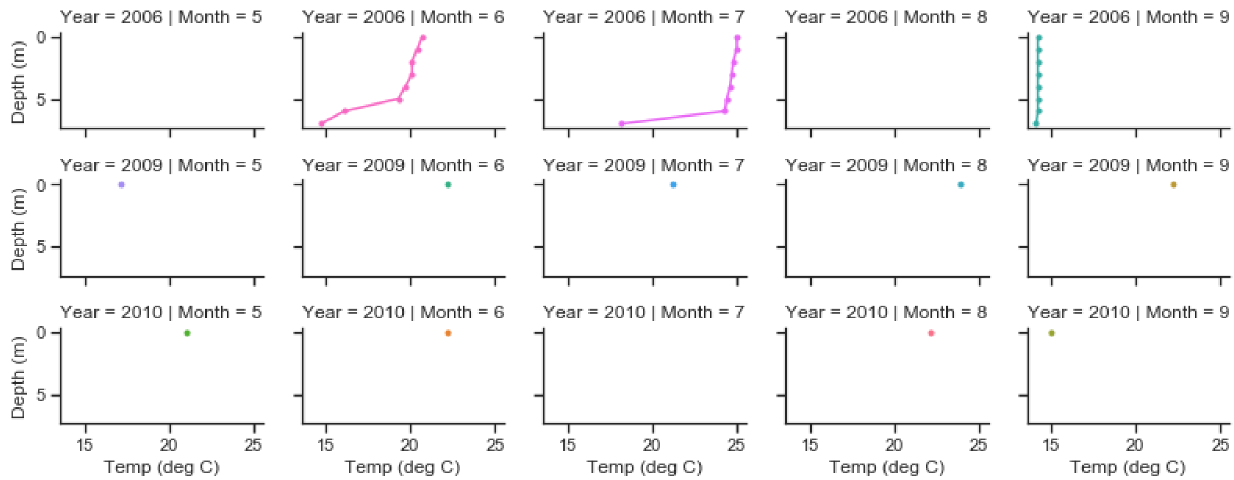


Figure H-9. Lower Mission Lake Profiles for Temperature at Site 203

Water temperature profiles indicate temperature decreases with depth at site 203. DO profiles indicate concentration losses with depth during June and July, indicating large oxygen depletion rates are occurring. Lower Mission Lake exhibited clinograde-like oxygen patterns with values decreasing with depth with values of zero mg/L observed on several dates. When oxygen concentrations approach zero along lake bottoms, internal P loading from sediments is expected. The DO profiles often show a difference of more than 5 mg/L between the maximum and minimum measured DO concentrations.

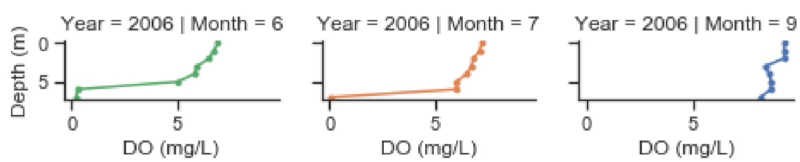


Figure H-10. Lower Mission Lake Profiles for DO at Site 203

Aquatic Plants

A qualitative survey of aquatic plants in Lower Mission Lake has not been completed.

Fisheries

The DNR Fisheries surveyed Lower Mission Lake in 2007 and 2014. From these surveys, the DNR Fisheries Lake FIBI Bioassessments noted a presence of intolerant species in the gill nets (Rock Bass), a high biomass of top carnivores in the gill net survey (primarily Northern Pike and Walleye), and relatively large number of vegetation dwelling (8-10) and intolerant (5-7) species surveyed. Northern Pike and Walleye dominated the biomass of fish sampled by gill nets. Bowfin, Bluegill, and Northern Pike were most abundant by biomass in the trap net surveys. A diverse suite of species was sampled during each nearshore survey, with 21 species in each of the 2014 surveys. Intolerant species sampled in one or more surveys included Banded Killifish, Blackchin Shiner, Blacknose Shiner, Iowa Darter, Mimic Shiner, Pugnose Shiner, and Rock Bass. Tolerant species sampled included Fathead Minnow and Green Sunfish [DNR 2017]. The 2007 survey did note the presence of black bullhead at a below normal catch rate, while the 2014 survey did not note the presence of black bullhead or common carp. Bottom feeding fish can stir up bottom sediments and increase P contributions to a lake.

Appendix I: Moose (77-0026-00)

Land Cover

Land cover defined by the University of Minnesota [2016] is summarized for the Moose Watershed in Table I-1 with the majority of the land cover consisting of row crops (30.7%), grassland (19.0%), forest (18.2%), and open water (13.9%).

Table I-1. Moose Watershed Land Cover.

Impairment	Developed (%)	Wetlands (%)	Open Water (%)	Forest (%)	Grassland (%)	Hay/ Pastures (%)	Row Crops (%)
Moose	7.8	1.5	13.9	18.2	19.0	9.0	30.7

Physical Characteristics

Moose Lake is located 2 miles north of Burtrum, Minnesota, in Todd County in the southern portion of the Mississippi-Brainerd HUC-8. From a regulatory standpoint, Moose Lake is categorized as a deep NCHFs ecoregion lake. Select lake morphometric and watershed physical characteristics are listed in Table I-2. Moose Lake has one public access maintained by the DNR that includes parking for approximately six boat trailers. Figure I-1 shows aerial imagery of Moose Lake. Figure I-2 shows lake level data from Moose Lake.

Table I-2. Select Lake and Watershed Physical Characteristics for Moose Lake.

Characteristic	Moose Lake	Source
Lake Surface Area (acres)	130.7	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	50	DNR LakeFinder Fish Lake Surveys
Shore Length (miles)	2.01	DNR LakeFinder Fish Lake Surveys
Mean Depth (feet [ft])	15[(c)]	DNR LakeFinder Fish Lake Surveys (a), Calculated (b), or Estimated from Lake Map (c)
Maximum Depth (ft)	26	DNR LakeFinder Fish Lake Surveys
Average Water Clarity (ft)	3[(a)]	DNR LakeFinder Fish Lake Surveys (a) or Average Growing Season Secchi Disk Depth (SDD)(b)
Recorded Water Level Range (ft)	2.3	DNR LakeFinder Water Level
Percent Lake Littoral Surface Area	38.2	Calculated
Number of Islands	0	DNR Lakefinder Map
Public Access Sites	1	DNR LakeFinder Water Access Sites
Drainage Area, Including Lake (acres)	997	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	7.6	Calculated, Large in Bold
Wetland Area (acres)	102.7	Wetlands Layer
Number of Upland Lakes	0	USGS Topographic Maps
Number of Perennial Inlet Streams	0	NHD Flowlines Fcode 46006
Lake Volume (acre-feet)	1,961.1	Calculated
Maximum Fetch Length (ft)	4,005	Measured Using ArcGIS Imagery
Lake Geometry Ratio (A^0.25/Dmax), A is surface area in m^2 and Dmax is max depth in meters (m)	3.4	Calculated (Shallow>5.3, Medium 1.6–5.3, Deep<0.9)
Lake Geometry Classification	Medium	
Osgood Index (Dmean/sqrt[A]), A is surface area in km^2 and Dmean is mean depth in m	6.3	Calculated (Polymictic<4, Intermediate 4–9, Dimictic>9)
Osgood Index Category	Intermediate	
Estimated Water Residence Time (days)	1027	HSPF Model Application
Shore Land Properties		Imagery

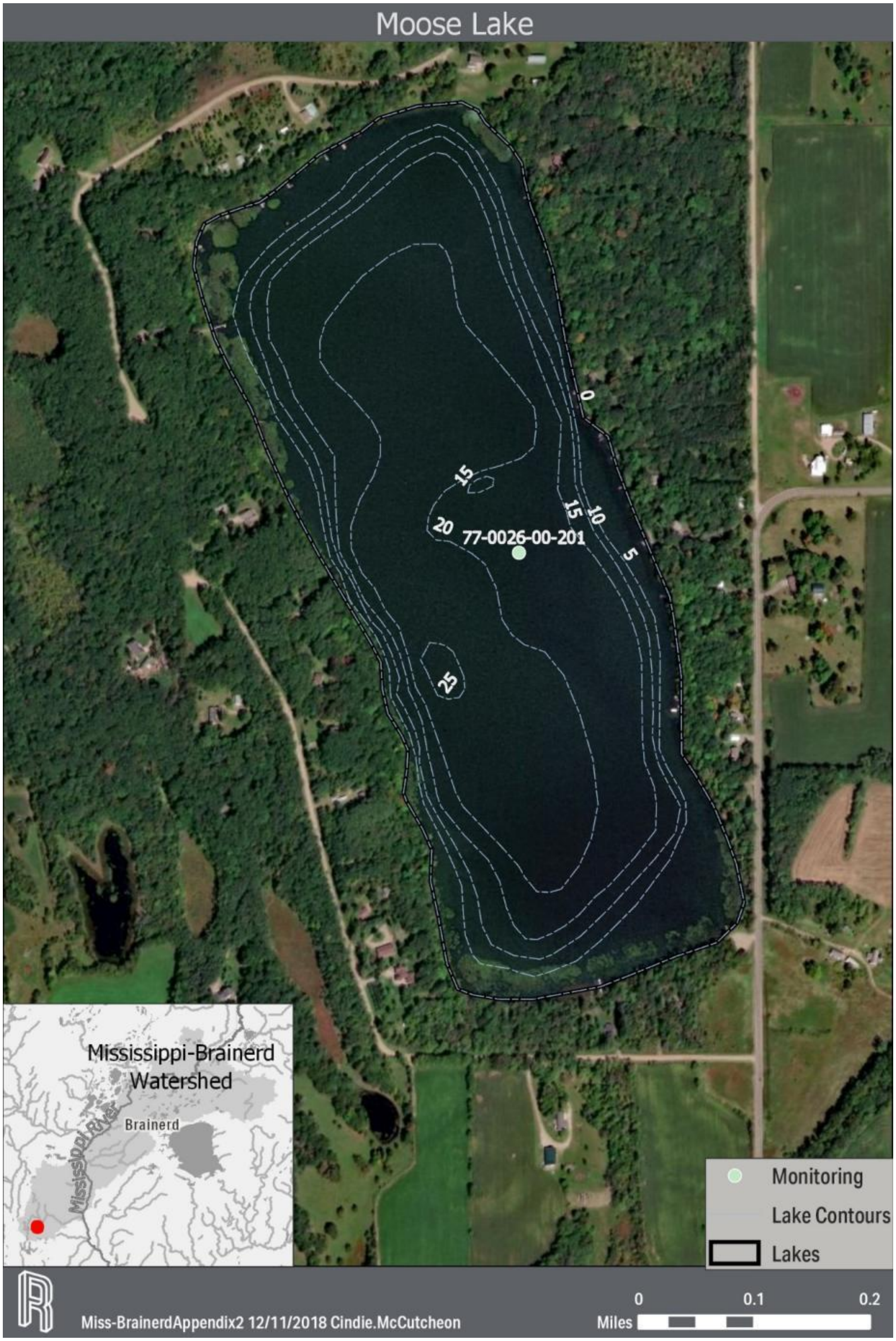


Figure I-1. Moose Lake Bathymetry and Aerial Imagery

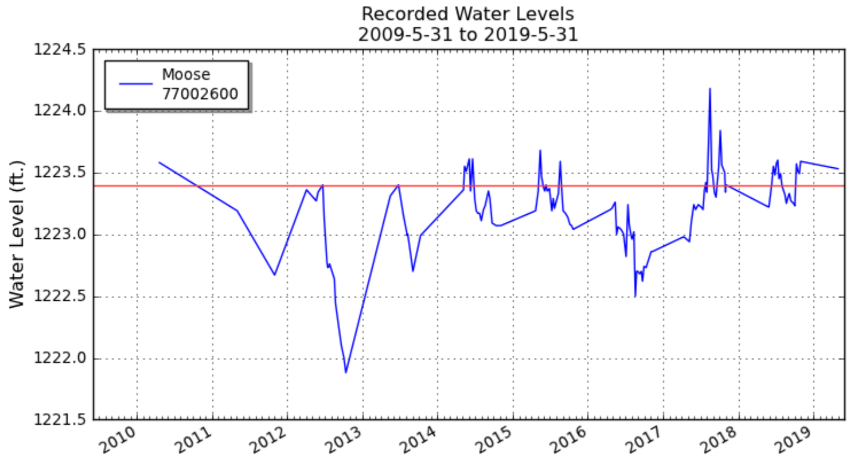


Figure I-2. Moose Lake Levels

Water Quality

Monitoring data annual sample counts are shown in Table I-3. Only 2016 TP and Chl-*a* data were available; therefore, 2016 data are summarized in Table I-4 as mean growing season values for TP, Chl-*a*, and Secchi transparency (Secchi). Corresponding lake water quality standards are also included. Mean values for TP and Chl-*a* are above the water quality standard, while the mean SDD meets the water quality standard. These data indicate that Moose Lake exceeds the P standard and will require reductions to achieve lake standards. Extreme high values of TP and Chl-*a* were 68 µg/L and 46.3 µg/L, respectively, while the lowest Secchi reading was 0.6 m. Individual growing season means from data available from 1990 through 2016 are plotted in Figures I-3 to I-5 and show that the TP and Chl-*a* water quality standards were exceeded in 2016, the only year with data. SDD data was available for other years and was often in compliance with the standard.

Table I-3. Growing Season TP, Chl-*a*, and Secchi Number of Samples Annually.

Lake	Constituent	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[a]	Total
Moose	TP											3	3[b]
	Chl-*a*											4	4[b]
	Secchi		15	17	12	10	13	11	16	14	13	20	121

(a) 2016 data not included in total or overall growing season means unless no other data were available.

(b) Only 2016 samples available for total.

Table I-4. TP, Chl-*a*, and Secchi Growing Season Means (2016).

Parameter	Minimum	Mean	Maximum	Standard Deviation	Lake Standards
TP (µg/L)	23.0	49.3	68.0	23.5	≤40
Chl-*a* (µg/L)	3.6	27.1	46.3	20.7	≤14
SDD (m)	0.5	1.5	4.9	1.0	≥1.4

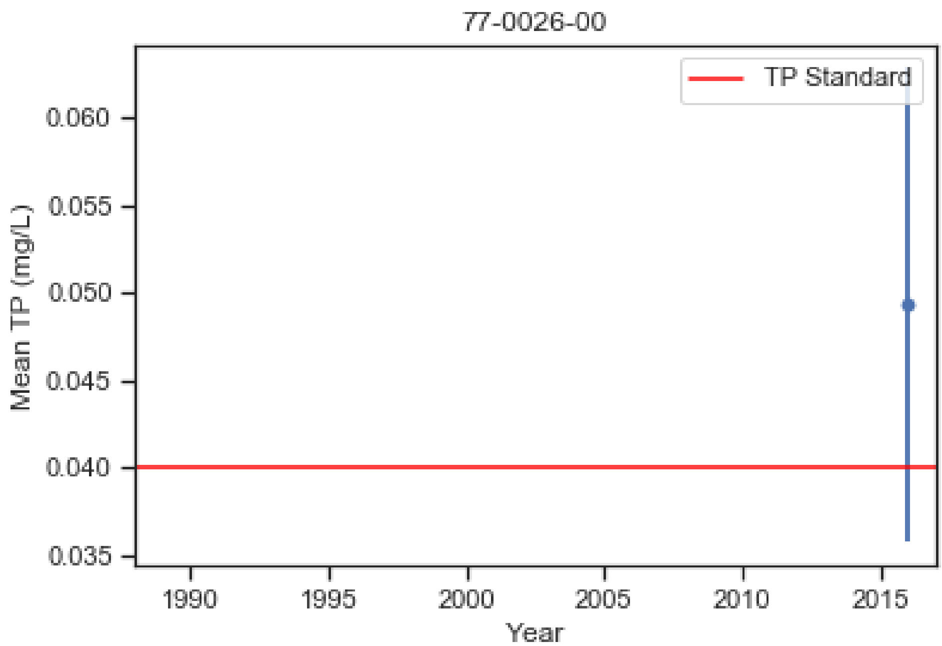


Figure I-3. Moose Lake Annual Growing Season Mean TP Concentrations

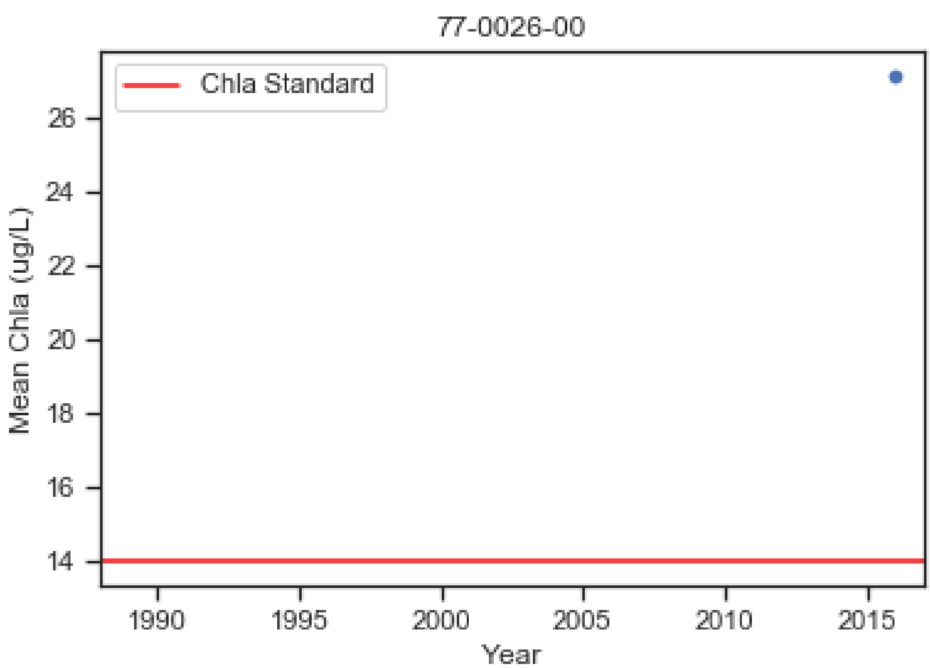


Figure I-4. Moose Lake Annual Growing Season Mean Chl-*a* Concentrations

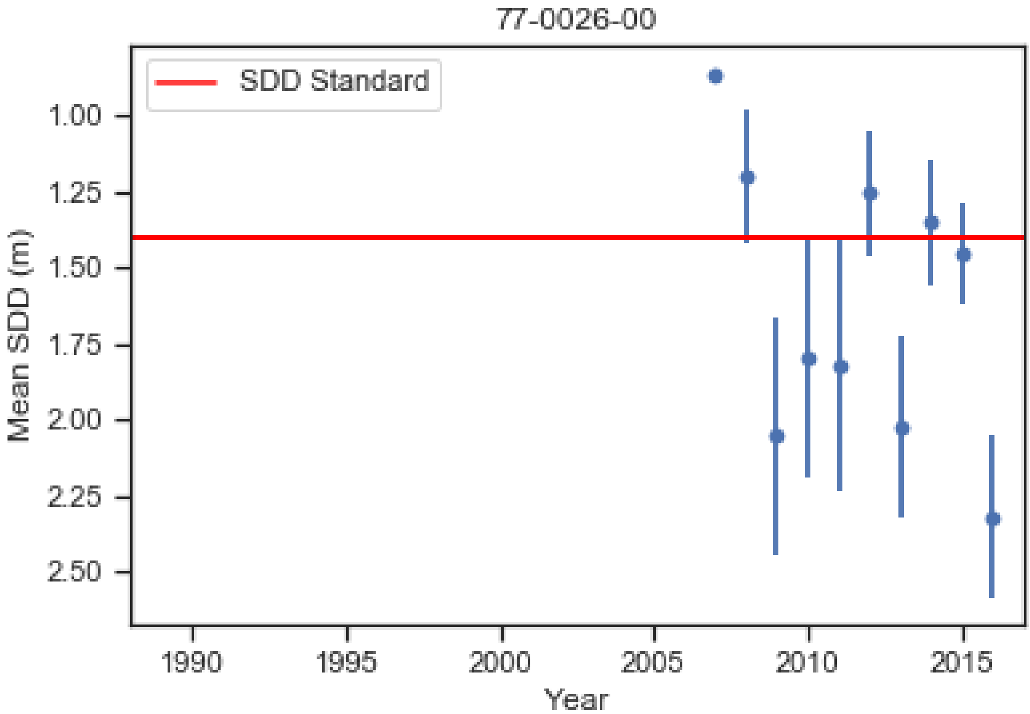


Figure I-5. Moose Lake Annual Growing Season Mean Secchi

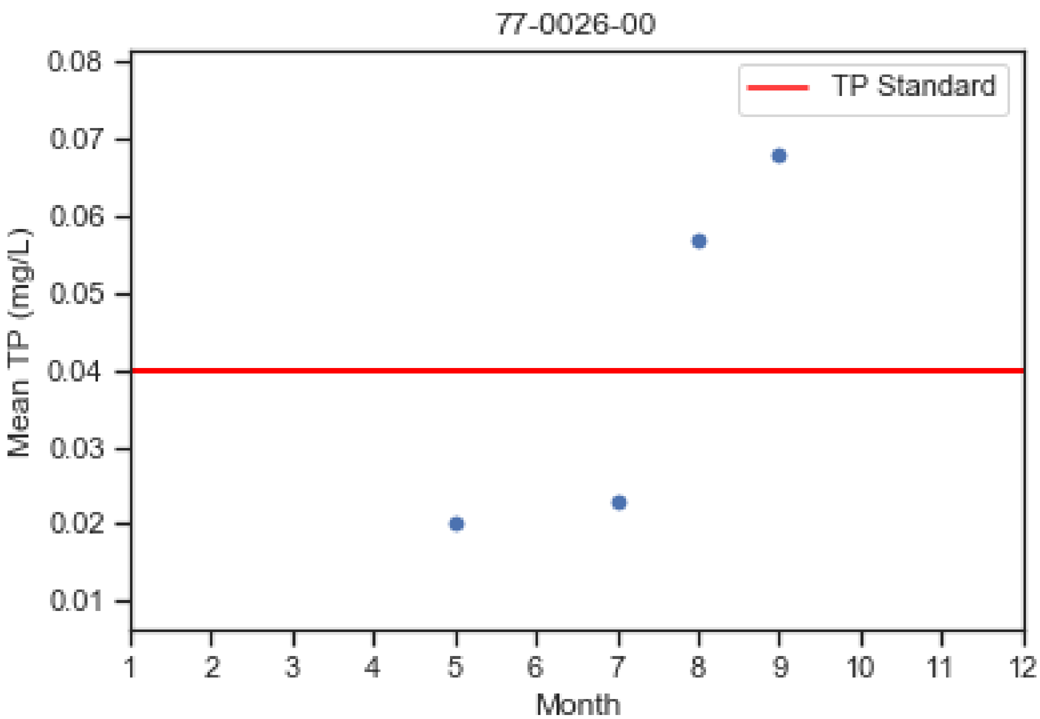


Figure I-6. Moose Lake Growing Season Monthly Mean TP (2016)

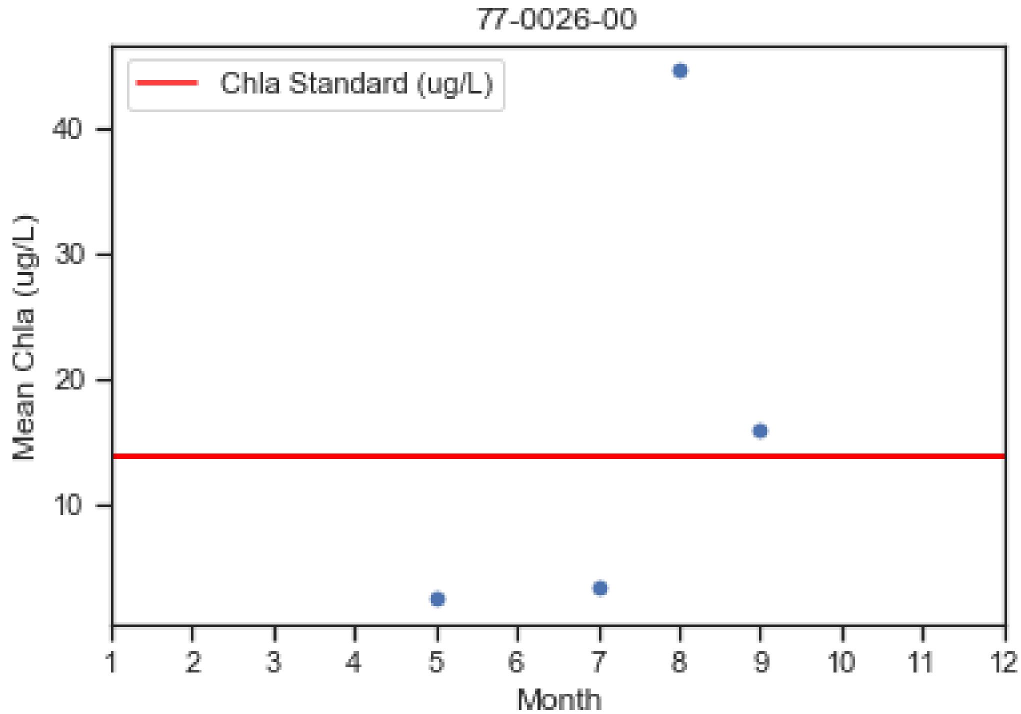


Figure I-7. Moose Lake Growing Season Monthly Mean Chl-*a* (2016)

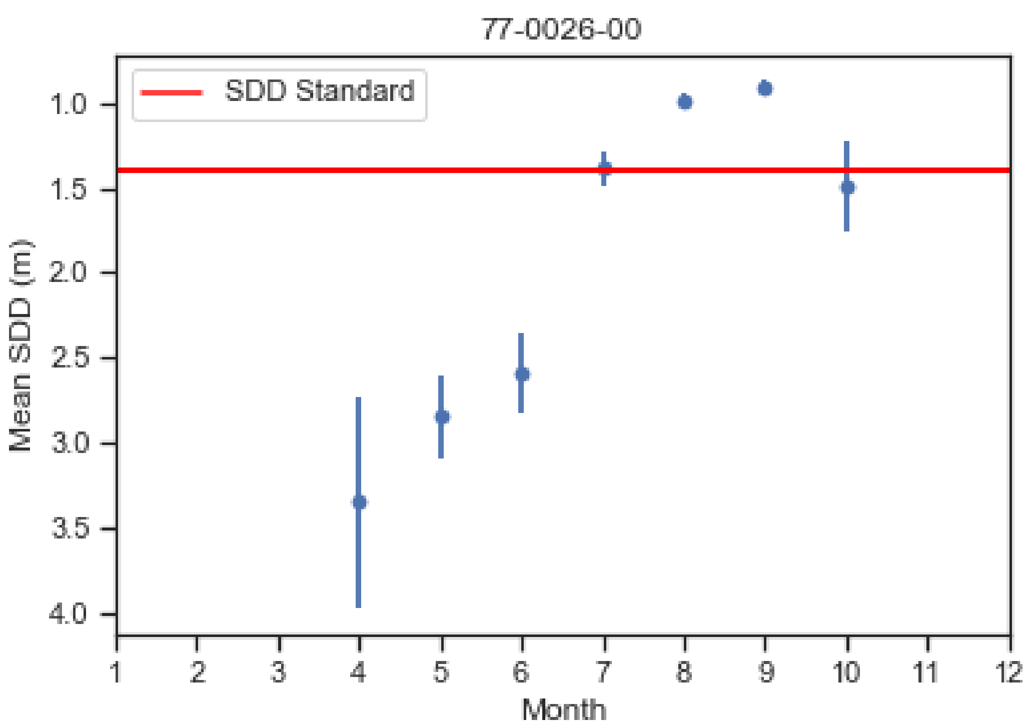


Figure I-8. Moose Lake Monthly Growing Season Mean Secchi

Dissolved Oxygen and Temperature Summary

DO and temperature data monitored by depth were examined in an effort to better define lake-mixing patterns affecting biological responses and lake P dynamics. Available data from all sites from 2006 through 2016 are plotted in Figures I-9 and I-10 for temperature and DO.

Water temperature profiles indicate fairly well-mixed conditions at site 201 because temperatures are relatively similar going from the surface to depth. Slight cooling occurs with depth in June and July. DO profiles indicate a fairly well mixed condition, with concentrations only slightly dropping and occasionally rising with depth.

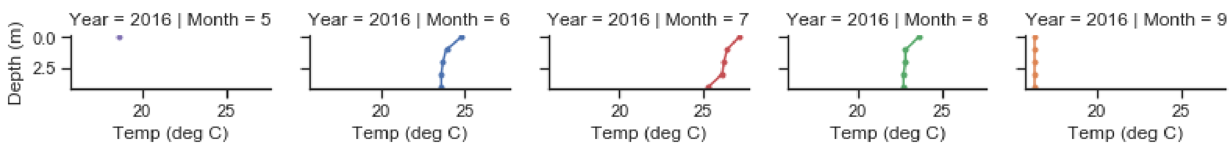


Figure I-9. Moose Lake Profiles for Temperature at Site 201

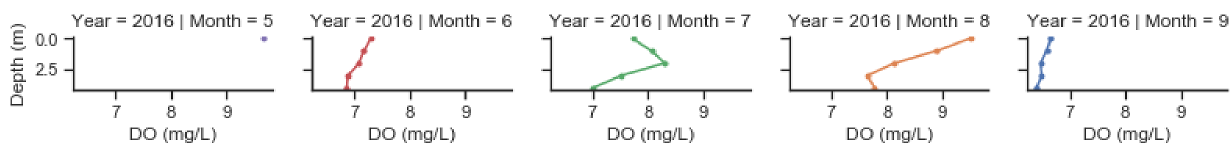


Figure I-10. Moose Lake Profiles for DO at Site 201

Aquatic Plants

A qualitative survey of aquatic plants in Moose Lake was performed on July 2, 2003, by the DNR. This survey found 12 species of submersed plants, 3 species of free-floating plants, 1 species of floating-leaf plants, 2 species of emergent plants, and 5 species of shoreland (wetland) plants. The exotic invasive species curly-leaf pondweed (*Potamogeton Crispus*) was present.

Fisheries

The DNR Fisheries surveyed Moose Lake in 2012, 2014, and 2017. From these surveys, the DNR Fisheries Lake FIBI Bioassessments noted that there was a low number of intolerant species (1, Iowa Darter) and relatively low biomass insectivores and high biomass of omnivores in the trap nets (significant catches of Yellow Bullhead). In the earlier survey, three tolerant species were surveyed. There was an absence of tolerant species, as well as a higher proportion of small benthic species. Northern Pike and Walleye were most abundant by biomass in the gill nets. Yellow Bullhead were also most abundant by biomass in 2017. In nearshore surveys of 2012 and 2014. Small gamefish (primarily sunfish species and Largemouth Bass) accounted for most of the fish caught during the nearshore surveys [DNR 2017]. The 2012 survey noted the presence of black bullhead with a below normal CPUE. Common carp and black bullhead were also present in 2014. Black bullhead and common carp can stir up bottom sediments and increase P contributions to a lake.

Appendix J: Ripple (01-0146-00)

Land Cover

Land cover defined by the University of Minnesota [2016] is summarized for the Ripple Watershed in Table J-1, with the majority of the land cover consisting of forest (38.4%), wetlands (26.2%), and open water (17.2%).

Table J-1. Ripple Watershed Land Cover.

Impairment	Developed (%)	Wetlands (%)	Open Water (%)	Forest (%)	Grassland (%)	Hay/ Pastures (%)	Row Crops (%)
Ripple	5.5	26.2	17.2	38.4	5.4	5.1	1.9

Physical Characteristics

Ripple Lake is located about 4 miles south of Aitkin, Minnesota, in Aitkin County in the northern portion of the Mississippi-Brainerd HUC-8. From a regulatory standpoint, Ripple Lake is categorized as a deep NLF ecoregion lake. Select lake morphometric and watershed physical characteristics are listed in Table J-2. Ripple Lake has one public access maintained by the DNR that includes parking for approximately six boat trailers. Figure J-1 shows aerial imagery of Ripple Lake. Figure J-2 shows lake level data from Ripple Lake.

Table J-2 Select Lake and Watershed Physical Characteristics for Ripple Lake.

Characteristic	Ripple Lake	Source
Lake Surface Area (acres)	630.5	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	295	DNR LakeFinder Fish Lake Surveys
Shore Length (miles)	8.89	DNR LakeFinder Fish Lake Surveys
Mean Depth (feet [ft])	13.4(b)	DNR LakeFinder Fish Lake Surveys (a), Calculated (b), or Estimated from Lake Map (c)
Maximum Depth (ft)	39	DNR LakeFinder Fish Lake Surveys
Average Water Clarity (ft)	4(a)	DNR LakeFinder Fish Lake Surveys (a) or Average Growing Season Secchi Disk Depth (SDD) (b)
Recorded Water Level Range (ft)	3.85	DNR LakeFinder Water Level
Percent Lake Littoral Surface Area	46.8	Calculated
Number of Islands	1	DNR Lakefinder Map
Public Access Sites	1	DNR LakeFinder Water Access Sites
Drainage Area, Including Lake (acres)	66,408	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	**105.3**	Calculated, Large in Bold
Wetland Area (acres)	19,367.2	MN Wetlands Layer
Number of Upland Lakes	46	USGS Topographic Maps
Number of Perennial Inlet Streams	1	NHD Flowlines Fcode 46006
Lake Volume (acre-ft)	8,456.2	Calculated
Maximum Fetch Length (ft)	8,638	Measured Using ArcGIS Imagery
Lake Geometry Ratio (A^0.25/Dmax), A is surface area in m^2 and Dmax is max depth in m	3.4	Calculated (Shallow>5.3, Medium1.6–5.3, Deep<0.9)
Lake Geometry Classification	Medium	
Osgood Index (Dmean/sqrt[A]), A is surface area in km^2 and Dmean is mean depth in m	2.6	Calculated (Polymictic<4, Intermediate4–9,Dimictic>9)
Osgood Index Category	Polymictic	
Estimated Water Residence Time (days)	85	HSPF Model Application
Shore Land Properties		Imagery

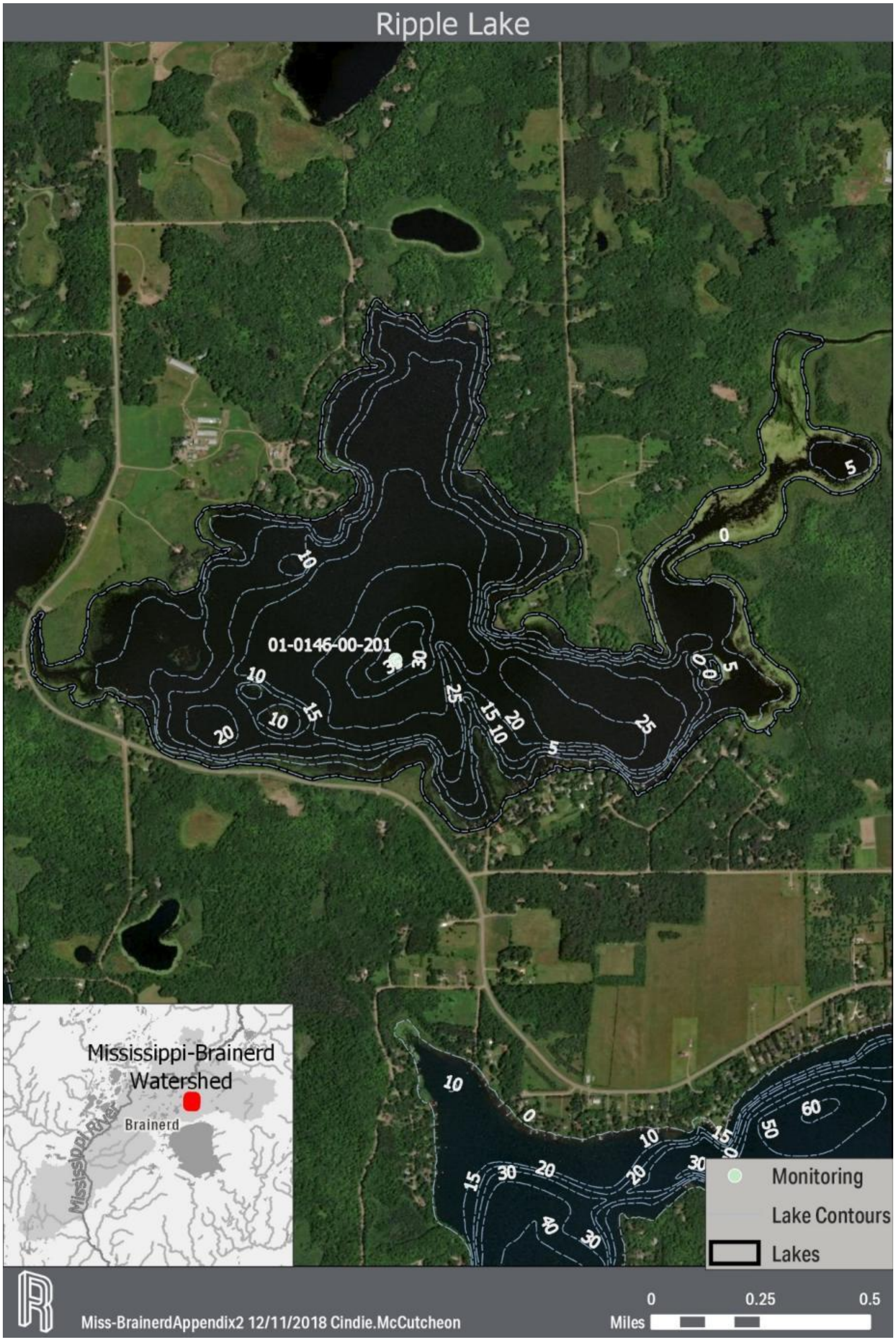


Figure J-1. Ripple Lake Bathymetry and Aerial Imagery

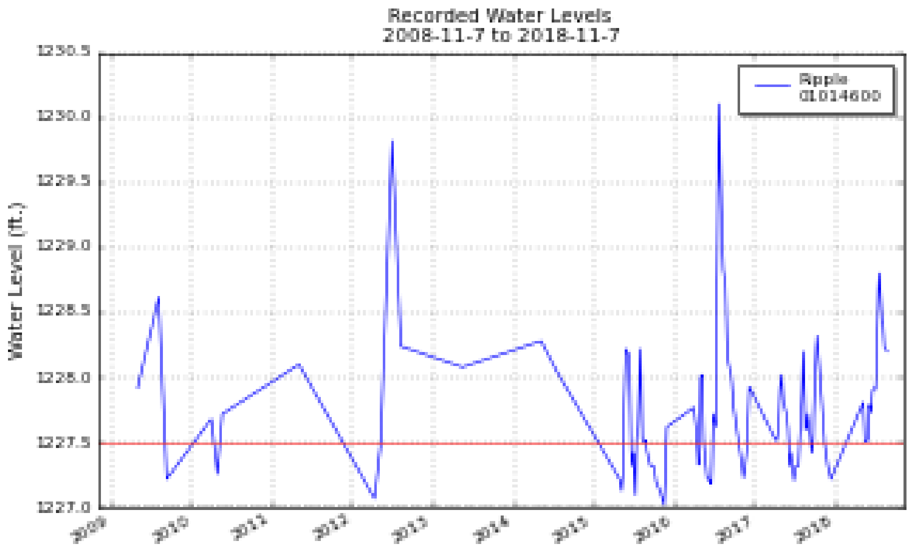


Figure J-2. Ripple Lake Levels

Water Quality

Monitoring data annual sample counts are shown in Table J-3 and are summarized over the TMDL period (2006 through 2015) in Table J-4 as mean growing season values for TP, Chl-*a*, and Secchi transparency (Secchi). Data collected in 2016 are also shown but were not included for monthly or overall averaging unless no other data were available. Corresponding lake water quality standards are also included. Mean values for TP and Chl-*a* are above the water quality standard. Similarly, the mean SDD did not meet the water quality standard. These data indicate that Ripple Lake exceeds the P standard and will require reductions to achieve lake standards. Extreme high values of TP and Chl-*a* were 79 micrograms per liter (µg/L) and 33.6 µg/L, respectively, while the lowest Secchi reading was 0.8 m. Individual growing season means from data available from 1990 through 2016 are plotted in Figures J-3 through J-5 and show that the water quality standards are exceeded most years with available data.

Multiyear growing season mean monthly water quality observations are summarized in Figures J-6 through J-8 for data available from 2006 through 2015. Plots of this mean monthly data indicate a variable water quality condition throughout the growing season. Error bars in annual and monthly P and Secchi plots indicate standard error.

Table J-3.Growing Season TP, Chl-*a*, and Secchi Number of Samples Annually.

Lake	Constituent	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[a]	Total
Ripple	TP		9									4	9
	Chl-*a*		9									4	9
	Secchi		8	6	4	6	3	5	4	5	6	11	47

(a) 2016 data not included in total or overall growing season means unless no other data were available.

Table J-4. TP, Chl-*a*, and Secchi Growing Season Means (2006–2015).

Parameter	Minimum	Mean	Maximum	Standard Deviation	Lake Standards
TP (µg/L)	26.0	34.2	44.0	5.6	≤30
Chl-*a* (µg/L)	11.5	20.0	33.6	7.8	≤9
SDD (m)	0.8	1.6	3.5	0.5	≥2

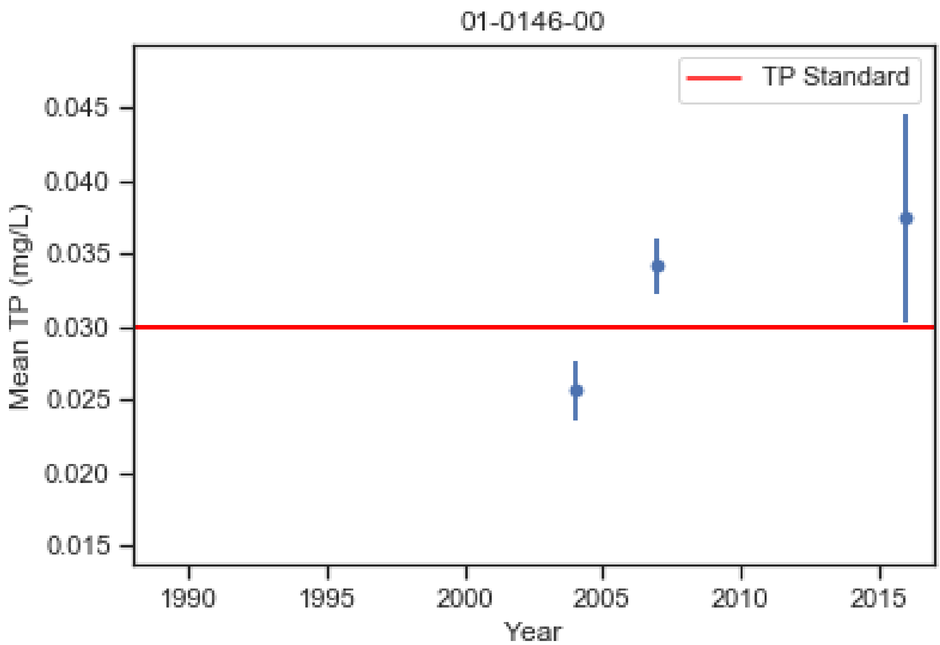


Figure J-3. Ripple Lake Annual Growing Season Mean TP Concentrations

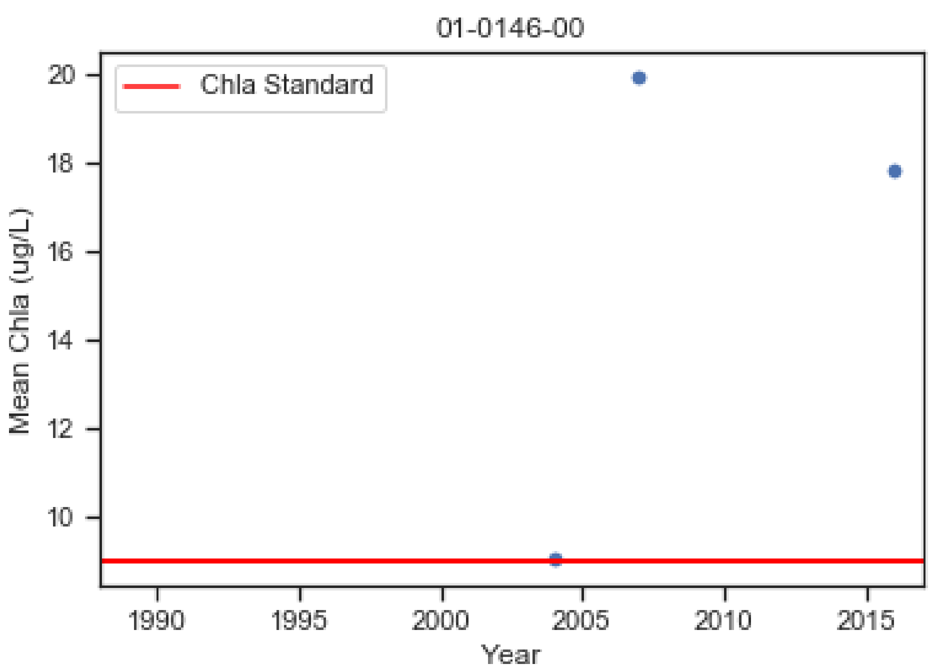


Figure J-4. Ripple Lake Annual Growing Season Mean Chl-*a* Concentrations

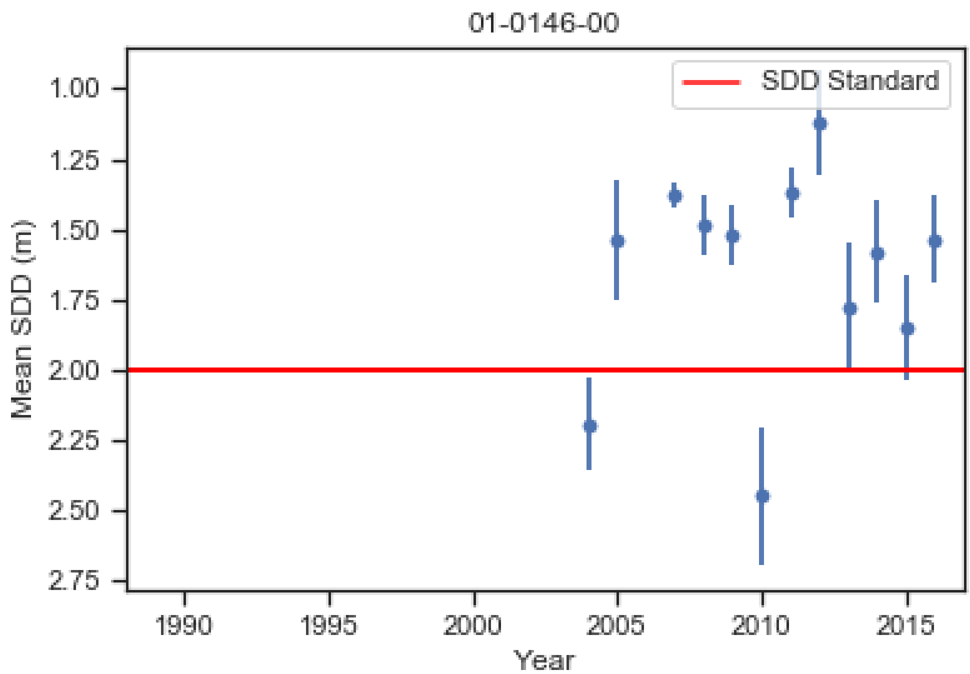


Figure J-5. Ripple Lake Annual Growing Season Mean Secchi

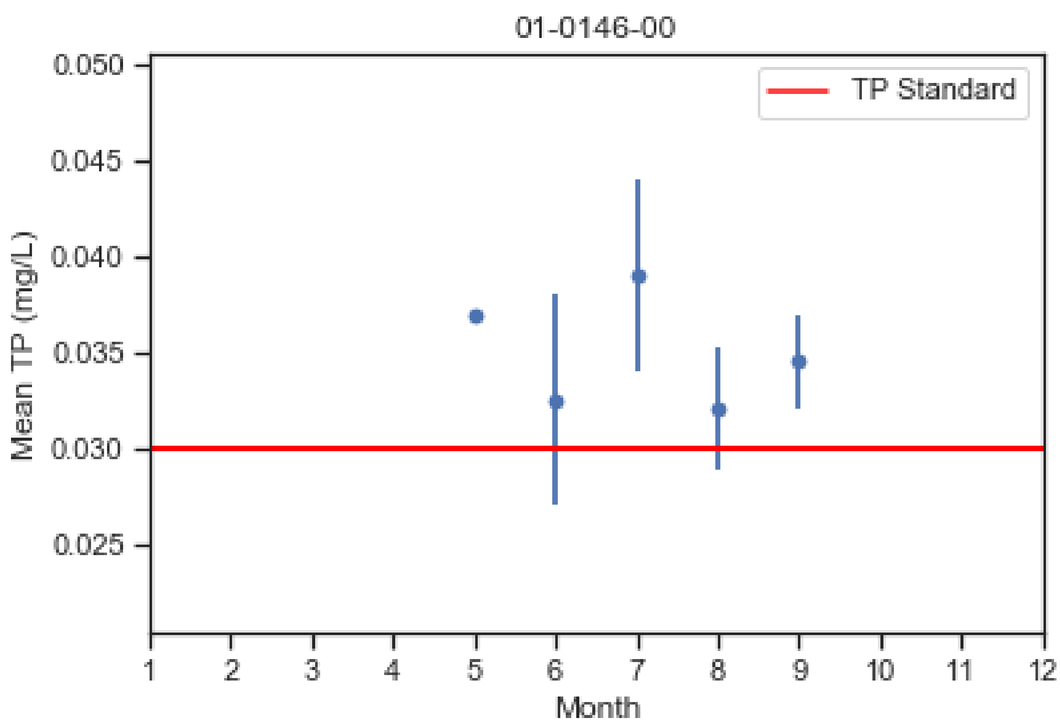
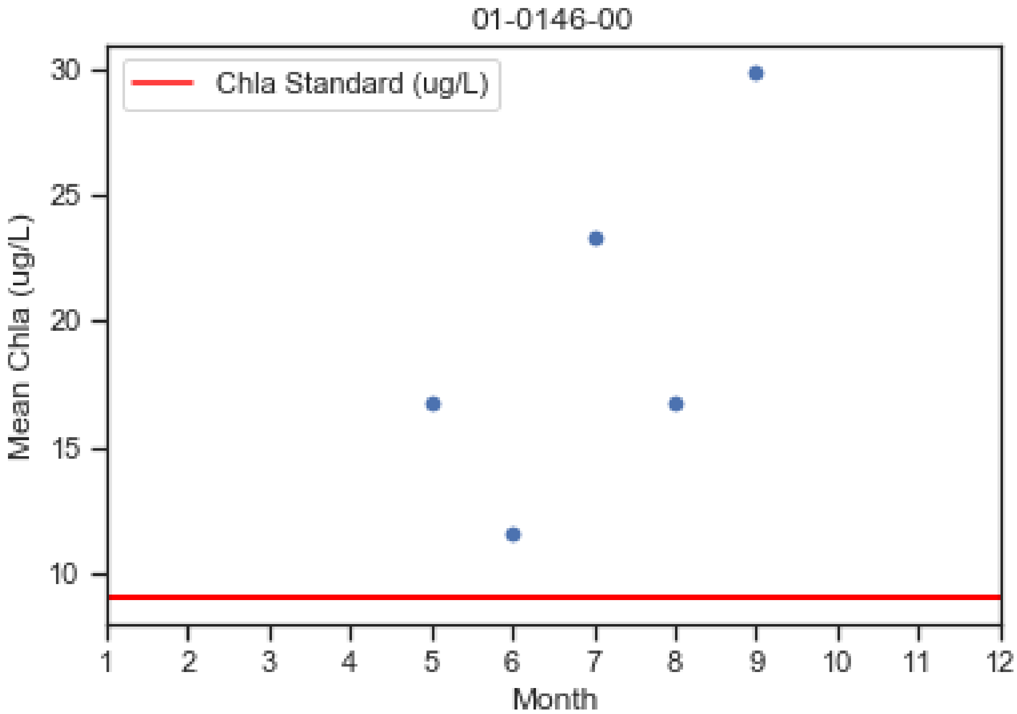


Figure J-6. Ripple Lake Growing Season Monthly Mean TP (All Available Data 2006–2015)

Figure J-7. Ripple Lake Growing Season Monthly Mean Chl-*a* (All Available Data 2006–2015)



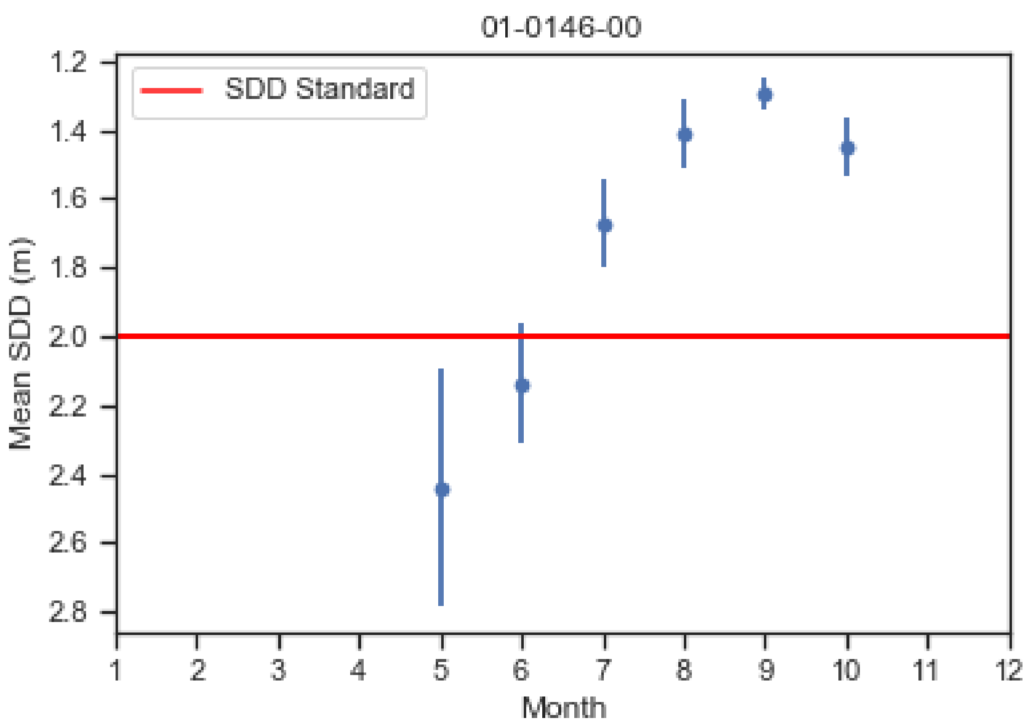


Figure J-8. Ripple Lake Monthly Growing Season Mean Secchi (All Available Data 2006–2015)

Dissolved Oxygen and Temperature Summary

DO and temperature data monitored by depth were examined in an effort to better define lake-mixing patterns affecting biological responses and lake P dynamics. Available data from all sites from 2006 through 2016 are plotted in Figures J-9 and J-10 for temperature and DO.

Water temperature profiles indicate a dramatic decrease in temperature with depth at site 201 during almost all sample dates. DO profiles indicate concentration losses with depth during all months, indicating large oxygen depletion rates are occurring. Ripple Lake exhibited clinograde-like oxygen patterns with values decreasing with depth with values of zero mg/L observed on several dates. When oxygen concentrations approach zero along lake bottoms, internal P loading from sediments is expected. The DO profiles often show a difference of more than 5 mg/L between the maximum and minimum measured DO concentrations.

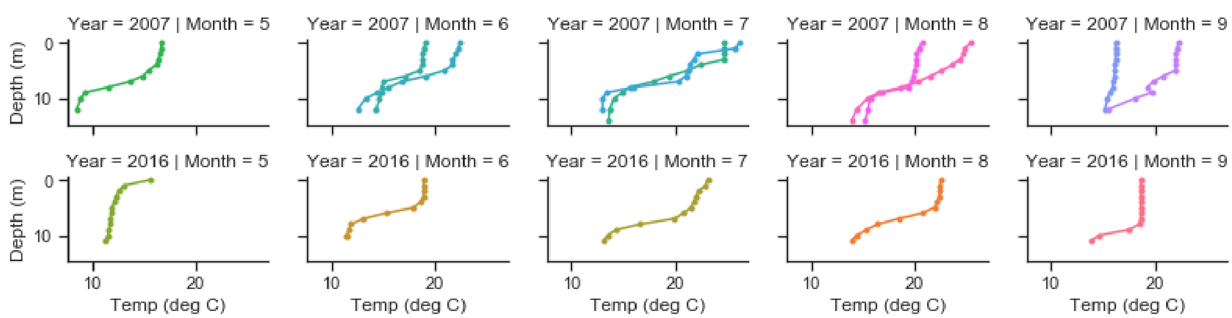


Figure J-9. Ripple Lake Profiles for Temperature at Site 201

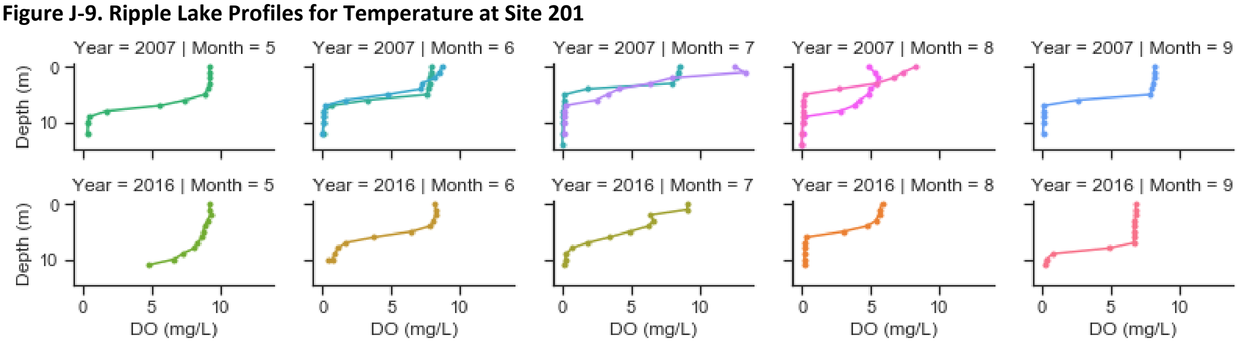


Figure J-10. Ripple Lake Profiles for DO at Site 201

Aquatic Plants

A qualitative survey of aquatic plants in Ripple Lake was performed on August 29, 1995, by the DNR. This survey found 13 species of submersed plants, 5 species of free-floating plants, 8 species of floating-leaf plants, 10 species of emergent plants, and 8 species of shoreland (wetland) plants. The exotic invasive species curly-leaf pondweed (*Potamogeton Crispus*) was not present.

Fisheries

The DNR Fisheries surveyed Ripple Lake in 2013 and 2016. From these surveys, the DNR Fisheries Lake FIBI Bioassessments noted that only 5 of 14 stations were seined and only a 15-foot seine was used, and that Black Bullhead dominated the nearshore catch, and only 1 intolerant species was sampled (Rock Bass). In 2016, 10 stations were seined, a 50-foot seine was used at most stations, and there were 5 intolerant species were sampled (Blacknose Shiner, Iowa Darter, Least Darter, Logperch, and Rock Bass). There were intolerant species in the gill net catch (Rock Bass) in 2013, and a high number and proportion of small benthic species sampled in 2016. There was a high biomass of omnivorous species (primarily Yellow Bullhead) and a low biomass of insectivores in 2013 [DNR 2017]. The 2013 and 2016 surveys noted the presence of black bullhead at lower than normal catch rates. Black bullhead can stir up bottom sediments and increase P contributions to a lake.

Appendix K: Sebie (18-0161-00)

Land Cover

Land cover defined by the University of Minnesota [2016] is summarized for the Sebie Watershed in Table K-1. The majority of the land cover consists of forest (38.3%), wetlands (17.8%), grassland (15.1%), and row crops (14.4%).

Table K-1. Sebie Watershed Land Cover.

Impairment	Developed (%)	Wetlands (%)	Open Water (%)	Forest (%)	Grassland (%)	Hay/ Pastures (%)	Row Crops (%)
Sebie	4.6	17.8	2.7	38.3	15.1	7.1	14.4

Physical Characteristics

Sebie Lake is located about 1.5 miles east of Fort Ripley, Minnesota, in Crow Wing County in the central portion of the Mississippi-Brainerd HUC-8. From a regulatory standpoint, Sebie Lake is categorized as a deep NLF ecoregion lake. Select lake morphometric and watershed physical characteristics are listed in Table K-2. Sebie Lake has one public access maintained by Crow Wing County that includes parking for approximately four boat trailers. Figure K-1 shows aerial imagery of Sebie Lake. Figure K-2 shows lake level data from Sebie Lake.

Table K-2. Select Lake and Watershed Physical Characteristics for Sebie Lake.

Characteristic	Sebie Lake	Source
Lake Surface Area (acres)	185.3	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	117	DNR LakeFinder Fish Lake Surveys
Shore Length (miles)	2.29	DNR LakeFinder Fish Lake Surveys
Mean Depth (feet (ft))	15[c]	DNR LakeFinder Fish Lake Surveys (a), Calculated (b), or Estimated from Lake Map (c)
Maximum Depth (ft)	27	DNR LakeFinder Fish Lake Surveys
Average Water Clarity (ft)	6.5[a]	DNR LakeFinder Fish Lake Surveys (a) or Average Growing Season Secchi Disk Depth (b)
Recorded Water Level Range (ft)	3.28	DNR LakeFinder Water Level
Percent Lake Littoral Surface Area	63.1	Calculated
Number of Islands	0	DNR LakeFinder Map
Public Access Sites	1	DNR LakeFinder Water Access Sites
Drainage Area, Including Lake (acres)	19,074	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	**102.9**	Calculated, Large in Bold
Wetland Area (acres)	3390	MN Wetlands Layer
Number of Upland Lakes	4	USGS Topographic Maps
Number of Perennial Inlet Streams	1	NHD Flowlines Fcode 46006
Lake Volume (acre-feet)	2,779.7	Calculated
Maximum Fetch Length (ft)	4,334	Measured Using ArcGIS Imagery
Lake Geometry Ratio (A^0.25/Dmax), A is surface area in m2 and Dmax is max depth in m	3.6	Calculated (Shallow >5.3, Medium 1.6-5.3, Deep <0.9)
Lake Geometry Classification	Medium	
Osgood Index (Dmean/sqrt(A)), A is surface area in km2 and Dmean is mean depth in m	5.3	Calculated (Polymictic <4, Intermediate 4-9, Dimictic >9)
Osgood Index Category	Intermediate	
Estimated Water Residence Time (days)	72	HSPF Model Application
Shore Land Properties		Imagery

Figure K-1. Sebie Lake Aerial Imagery

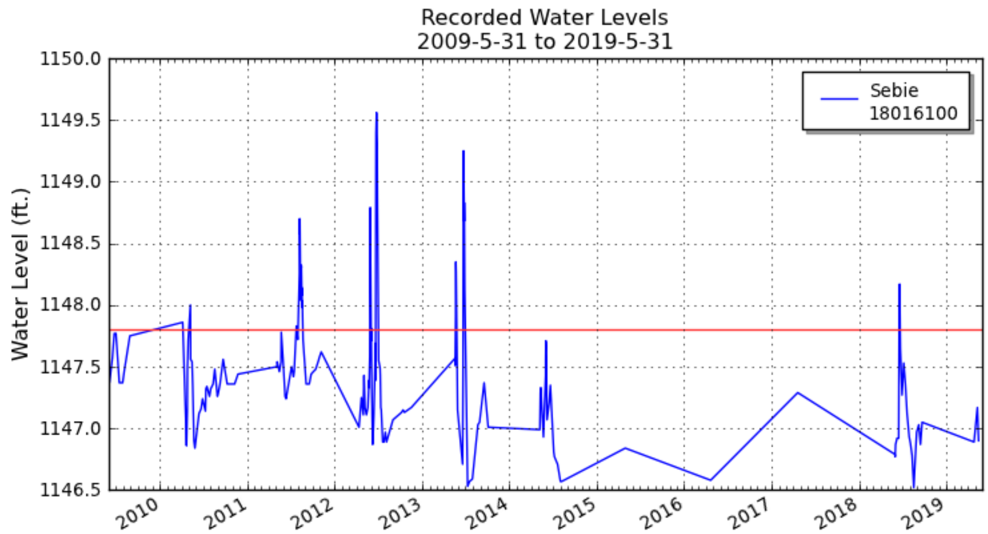


Figure K-2. Sebie Lake Levels.

Water Quality

Monitoring-data annual sample counts are shown in Table K-3. Table K-4 summarizes them as mean-growing season values for TP, Chl-*a*, and Secchi transparency (Secchi) over the TMDL period (2006 through 2015). Data collected in 2016 are also shown but were not included for monthly or overall averaging unless no other data were available. Corresponding lake water quality standards are also included. Mean values for TP and Chl-*a* are above the water quality standard, while the mean SDD meets the water quality standard. These data indicate that Sebie Lake exceeds the P standard and will require reductions to achieve lake standards. Extreme high values of TP and Chl-*a* were 86 µg/L and 31 µg/L, respectively, while the lowest Secchi reading was 0.5 meters (m). Individual-growing season means from data available between 1990 and 2016 are plotted in Figures K-2 to K-4, and show that most years were not in compliance with the nutrient water quality standards.

Multiyear growing season mean monthly water quality observations are summarized in Figures K-5 through K-7 for data available from 2006 through 2015. Plots of this mean monthly data indicate a variable water quality condition throughout the growing season. Error bars in the annual and monthly P and Secchi plots indicate standard error.

Table K-3. Growing Season TP, Chl-*a*, and Secchi Transparency Number of Samples Annually.

Lake	Constituent	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Sebie	TP			5	4	3	3	4	4	5		4	28
	Chl-*a*			5	4	3	3	4	4	5		4	28
	Secchi		3	9	8	6	2	3	4	5		4	40

(a) 2016 Data not included in total or overall growing season means unless no other data were available

Table K-4. TP, Chl-*a*, and Secchi Transparency Growing Season Means (2006-2015).

Parameter	Minimum	Mean	Maximum	Standard Deviation	Lake Standards
TP (µg/L)	24.0	42.6	86.0	16.0	≤30
Chl-*a* (µg/L)	4.0	17.5	31.0	7.3	≤9
Secchi disk depth (m)	0.5	1.4	3.1	0.6	≥2

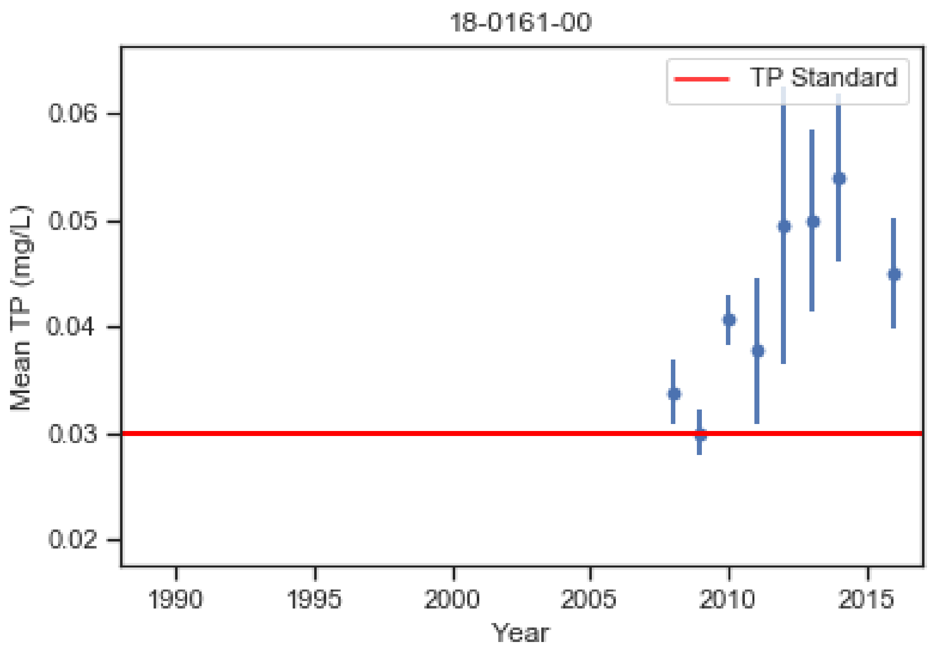


Figure K-3. Sebie Lake Annual Growing Season Mean Total Phosphorus Concentrations

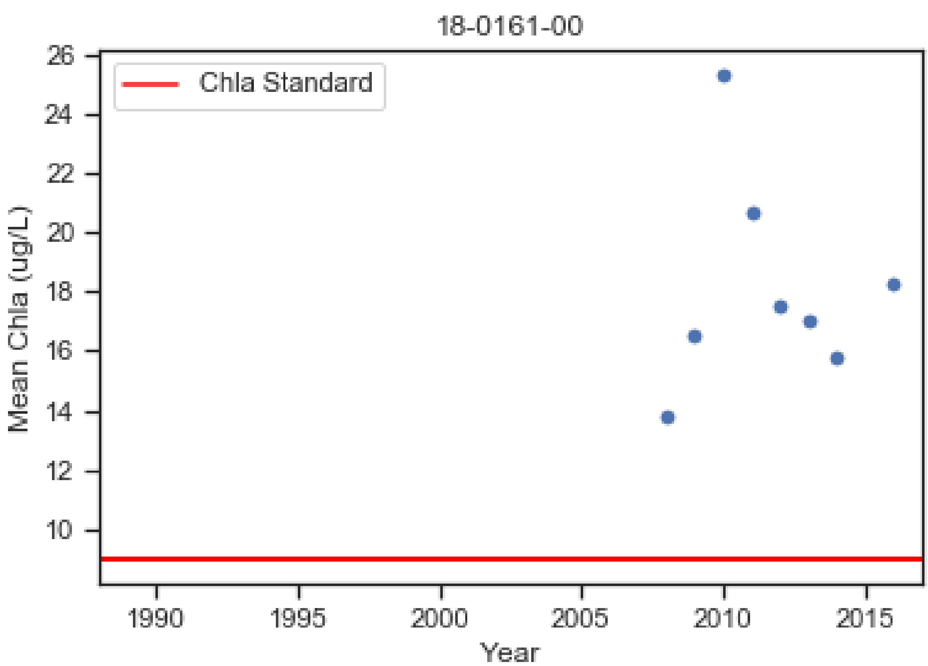


Figure K-4. Sebie Lake Annual Growing Season Mean Chl-*a* Concentrations

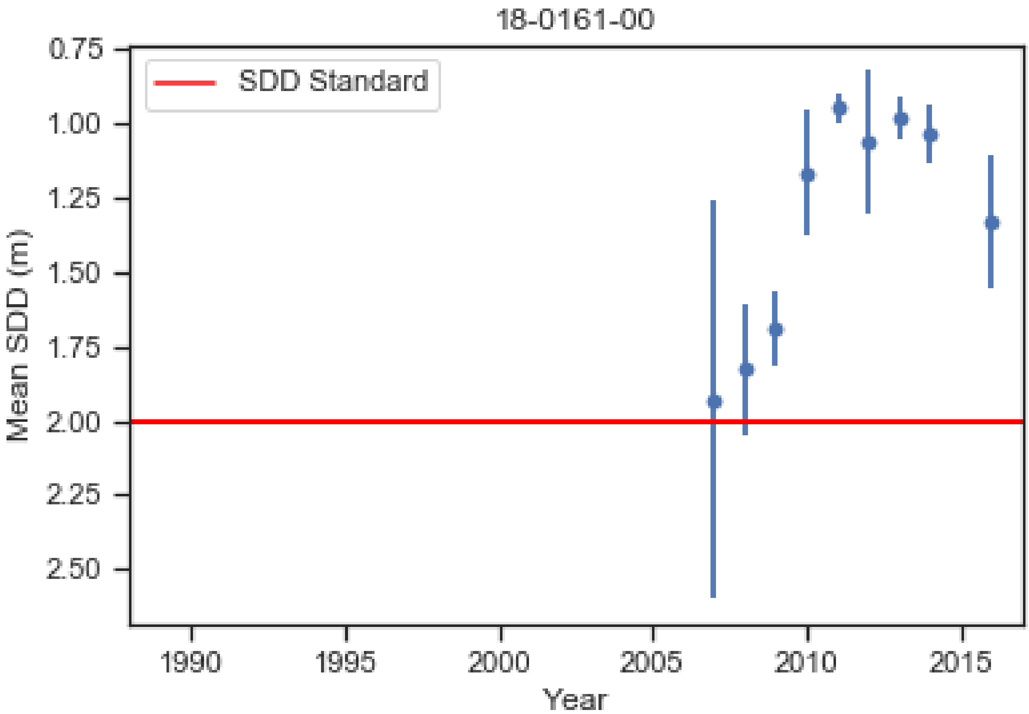


Figure K-5. Sebie Lake Annual Growing Season Mean Secchi Transparency

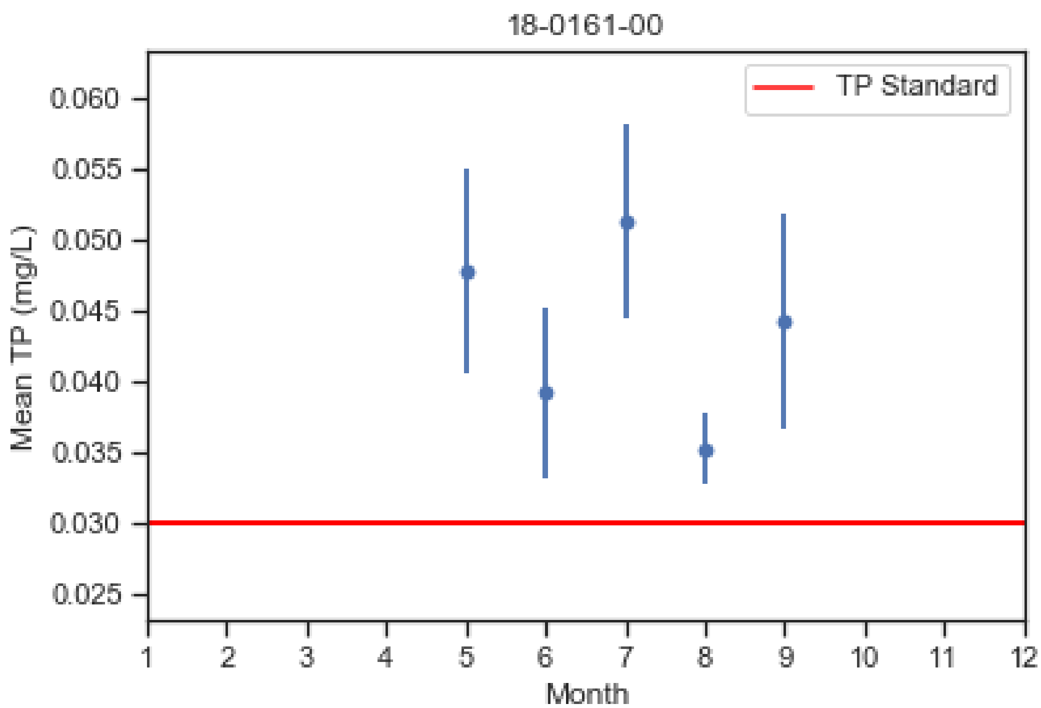


Figure K-6. Sebie Lake Growing Season Monthly Mean Total Phosphorus (All Available Data 2006–2015)

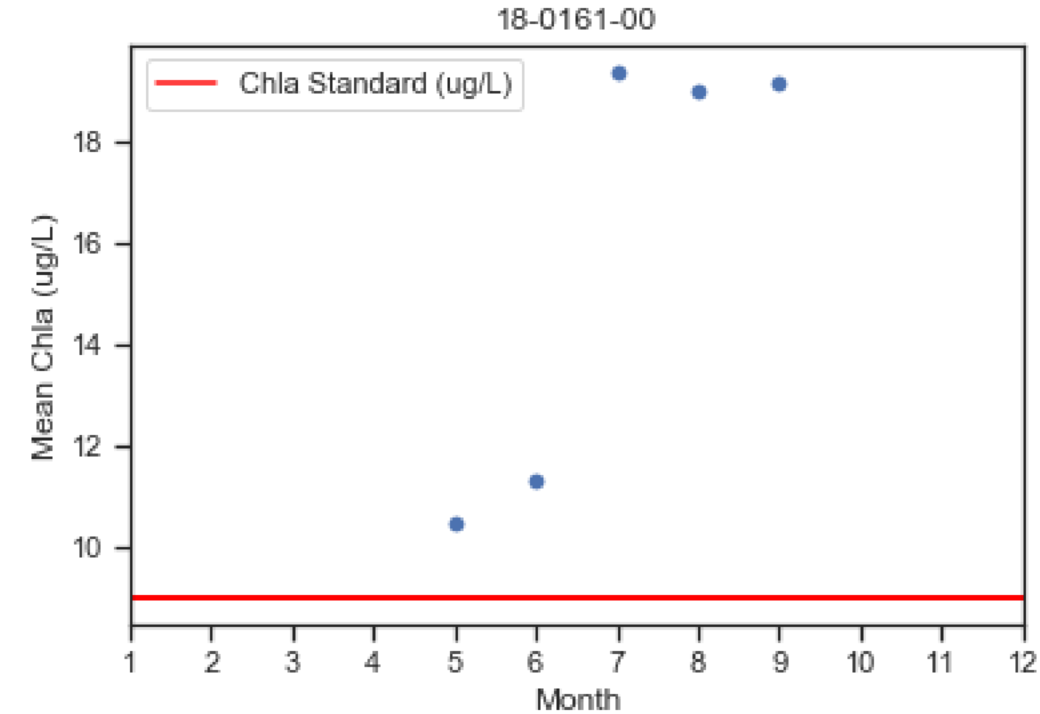


Figure K-7. Sebie Lake Growing Season Monthly Mean Chl-*a* (All Available Data 2006 and 2015)

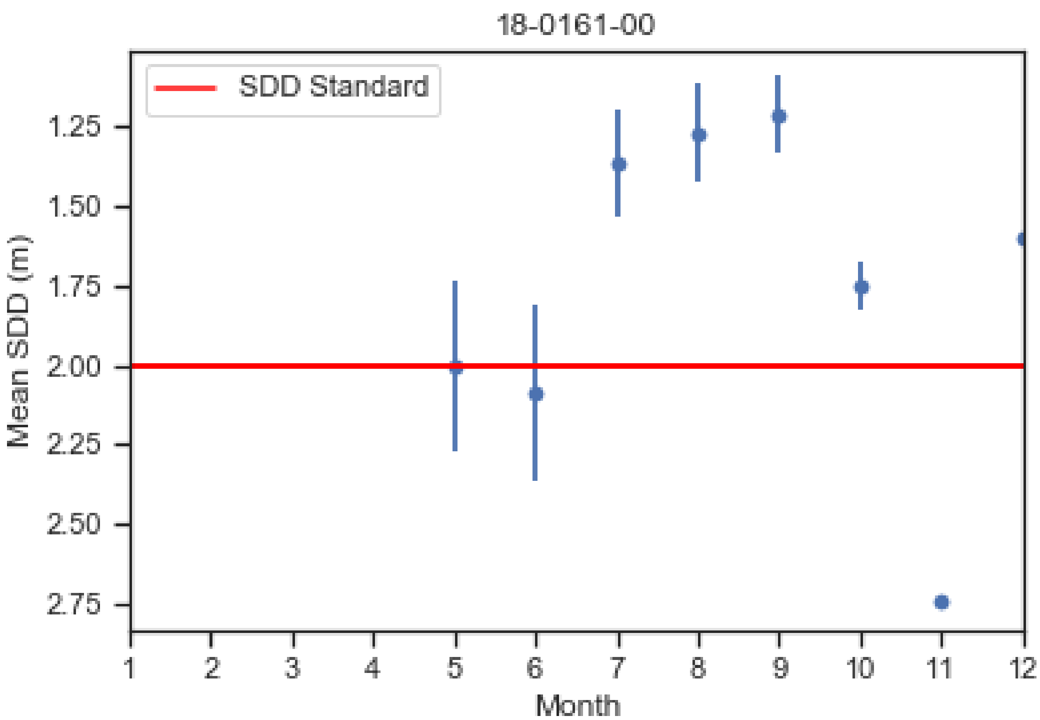


Figure K-8. Sebie Lake Monthly Growing Season Mean Secchi Transparency (All Available Data Between 2006 and 2015)

Dissolved Oxygen and Temperature Summary

No DO profiles were available in Sebie Lake between 2006 and 2018. Temperature spot data were monitored on multiple dates, as shown in Figure K-9. No conclusions about mixing patterns or lake P dynamics can be drawn from these data.

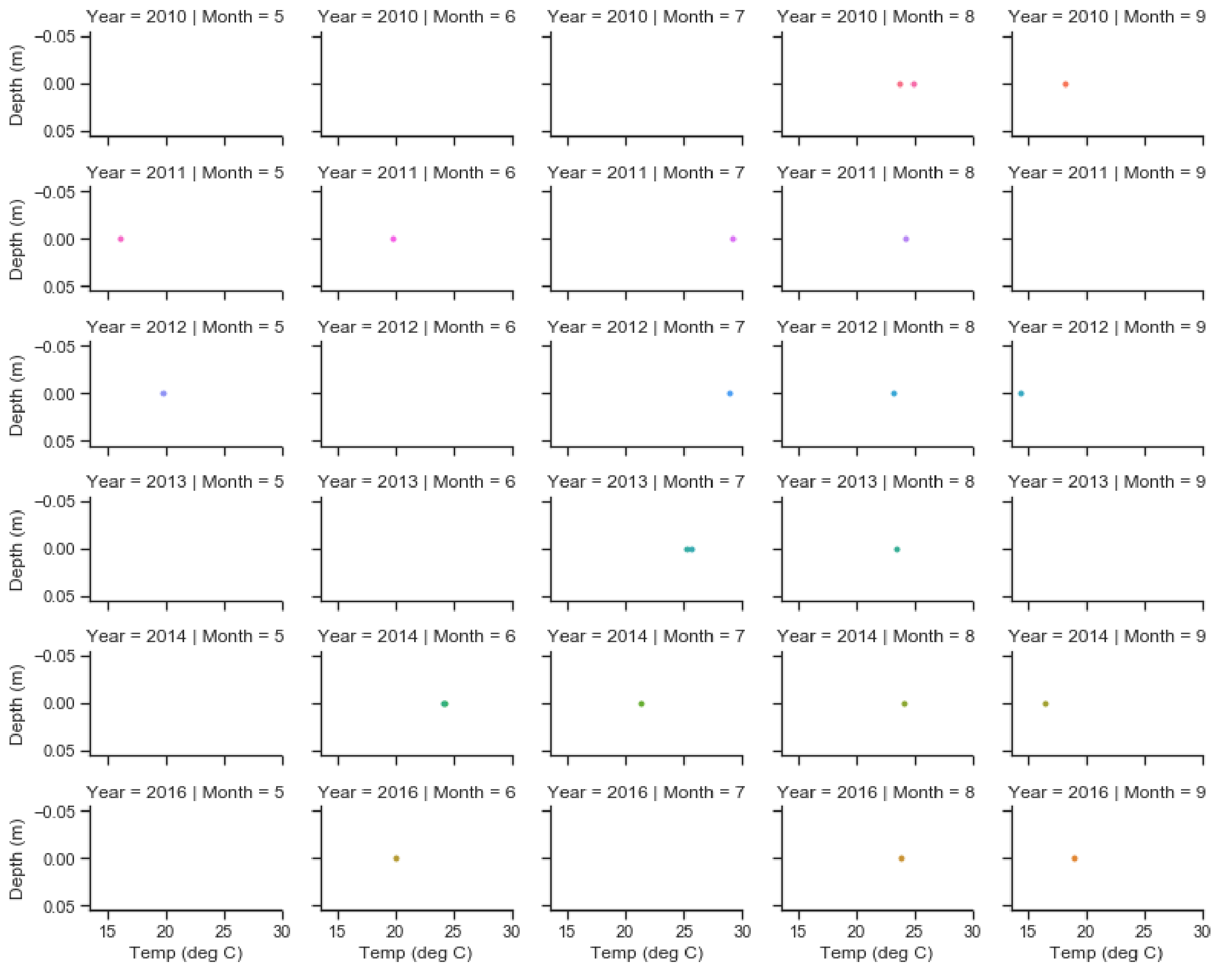


Figure K-9. Sebie Lake Profiles for Temperature at Site 201

Aquatic Plants

A qualitative survey of aquatic plants in Sebie Lake was performed on June 21, 1995, by the DNR. This survey found 13 species of submersed plants, 3 species of free-floating plants, 6 species of floating-leaf plants, 6 species of emergent plants, and 12 species of shoreland (wetland) plants. The exotic invasive species curly-leaf pondweed (*Potamogeton Crispus*) was found around much of the shoreline during the 2007 fish survey. Lakeshore owners with a DNR issued permit have been applying chemicals to control the plant.

Fisheries

The DNR Fisheries surveyed Sebie Lake on July 9, 2007. The northern pike population was moderate. Black crappie were present in very good numbers, bluegill abundance was moderate. The survey noted the presence of black bullhead and common carp at CPUE rates towards the low end of the normal ranges. Black bullhead and common carp can stir up bottom sediments and increase P contributions to a lake.

Appendix L: Trace (77-0009-00)

Land Cover

Land cover defined by the University of Minnesota [2016] is summarized for the Trace Watershed in Table L-1 with the majority of the land cover consisting of open water (30.6%), row crops (29.2%), wetlands (14.6%), and developed land (11.3%).

Table L-1. Trace Watershed Land Cover.

Impairment	Developed (%)	Wetlands (%)	Open Water (%)	Forest (%)	Grassland (%)	Hay/ Pastures (%)	Row Crops (%)
Trace	11.3	14.6	30.6	1.9	5.6	6.8	29.2

Physical Characteristics

Trace Lake is located on the northwest side of the town of Grey Eagle, Minnesota, in Todd County in the southern portion of the Mississippi-Brainerd HUC-8. From a regulatory standpoint, Trace Lake is categorized as a shallow NCHF ecoregion lake. Select lake morphometric and watershed physical characteristics are listed in Table L-2. Trace Lake has one public access maintained by the City of Grey Eagle that includes parking for approximately four boat trailers. Figure L-1 shows aerial imagery of Trace Lake. One lake level reading at Trace Lake, of 1,207.91 feet (ft), was recorded on May 4, 2006.

Table L-2. Select Lake and Watershed Physical Characteristics for Trace Lake.

Characteristic	Trace	Source
Lake Surface Area (acres)	253.4	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	256	DNR LakeFinder Fish Lake Surveys
Shore Length (miles)	2.8	DNR LakeFinder Fish Lake Surveys
Mean Depth (ft)	4.4(b)	DNR LakeFinder Fish Lake Surveys (a), Calculated (b), or Estimated from Lake Map (c)
Maximum Depth (ft)	6	DNR LakeFinder Fish Lake Surveys
Average Water Clarity (ft)	2.6(b)	DNR LakeFinder Fish Lake Surveys (a) or Average Growing Season Secchi Disk Depth (b)
Recorded Water Level Range (ft)	0	DNR LakeFinder Water Level
Percent Lake Littoral Surface Area	100.0	Calculated
Number of Islands	0	DNR LakeFinder Map
Public Access Sites	1	DNR LakeFinder Water Access Sites
Drainage Area, Including Lake (acres)	819	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	3.2	Calculated, Large in Bold
Wetland Area (acres)	74.9	MN Wetlands Layer
Number of Upland Lakes	0	USGS Topographic Maps
Number of Perennial Inlet Streams	1	NHD Flowlines Fcode 46006
Lake Volume (acre-feet)	1,121.7	Calculated
Maximum Fetch Length (ft)	5,424	Measured Using ArcGIS Imagery
Lake Geometry Ratio (A^0.25/Dmax), A is surface area in m2 and Dmax is max depth in m	17.4	Calculated (Shallow>5.3, Medium1.6-5.3, Deep<0.9)
Lake Geometry Classification	Shallow	
Osgood Index (Dmean/sqrt(A)), A is surface area in km^2 and Dmean is mean depth in m	1.3	Calculated (Polymictic<4, Intermediate4-9,Dimictic>9)
Osgood Index Category	Polymictic	
Estimated Water Residence Time (years/days)	969	HSPF Model Application
Shore Land Properties		Imagery

Figure L-1. Trace Lake Bathymetry and Aerial Imagery

Water Quality

Monitoring-data annual sample counts are shown in Table L-3. Table L-4 summarizes them as mean-growing season values for TP, Chl-*a*, and Secchi transparency (Secchi) over the TMDL period (2006 through 2015). Data collected in 2016 are also shown but were not included for monthly or overall averaging unless no other data were available. Corresponding lake water quality standards are also included. Mean values for TP and Chl-*a* are above the water quality standard. Similarly, the mean SDD did not meet the water quality standard. These data indicate that Trace Lake exceeds the P standard and will require reductions to achieve lake standards. Extreme high values of TP and Chl-*a* were 137 µg/L and 97.5 µg/L, respectively, while the lowest Secchi reading was 0.5 meters (m). Individual growing season means from data available between 1990 and 2016 are plotted in Figures L-2 to L-4, and show that the water quality standards were not met in most years when data was available.

Table L-3. Growing Season TP, Chl-a, and Secchi Transparency Number of Samples Annually.

Lake	Constituent	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[(a)]	Total
Trace	TP	16		4								4	20
	Chl-*a*	16		4								4	20
	Secchi	16		4								3	20

(a) 2016 Data not included in total or overall growing season means unless no other data were available

Table L-4. TP, Chl-a, and Secchi Transparency Growing Season Means (2006-2015).

Parameter	Minimum	Mean	Maximum	Standard Deviation	Lake Standards
TP (µg/L)	37.0	83.6	137.0	32.1	≤60
Chl-*a* (µg/L)	2.1	48.5	97.5	32.5	≤20
Secchi disk depth (m)	0.5	0.8	1.7	0.4	≥1

Multiyear growing season mean monthly water quality observations are summarized in Figures L-5 through L-7 for data available from 2006 through 2015. Plots of this mean monthly data indicate a general decline in water quality from June through August, with a slight improvement in September. Error bars in the annual and monthly P and Secchi plots indicate standard error.

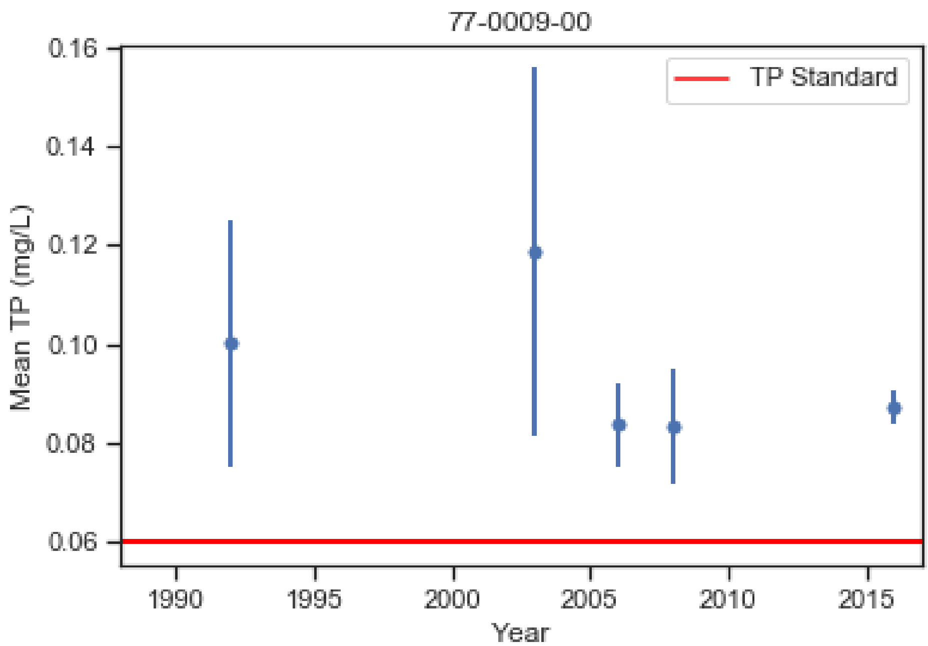


Figure L-2. Trace Lake Annual Growing Season Mean TP Concentrations

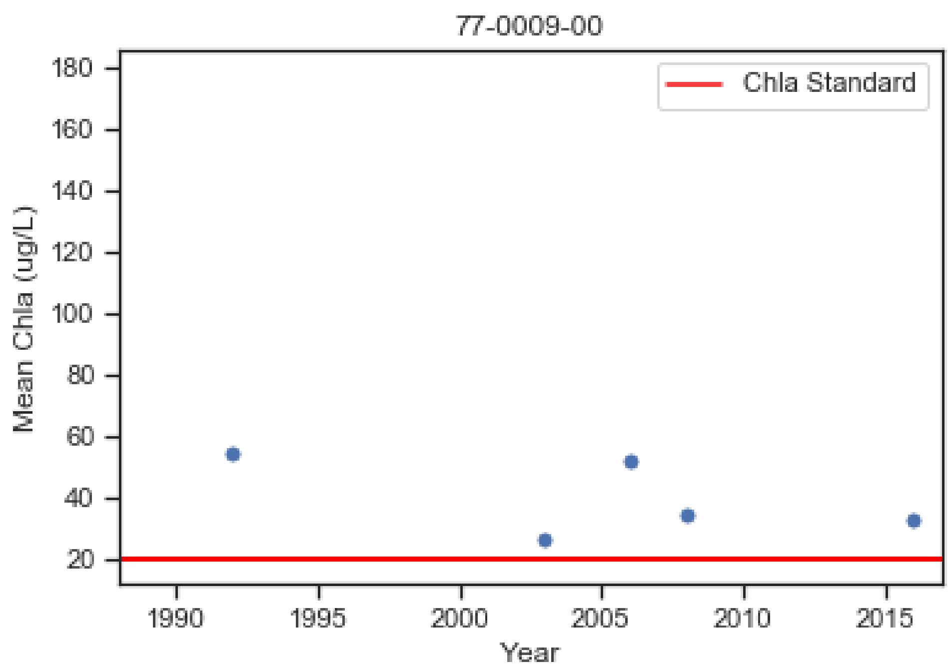


Figure L-3. Trace Lake Annual Growing Season Mean Chl-*a* Concentrations

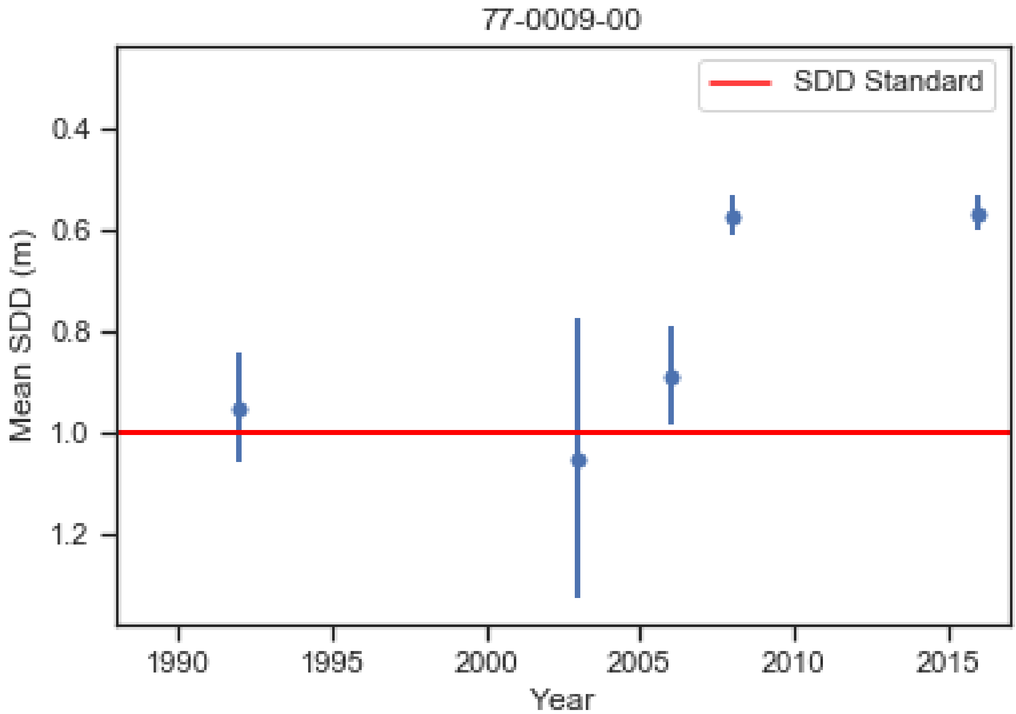


Figure L-4. Trace Lake Annual Growing Season Mean Secchi Transparency

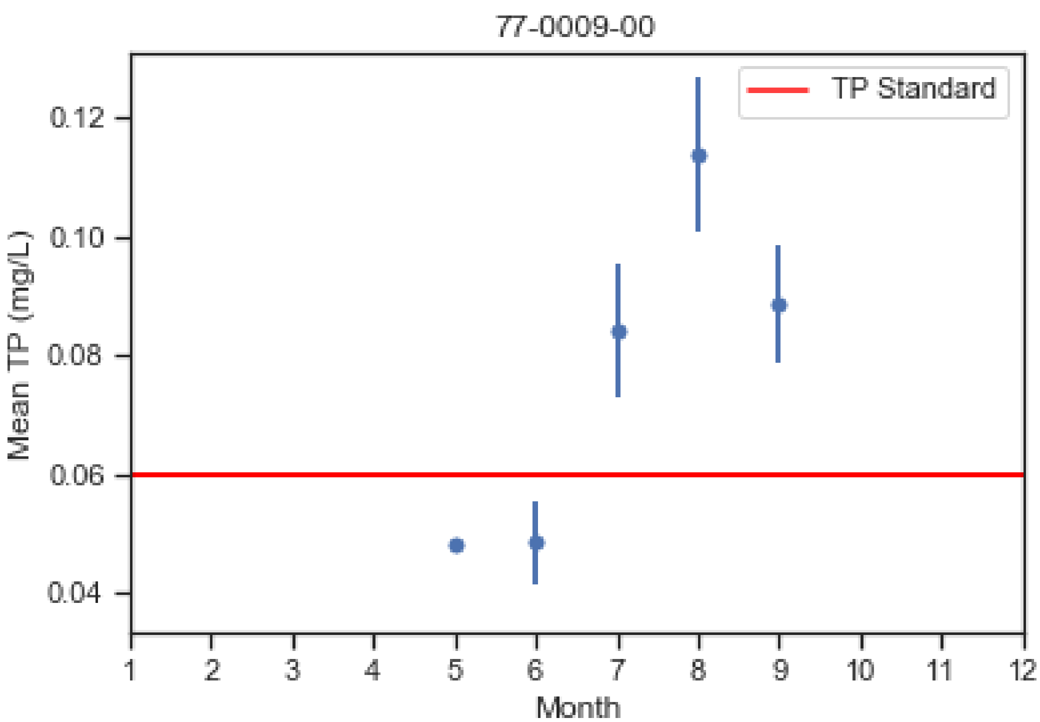


Figure L-5. Trace Lake Growing Season Monthly Mean TP (All Available Data Between 2006 and 2015)

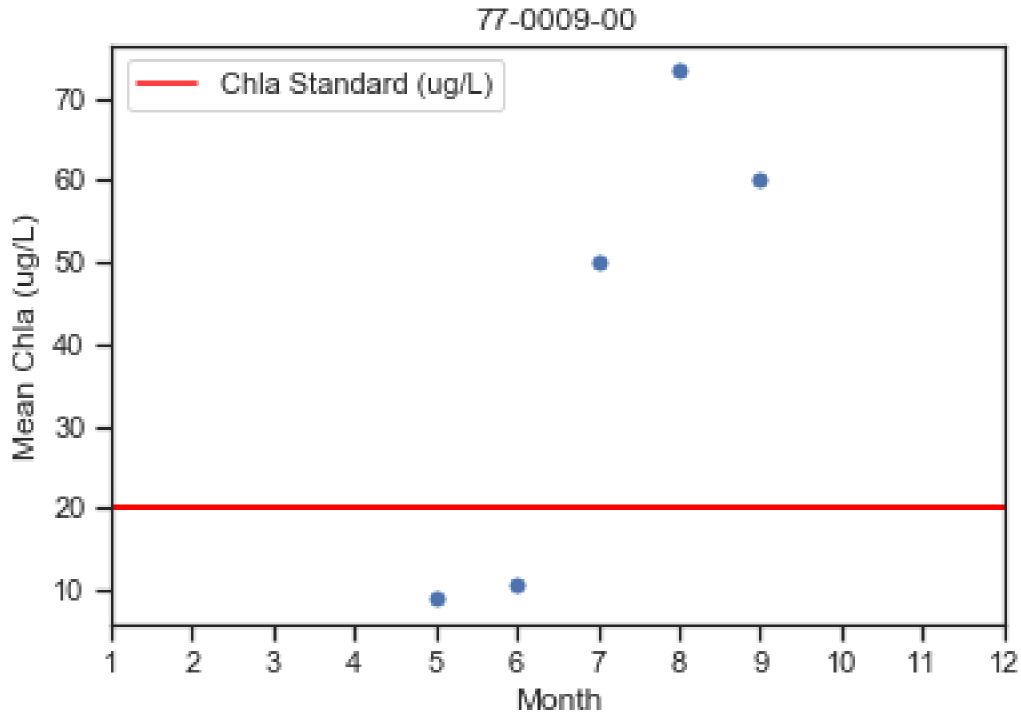


Figure L-6. Trace Lake Growing Season Monthly Mean Chl-*a* (All Available Data Between 2006 and 2015)

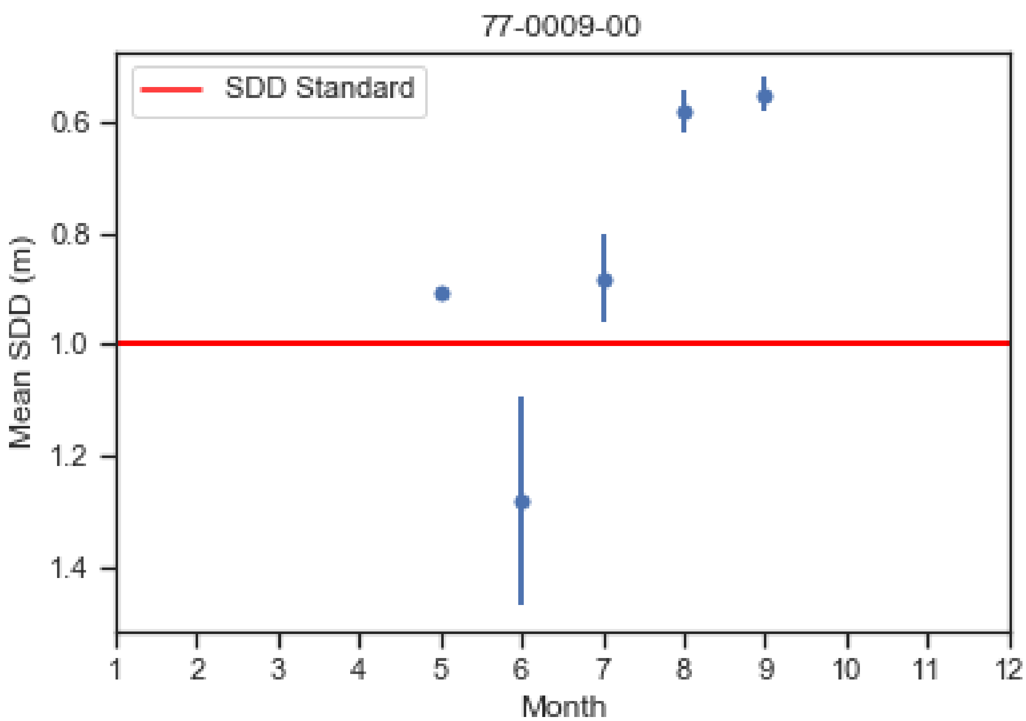


Figure L-7. Trace Lake Monthly Growing Season Mean Secchi Transparency (All Available Data Between 2006 and 2015)

Dissolved Oxygen and Temperature Summary

DO and temperature data, monitored by depth, were examined in an effort to better define lake-mixing patterns affecting biological responses and lake P dynamics. Available data from all sites from 2006 through 2016 are plotted in Figures L-8 through L-9 for temperature and DO. Water temperature profiles indicate well-mixed conditions at site 201, with temperatures relatively similar from surface to depth. DO profiles indicate only slight concentration loss, with depth further indicating this shallow lake is well-mixed.

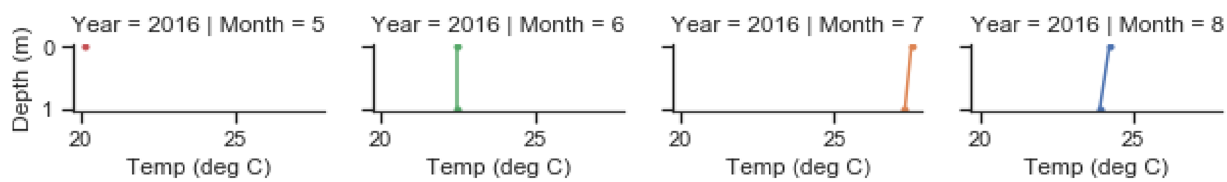


Figure L-8. Trace Lake Profiles for Temperature at Site 201

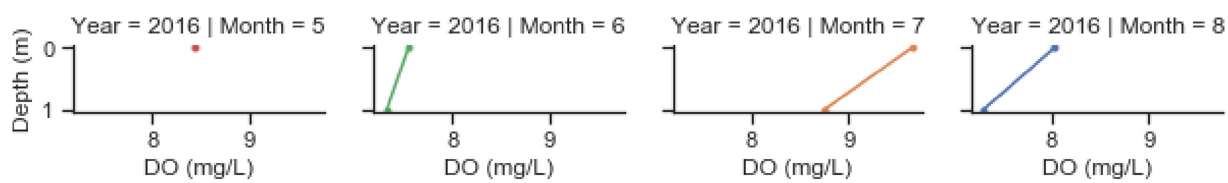


Figure L-9. Trace Lake Profiles for DO at Site 201

Aquatic Plants

A qualitative survey of aquatic plants in Trace Lake was performed on July 13, 2004, by the DNR. This survey found six species of submersed plants, three species of free-floating plants, no species of floating-leaf plants, three species of emergent plants, and three species of shoreland (wetland) plants. The exotic invasive species curly-leaf pondweed (*Potamogeton Crispus*) was not present.

Fisheries

The DNR Fisheries surveyed Trace Lake on June 10, 1986. The survey showed low rates of carp, fathead minnow, white sucker, black bullhead, yellow bullhead, brown bullhead, hybrid sunfish, and pumpkinseed. Green sunfish catches were well above average during the survey. Black bullhead and common carp can stir up bottom sediments and increase P contributions to a lake.

Appendix M: Lake Data Summary

Table M-1. Lake Data Summary.

Lake	BATHTUB Models Employed		
	Phosphorus	Chlorophyll-*a*	Secchi
Big Swan	3	2	1
Crow Wing	3	2	1
Elm Island	7	2	1
Fawn	4	2	1
Fleming	4	2	1
Gun	3	2	1
Lower Mission	8	2	1
Moose	8	2	1
Ripple	4	2	1
Sebie	4	2	1
Trace	8	5	1

Phosphorus Model 8: Canfield and Bachmann Lakes

Phosphorus Model 7: Settling Velocity

Phosphorus Model 4: Canfield and Bachmann, Reservoir

Phosphorus Model 3: 2nd Order Fixed

Chlorophyll-a Model 5: Jones and Bachman

Chlorophyll-a Model 2: P, Light, Turbidity

Secchi Model 1: Chlorophyll-a and Turbidity

Appendix N: BATHTUB Input and Model Summary

This appendix includes the text files that correspond to the calibrated BATHTUB models for existing conditions and for proposed conditions. A text editor can be used to save the text from this appendix as two separate .btb files, which can then be read by BATHTUB.

Big Swan Existing

Vers 6.14f (04/28/2015)
Big Swan
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
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3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
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3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
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5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
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12,"FLUSHING EFFECT",1,0
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1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0

Big Swan Proposed

2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Vers 6.14f (04/28/2015)
Big Swan
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.73,.05
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",3
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
2,"Segments"
1,"South Pool",2,1,2.9,5.31,3.4,4.8,.12,0,0,.08,1.27,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",1.23,0
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",45.3,.1,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",25.14,.16,1.330743,0
1,"SECCHI M",2.49,.03,1.764165,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
2,"North Pool",0,1,.69,4.14,1.72,4,.12,0,.5,.08,.2,0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",1.23,0
2,"TOTAL N",0,0
2,"CONSERVATIVE SUB",0,0,1,0
2,"TOTAL P MG/M3",0,0,1,0
2,"TOTAL N MG/M3",0,0,1,0
2,"CHL-A MG/M3",0,0,1.25,0
2,"SECCHI M",2.68,0,1.886311,0
2,"ORGANIC N MG/M3",0,0,1,0
2,"TP-ORTHO-P MG/M3",0,0,1,0
2,"HOD-V MG/M3-DAY",0,0,1,0
2,"MOD-V MG/M3-DAY",0,0,1,0
7,"Tributaries"
1,"Big Swan Tributary 555",1,1,22.31,4.83,.1,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",83.6,.01
1,"TOTAL N",0,0
1,"ORTHO P",37.5,.02
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"Big Swan Tributary 561",1,1,3.31,.433,.28,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",60,.01
2,"TOTAL N",0,0
2,"ORTHO P",30,.02
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"South Pool Lakeshed",1,1,58.8528,12.375,.1,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",80,.01
3,"TOTAL N",0,0
3,"ORTHO P",37.5,.015
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
4,"SSTS South Pool",1,1,.01,.0009,.3,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",1,.3
4,"TOTAL N",0,0
4,"ORTHO P",1,.3
4,"INORGANIC N",0,0
4,"LandUses",0,0,0,0,0,0,0,0
5,"Outlet",1,4,90.1,17.46,.12,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",14.07,.06
5,"TOTAL N",0,0
5,"ORTHO P",2.33,.04
5,"INORGANIC N",0,0

5,"LandUses",0,0,0,0,0,0,0,0
6,"SSTS North Pool",2,1,.01,.0002,.3,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",1,.3
6,"TOTAL N",0,0
6,"ORTHO P",1,.3
6,"INORGANIC N",0,0
6,"LandUses",0,0,0,0,0,0,0,0
7,"North Pool Lakeshed",2,1,1.3761,.2782467,.1,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",80,.01
7,"TOTAL N",0,0
7,"ORTHO P",37.5,.015
7,"INORGANIC N",0,0
7,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Crow Wing Existing

Vers 6.14f (04/28/2015)
Crow Wing
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.77,.04
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.5
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",3
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2

9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main
Pool",0,1,1.53,3.35,2.3,3.3,.12,.0528,.5,.08,1.23,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",.335,0
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",37.74,.12,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",22.35,.17,1.178752,0
1,"SECCHI M",1.62,.04,1.034775,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
3,"Tributaries"
1,"Lakeshed",1,1,42.27,9.682,.1,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",87.9,.03
1,"TOTAL N",0,0
1,"ORTHO P",64.2,.37
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"SSTS",1,1,.01,.0025,.3,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",10000,.3
2,"TOTAL N",0,0
2,"ORTHO P",10000,.3
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"Outlet",1,4,43.8,9.54,.11,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",12.55,.06
3,"TOTAL N",0,0
3,"ORTHO P",2.22,.04
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0

6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Crow Wing Proposed

Vers 6.14f (04/28/2015)
Crow Wing
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.77,.04
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.5
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",3
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main
Pool",0,1,1.53,3.35,2.3,3.3,.12,.0528,.5,.08,1.23,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",.3098,0
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",37.74,.12,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",22.35,.17,1.178752,0
1,"SECCHI M",1.62,.04,1.034775,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
3,"Tributaries"
1,"Lakeshed",1,1,42.27,9.682,.1,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",45,.03
1,"TOTAL N",0,0
1,"ORTHO P",22.5,.37
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"SSTS",1,1,.01,.0025,.3,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",1,.3
2,"TOTAL N",0,0
2,"ORTHO P",1,.3
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0

3,"Outlet",1,4,43.8,9.54,.11,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",12.55,.06
3,"TOTAL N",0,0
3,"ORTHO P",2.22,.04
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Elm Island Existing

Vers 6.14f (04/28/2015)
Elm Island
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.75,.05
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",7
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1

6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main
Pool",0,1,2.1,2.74,2.33,2.7,.12,.0432,.5,.08,1.67,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",1.174,0
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",59.13,.06,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",32.81,.16,1.139716,0
1,"SECCHI M",1.15,.03,1,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
4,"Tributaries"
1,"Elm Island Tributary 101",1,1,230.78,38.76,.15,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",38.16,.027
1,"TOTAL N",0,0
1,"ORTHO P",11.84,.056
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"Lakeshed",1,1,16.89,3.327,.12,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",56.7,.03
2,"TOTAL N",0,0
2,"ORTHO P",34.7,.046
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"SSTS",1,1,.01,.0007,.3,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",10000,.3
3,"TOTAL N",0,0
3,"ORTHO P",10000,.3
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
4,"Outlet",1,4,249.75,41.9,.15,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",30.74,.03
4,"TOTAL N",0,0
4,"ORTHO P",1.99,.06
4,"INORGANIC N",0,0
4,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
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5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
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6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
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6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0

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7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

End of BATHTUB file – do not include this line in the .btb file. The “Notes” line near the end of the .btb file should be Line 465, and 11 empty lines should follow Line 465 (466–476) at the end of the file. Tests showed that removing these lines from the .btb file resulted in an “Input File Error” from BATHTUB

Elm Island Proposed

Vers 6.14f (04/28/2015)
Elm Island
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.75,.05
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",7
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main
Pool",0,1,2.1,2.74,2.33,2.7,.12,.0432,.5,.08,1.67,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",.12,0
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",59.13,.06,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",32.81,.16,1.139716,0
1,"SECCHI M",1.15,.03,1,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
4,"Tributaries"
1,"Elm Island Tributary 101",1,1,230.78,38.76,.15,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",23.148,.027
1,"TOTAL N",0,0
1,"ORTHO P",13.5,.056
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"Lakeshed",1,1,16.89,3.327,.12,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",35,.03
2,"TOTAL N",0,0
2,"ORTHO P",17.5,.046
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"SSTS",1,1,.01,.0007,.3,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",1,.3
3,"TOTAL N",0,0
3,"ORTHO P",1,.3
3,"INORGANIC N",0,0

3,"LandUses",0,0,0,0,0,0,0,0
4,"Outlet",1,4,249.75,41.9,.15,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",30.74,.03
4,"TOTAL N",0,0
4,"ORTHO P",1.99,.06
4,"INORGANIC N",0,0
4,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
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2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
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5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
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5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
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7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

End of BATHTUB file – do not include this line in the .btb file. The "Notes" line near the end of the .btb file should be Line 465, and 11 empty lines should follow Line 465 (466–476) at the end of the file. Tests showed that removing these lines from the .btb file resulted in an "Input File Error" from BATHTUB

Fawn Existing

Vers 6.14f (04/28/2015)
Fawn
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.73,.05
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",4
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55

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4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main Pool",0,1,.49,3.05,.99,3.05,.12,0,.5,.33,.64,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",1.1178,.5
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",54.75,.09,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",42.55,.19,1.79867,0
1,"SECCHI M",.72,.04,1,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
3,"Tributaries"
1,"Lakeshed",1,1,9.68,2.399276,.1,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",65.16095,.02
1,"TOTAL N",0,0
1,"ORTHO P",42.0377,.033
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"SSTS",1,1,.01,.0008,.3,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",10000,.3
2,"TOTAL N",0,0
2,"ORTHO P",10000,.3
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"Outlet",1,4,10.17,2.4,.07,0
3,"CONSERVATIVE SUBST.",0,0
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3,"TOTAL N",0,0
3,"ORTHO P",43.62,.03
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
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2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
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3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
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3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
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4,"TOTAL N",0,0
4,"ORTHO P",0,0
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5,"Runoff",0,0
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5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
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6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
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7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
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7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

nd of BATHTUB file – do not include this line in the .btb file. The “Notes” line near the end of the .btb file should be Line 465, and 11 empty lines should follow Line 465 (466–476) at the end of the file. Tests showed that removing these lines from the .btb file resulted in an “Input File Error” from BATHTUB

Fawn Proposed

Vers 6.14f (04/28/2015)
Fawn
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.73,.05
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",4
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main Pool",0,1,.49,3.05,.99,3.05,.12,0,.5,.33,.64,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",.35,.5
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",54.75,.09,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",42.55,.19,1.79867,0
1,"SECCHI M",.72,.04,1,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
3,"Tributaries"
1,"Lakeshed",1,1,9.68,2.399276,.1,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",22.46,.02
1,"TOTAL N",0,0
1,"ORTHO P",25,.033
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"SSTS",1,1,.01,.0008,.3,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",1,.3
2,"TOTAL N",0,0
2,"ORTHO P",1,.3
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"Outlet",1,4,10.17,2.4,.07,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",67.44,.04
3,"TOTAL N",0,0
3,"ORTHO P",43.62,.03
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"

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1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
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2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
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4,"ORTHO P",0,0
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5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
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5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
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6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
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7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"
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End of BATHTUB file – do not include this line in the .btb file. The “Notes” line near the end of the .btb file should be Line 465, and 11 empty lines should follow Line 465 (466–476) at the end of the file. Tests showed that removing these lines from the .btb file resulted in an “Input File Error” from BATHTUB

Fleming Existing

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Vers 6.14f (04/28/2015)
Fleming
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.74,.048
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",4
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
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16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main_Pool",0,1,1.29,1.83,1.93,1.8,.12,0,.5,.08,1.32,0,0
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1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
3,"Tributaries"
1,"Fleming Lakeshed",1,1,17.45,3.512,.13,0
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1,"ORTHO P",77.7,.038
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
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2,"TOTAL N",0,0
2,"ORTHO P",10000,.3
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"Outlet",1,4,18.74,3.39,.15,0
3,"CONSERVATIVE SUBST.",0,0
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3,"TOTAL N",0,0
3,"ORTHO P",2.22,.07
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Fleming Proposed

```
Vers 6.14f (04/28/2015)
Fleming
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.74,.048
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",4
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main_Pool",0,1,1.29,1.83,1.93,1.8,.12,0,.5,.08,1.32,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",.03,.5
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",53,.08,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",33.24,.12,1.026382,0
1,"SECCHI M",1.12,.04,1.02032,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
3,"Tributaries"
1,"Fleming Lakeshed",1,1,17.45,3.512,.13,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",42.52,.03
1,"TOTAL N",0,0
1,"ORTHO P",21.26,.038
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"Fleming SSTS",1,1,.01,.0005,.3,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",1,.3
2,"TOTAL N",0,0
2,"ORTHO P",1,.3
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"Outlet",1,4,18.74,3.39,.15,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",22.11,.07
3,"TOTAL N",0,0
3,"ORTHO P",2.22,.07
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
```

3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Gun Existing

Vers 6.14f (04/28/2015)
Gun Lake
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.74,.05
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",3
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main Pool",0,1,2.88,5.49,3.39,4.9,.12,0,.5,.25,.14,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",.7,.5
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0

1,"TOTAL P MG/M3",29.78,.08,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",9.61,.11,.8331889,0
1,"SECCHI M",2.03,.05,1,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
4,"Tributaries"
1,"Gun Tributary 61",1,1,27.05,5.93,.12,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",99.27,.03
1,"TOTAL N",0,0
1,"ORTHO P",55.74,.04
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"Lakeshed",1,1,8.73,1.86,.12,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",129.1,.032
2,"TOTAL N",0,0
2,"ORTHO P",103,.039
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"SSTS",1,1,.01,.0006,.3,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",10000,.3
3,"TOTAL N",0,0
3,"ORTHO P",10000,.3
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
4,"Outlet",1,4,38.59,7.42,.14,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",12,.07
4,"TOTAL N",0,0
4,"ORTHO P",1.88,.04
4,"INORGANIC N",0,0
4,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
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8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Gun Proposed

Vers 6.14f (04/28/2015)
Gun Lake
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.74,.05
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",3
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main Pool",0,1,2.88,5.49,3.39,4.9,.12,0,.5,.25,.14,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",.7,.5
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",29.78,.08,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",9.61,.11,.8331889,0
1,"SECCHI M",2.03,.05,1,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
4,"Tributaries"
1,"Gun Tributary 61",1,1,27.05,5.93,.12,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",71.897,.03
1,"TOTAL N",0,0
1,"ORTHO P",37.5,.04
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"Lakeshed",1,1,8.73,1.86,.12,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",90,.032
2,"TOTAL N",0,0
2,"ORTHO P",45,.039
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"SSTS",1,1,.01,.0006,.3,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",1,.3
3,"TOTAL N",0,0
3,"ORTHO P",1,.3
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
4,"Outlet",1,4,38.59,7.42,.14,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",12,.07
4,"TOTAL N",0,0
4,"ORTHO P",1.88,.04
4,"INORGANIC N",0,0
4,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0

2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
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6,"TOTAL N",0,0
6,"ORTHO P",0,0
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7,"CONSERVATIVE SUBST.",0,0
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7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Lower Mission Existing

Vers 6.14f (04/28/2015)
Lower Mission
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.73,.05
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",8
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main Pool",0,1,2.96,3.51,3.43,3.5,.12,.01,.5,.08,1.34,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",.4025,.5

1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",46.5,.14,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",18.78,.22,.8360857,0
1,"SECCHI M",2.19,.06,1.203405,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
4,"Tributaries"
1,"Lower Mission Tributary 218",1,1,24.37,3.08,.16,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",24.5,.02
1,"TOTAL N",0,0
1,"ORTHO P",12.25,.03
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"Lakeshed",1,1,19.69,3.547,.11,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",95.2,.03
2,"TOTAL N",0,0
2,"ORTHO P",73.7,.036
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"SSTS",1,1,.01,.0015,.3,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",10000,.3
3,"TOTAL N",0,0
3,"ORTHO P",10000,.3
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
4,"Outlet",1,4,46.92,6.28,.15,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",8.74,.04
4,"TOTAL N",0,0
4,"ORTHO P",1.67,.03
4,"INORGANIC N",0,0
4,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Lower Mission Proposed

Vers 6.14f (04/28/2015)
Lower Mission
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.73,.05
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",8
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main Pool",0,1,2.96,3.51,3.43,3.5,.12,.01,.5,.08,1.34,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",.0986,.5
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",46.5,.14,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",18.78,.22,.8360857,0
1,"SECCHI M",2.19,.06,1.203405,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
4,"Tributaries"
1,"Lower Mission Tributary 218",1,1,24.37,3.08,.16,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",16.5,.02
1,"TOTAL N",0,0
1,"ORTHO P",8.25,.03
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"Lakeshed",1,1,19.69,3.547,.11,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",57,.03
2,"TOTAL N",0,0
2,"ORTHO P",28.5,.036
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"SSTS",1,1,.01,.0015,.3,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",1,.3
3,"TOTAL N",0,0
3,"ORTHO P",1,.3
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
4,"Outlet",1,4,46.92,6.28,.15,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",8.74,.04
4,"TOTAL N",0,0
4,"ORTHO P",1.67,.03
4,"INORGANIC N",0,0
4,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0

2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Moose Existing

Vers 6.14f (04/28/2015)
Moose
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.73,.05
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",8
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main Pool",0,1,.53,4.57,1.22,4.3,.12,0,0,.08,3.26,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",.2157,0

1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",49.33,.27,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",27.14,.38,1.272424,0
1,"SECCHI M",1.52,.06,1.15292,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
3,"Tributaries"
1,"Lakeshed",1,1,3.5,.86,.11,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",147.47,.01
1,"TOTAL N",0,0
1,"ORTHO P",116.51,.016
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"SSTS",1,1,.01,.0005,.3,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",10000,.3
2,"TOTAL N",0,0
2,"ORTHO P",10000,.3
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"Outlet",1,4,4.03,.86,.11,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",150.3,.07
3,"TOTAL N",0,0
3,"ORTHO P",118.5,.21
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Moose Proposed

Vers 6.14f (04/28/2015)

Moose

4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.73,.05
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",8
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main Pool",0,1,.53,4.57,1.22,4.3,.12,0,0,.08,3.26,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",.15,0
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",49.33,.27,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",27.14,.38,1.272424,0
1,"SECCHI M",1.52,.06,1.15292,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
3,"Tributaries"
1,"Lakeshed",1,1,3.5,.86,.11,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",87.4,.01
1,"TOTAL N",0,0
1,"ORTHO P",0,.016
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0,0
2,"SSTS",1,1,.01,.0005,.3,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",1,.3
2,"TOTAL N",0,0
2,"ORTHO P",1,.3
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0,0
3,"Outlet",1,4,4.03,.86,.11,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",150.3,.07
3,"TOTAL N",0,0
3,"ORTHO P",118.5,.21
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0

4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Ripple Existing

Vers 6.14f (04/28/2015)
Ripple
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.79,.05
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",4
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Ripple",0,1,2.55,4.08,2.63,3.9,.12,0,0,.11,.63,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",.921,.5
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",34.22,.05,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",19.98,.13,1.282549,0
1,"SECCHI M",1.63,.05,1,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
4,"Tributaries"
1,"Ripple Tributary 103",1,1,249.75,41.89,.15,0

1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",35.42,.02
1,"TOTAL N",0,0
1,"ORTHO P",2.27,.055
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"Lakeshed",1,1,16.71,3.324,.12,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",60.5,.03
2,"TOTAL N",0,0
2,"ORTHO P",38.6,.052
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"SSTS",1,1,.01,.0006,.3,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",10000,.3
3,"TOTAL N",0,0
3,"ORTHO P",10000,.3
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
4,"Outlet",1,4,268.75,45.02,.15,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",28.04,.03
4,"TOTAL N",0,0
4,"ORTHO P",1.84,.04
4,"INORGANIC N",0,0
4,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

End of BATHTUB file – do not include this line in the .btb file. The “Notes” line near the end of the .btb file should be Line 465, and 11 empty lines should follow Line 465 (466–476) at the end of the file. Tests showed that removing these lines from the .btb file resulted in an “Input File Error” from BATHTUB

Ripple Proposed

Vers 6.14f (04/28/2015)
Ripple
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.79,.05
3,"EVAPORATION (METERS)",.6,.05

4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",4
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Ripple",0,1,2.55,4.08,2.63,3.9,.12,0,0,.11,.63,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",.479,.5
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",34.22,.05,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",19.98,.13,1.282549,0
1,"SECCHI M",1.63,.05,1,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
4,"Tributaries"
1,"Ripple Tributary 103",1,1,249.75,41.89,.15,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",30,.02
1,"TOTAL N",0,0
1,"ORTHO P",15,.055
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"Lakeshed",1,1,16.71,3.324,.12,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",40,.03
2,"TOTAL N",0,0
2,"ORTHO P",20,.052
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"SSTS",1,1,.01,.0006,.3,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",1,.3
3,"TOTAL N",0,0
3,"ORTHO P",1,.3
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
4,"Outlet",1,4,268.75,45.02,.15,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",28.04,.03
4,"TOTAL N",0,0
4,"ORTHO P",1.84,.04
4,"INORGANIC N",0,0
4,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0

4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Sebie Existing

Vers 6.14f (04/28/2015)
Sebie
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.77,.04
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",4
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main Pool",0,1,.75,4.57,1.32,4.3,.12,0,0,.27,.23,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",42.57,.07,.7807753,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",17.5,.08,1.119372,0
1,"SECCHI M",1.42,.07,1,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0

5,"Tributaries"
1,"Sebie Tributary 433",1,1,12.21,2.77,.1,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",96.4,.022
1,"TOTAL N",0,0
1,"ORTHO P",51.91,.034
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"Sebie Tributary 435",1,1,20.35,4.62,.1,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",98.86,.28
2,"TOTAL N",0,0
2,"ORTHO P",52.95,.04
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"Lakeshed",1,1,76.44,10.058,.1,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",106,.03
3,"TOTAL N",0,0
3,"ORTHO P",78,.043
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
4,"SSTS",1,1,.01,.0005,.3,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",10000,.3
4,"TOTAL N",0,0
4,"ORTHO P",10000,.3
4,"INORGANIC N",0,0
4,"LandUses",0,0,0,0,0,0,0,0
5,"Outlet",1,4,77.19,17.44,.1,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",107.2,.03
5,"TOTAL N",0,0
5,"ORTHO P",58.9,.04
5,"INORGANIC N",0,0
5,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Sebie Proposed

Vers 6.14f (04/28/2015)
Sebie
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.77,.04
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",4
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",2
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main Pool",0,1,.75,4.57,1.32,4.3,.12,0,0,.27,.23,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",42.57,.07,.7807753,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",17.5,.08,1.119372,0
1,"SECCHI M",1.42,.07,1,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
5,"Tributaries"
1,"Sebie Tributary 433",1,1,12.21,2.77,.1,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",50,.022
1,"TOTAL N",0,0
1,"ORTHO P",25,.034
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"Sebie Tributary 435",1,1,20.35,4.62,.1,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",50,.28
2,"TOTAL N",0,0
2,"ORTHO P",25,.04
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"Lakeshed",1,1,76.44,10.058,.1,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",58.225,.03
3,"TOTAL N",0,0
3,"ORTHO P",25,.043
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
4,"SSTS",1,1,.01,.0005,.3,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",1,.3
4,"TOTAL N",0,0
4,"ORTHO P",1,.3
4,"INORGANIC N",0,0
4,"LandUses",0,0,0,0,0,0,0,0
5,"Outlet",1,4,77.19,17.44,.1,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",107.2,.03
5,"TOTAL N",0,0
5,"ORTHO P",58.9,.04
5,"INORGANIC N",0,0
5,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0

1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
5,"CONSERVATIVE SUBST.",0,0
5,"TOTAL P",0,0
5,"TOTAL N",0,0
5,"ORTHO P",0,0
5,"INORGANIC N",0,0
6,""
6,"Runoff",0,0
6,"CONSERVATIVE SUBST.",0,0
6,"TOTAL P",0,0
6,"TOTAL N",0,0
6,"ORTHO P",0,0
6,"INORGANIC N",0,0
7,""
7,"Runoff",0,0
7,"CONSERVATIVE SUBST.",0,0
7,"TOTAL P",0,0
7,"TOTAL N",0,0
7,"ORTHO P",0,0
7,"INORGANIC N",0,0
8,""
8,"Runoff",0,0
8,"CONSERVATIVE SUBST.",0,0
8,"TOTAL P",0,0
8,"TOTAL N",0,0
8,"ORTHO P",0,0
8,"INORGANIC N",0,0
"Notes"

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Trace Existing

Vers 6.14f (04/28/2015)
Trace
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.73,.05
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",8
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",5
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
1,"CONSERVATIVE SUBST.",0,0

2,"TOTAL P",26.8,.5
3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
1,"Segments"
1,"Main Pool",0,1,1.03,1.34,1.65,1.3,.12,0,.5,.08,2.74,0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",.1815,.5
1,"TOTAL N",0,0
1,"CONSERVATIVE SUB",0,0,1,0
1,"TOTAL P MG/M3",83.6,.09,1,0
1,"TOTAL N MG/M3",0,0,1,0
1,"CHL-A MG/M3",48.53,.15,.9356734,0
1,"SECCHI M",.82,.1,1.060465,0
1,"ORGANIC N MG/M3",0,0,1,0
1,"TP-ORTHO-P MG/M3",0,0,1,0
1,"HOD-V MG/M3-DAY",0,0,1,0
1,"MOD-V MG/M3-DAY",0,0,1,0
4,"Tributaries"
1,"Lakeshed",1,1,2.29,.666,.13,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",144.7,.11
1,"TOTAL N",0,0
1,"ORTHO P",116.6,.099
1,"INORGANIC N",0,0
1,"LandUses",0,0,0,0,0,0,0,0
2,"SSTS",1,1,.01,.0002,.3,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",10000,.3
2,"TOTAL N",0,0
2,"ORTHO P",10000,.3
2,"INORGANIC N",0,0
2,"LandUses",0,0,0,0,0,0,0,0
3,"Outlet",1,4,3.31,.52,.19,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",42.91,.06
3,"TOTAL N",0,0
3,"ORTHO P",1.95,.03
3,"INORGANIC N",0,0
3,"LandUses",0,0,0,0,0,0,0,0
4,"Grey Eagle WWTP",1,3,.01,.131,.5,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",780.31,.5
4,"TOTAL N",0,0
4,"ORTHO P",528.78,.5
4,"INORGANIC N",0,0
4,"LandUses",0,0,0,0,0,0,0,0
0,"Channels"
8,"Land Use Export Categories"
1,"landuse1"
1,"Runoff",0,0
1,"CONSERVATIVE SUBST.",0,0
1,"TOTAL P",0,0
1,"TOTAL N",0,0
1,"ORTHO P",0,0
1,"INORGANIC N",0,0
2,"landuse2"
2,"Runoff",0,0
2,"CONSERVATIVE SUBST.",0,0
2,"TOTAL P",0,0
2,"TOTAL N",0,0
2,"ORTHO P",0,0
2,"INORGANIC N",0,0
3,"landuse3"
3,"Runoff",0,0
3,"CONSERVATIVE SUBST.",0,0
3,"TOTAL P",0,0
3,"TOTAL N",0,0
3,"ORTHO P",0,0
3,"INORGANIC N",0,0
4,"landuse4"
4,"Runoff",0,0
4,"CONSERVATIVE SUBST.",0,0
4,"TOTAL P",0,0
4,"TOTAL N",0,0
4,"ORTHO P",0,0
4,"INORGANIC N",0,0
5,""
5,"Runoff",0,0
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8,"INORGANIC N",0,0
"Notes"

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Trace Proposed

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Vers 6.14f (04/28/2015)
Trace
4,"Global Parmameters"
1,"AVERAGING PERIOD (YRS)",1,0
2,"PRECIPITATION (METERS)",.73,.05
3,"EVAPORATION (METERS)",.6,.05
4,"INCREASE IN STORAGE (METERS)",0,.05
12,"Model Options"
1,"CONSERVATIVE SUBSTANCE",0
2,"PHOSPHORUS BALANCE",8
3,"NITROGEN BALANCE",0
4,"CHLOROPHYLL-A",5
5,"SECCHI DEPTH",1
6,"DISPERSION",1
7,"PHOSPHORUS CALIBRATION",2
8,"NITROGEN CALIBRATION",2
9,"ERROR ANALYSIS",1
10,"AVAILABILITY FACTORS",0
11,"MASS-BALANCE TABLES",1
12,"OUTPUT DESTINATION",2
17,"Model Coefficients"
1,"DISPERSION RATE",1,.7
2,"P DECAY RATE",1,.45
3,"N DECAY RATE",1,.55
4,"CHL-A MODEL",1,.26
5,"SECCHI MODEL",1,.1
6,"ORGANIC N MODEL",1,.12
7,"TP-OP MODEL",1,.15
8,"HODV MODEL",1,.15
9,"MODV MODEL",1,.22
10,"BETA M2/MG",.025,0
11,"MINIMUM QS",.1,0
12,"FLUSHING EFFECT",1,0
13,"CHLOROPHYLL-A CV",.62,0
14,"Avail Factor - TP",.33,0
15,"Avail Factor - Ortho P",1.93,0
16,"Avail Factor - TN",.59,0
17,"Avail Factor - Inorganic N",.79,0
5,"Atmospheric Loads"
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3,"TOTAL N",1000,.5
4,"ORTHO P",13.4,.5
5,"INORGANIC N",500,.5
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1,"Main Pool",0,1,1.03,1.34,1.65,1.3,.12,0,.5,.08,2.74,0,0
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1,"TOTAL N MG/M3",0,0,1,0
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1,"MOD-V MG/M3-DAY",0,0,1,0
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8,"ORTHO P",0,0
8,"INORGANIC N",0,0
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