Elk River Watershed Association

Phase I
TMDL Report

Elk River Bacteria and Turbidity TMDL

Big Elk Lake and Mayhew Lake Nutrient TMDLs

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Table of Contents

Table of Contents (cont.)

TABLES

Table of Contents (cont.)

Table of Contents (cont.)

FIGURES

Acronyms

Agency	Minnesota Pollution Control Agency
BMPs	Best Management Practices
CAFO	Confined Animal Feeding Operation
Carlson TSI	Carlson Trophic Status Index
CFR	Code of Federal Regulations
cfs	cubic feet per second
CFU/100 mL	colony forming units per 100 milliliters
CWA	Clear Water Act
DMR	Discharge Monitoring Report
DNR	Minnesota Department of Natural Resources
DO	Dissolved oxygen
EDA	Electronic Data Access
EPA	Environmental Protection Agency
ERWSA	Elk River Watershed Association
Lbs	Pounds
µg/L	micrograms per liter
mg/L	milligrams per liter
mi^2	square miles
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
NCHF	North Central Hardwood Forest
NO_2/ NO_3-N	Nitrate/ Nitrite- Nitrogen
NPS	non-point source
NTU	nephelometric turbidity unit
QA	Quality Assurance
QC	Quality Control
STORET	EPA's "STOrage and RETrevial" System
SWCD	Soil and Water Conservation District
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total phosphorus
TSS	Total Suspended Solids
USGS	United States Geological Survey
WASP	Water Quality Analysis Simulation Program
WWTP	Wastewater Treatment Plant
USDA	United States Department of Agriculture

1.0 Executive Summary

Section 303(d) of the Clean Water Act requires that the states publish a list of waters that do not meet water quality standards every two years; the water bodies on the list are considered to be “impaired”. Once a water body is placed on the list a Total Maximum Daily Load (TMDL) must be completed. The TMDL provides a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards. The TMDL is the sum of the point sources or wasteload allocations (WLAs), the non-point sources or load allocations and a margin of safety (MOS).

The Minnesota Pollution Control Agency (MPCA) listed Mayhew Lake and Big Elk Lake as impaired for Excess Nutrients (phosphorus) and Elk River reach 579 as impaired for fecal coliform bacteria (now *E. coli*) and turbidity. The impaired water bodies addressed in this TMDL are within the Elk River Watershed. All three water bodies are addressed in this study because: 1) they are all located within the Elk River Watershed and 2) the turbidity impairment in the Elk River is likely driven by algae resulting from nutrient impairments in the headwaters lakes (Big Elk Lake); thus, nutrient loading analysis proposed for the lake nutrient TMDLs will assist in quantifying the portion of the turbidity impairment due to algae.

The entire Elk River Watershed is located northwest of the Twin Cities metropolitan area in the NCHF ecoregion and is a major tributary to the Upper Mississippi River. The full drainage area of the Elk River consists of approximately 392,320 acres (613 square miles) of Sherburne County, Benton County, Mille Lacs County, and Morrison County. However; the majority of the Elk River Watershed lies within Benton and Sherburne Counties. Land use in the northern portion of the watershed is primarily agricultural and feedlot density is high. The southern portion of the watershed is mainly comprised of irrigated agriculture and urban/residential developments.

The bulk of this TMDL Phase I report summarizes the 2008 watershed reconnaissance and risk assessment survey, identifies TMDL modeling strategies and lays out the 2009 monitoring plan.

The watershed reconnaissance and risk assessment surveys were done to determine the risk of nutrient and sediment transport in the watershed as well as to identify the type and spatial extent of nutrient and sediment sources from channel erosion and mass wasting. The risk assessment results identify the area of the watershed above Big Elk Lake as having the highest nutrient and sediment delivery potential. The watershed reconnaissance survey findings suggested that there does not appear to be erosion from the first, second or third order streams.

The reconnaissance confirmed that algal turbidity from Big Elk Lake is driving the turbidity impairment in the listed reach of the Elk River. As a result of the close linkage between the individual impairments, the modeling strategy recommended to quantify the algal portion of the turbidity load to the Elk River and Big Elk Lake is the Water Quality Analysis Simulation Program (WASP). A suite of tools including BATHTUB and FLUX will be used to model Mayhew Lake. The tools will focus on analyzing the internal and external loads as well as the lake response to the loads for Mayhew Lake.

Finally, the 2009 monitoring plan described in this report identifies the monitoring locations, schedule and parameters to be analyzed. The monitoring plan identifies major tributary and lake sampling points and locations as well as tributary monitoring locations. A total of 20 monitoring stations are identified and will be analyzed for a suite of parameters including TSS, TP, OP, TKN, iron, turbidity, Chl-a, *E.Coli*, NO2+NO3 in addition to a number of field parameters. Additionally, in-stream sources of turbidity along the main stem of the Elk River will be quantified at eight locations.

2.0 Introduction/ Problem Statement

Water quality evaluations conducted by the State of Minnesota have determined that Mayhew Lake, Big Elk Lake, and reach 579 of the Elk River exceed State established Standards as described below in table 1.0. This TMDL Phase I report applies to the aforementioned surface waters.

The Clean Water Act Requires the State to develop TMDLs for impaired waters. A TMDL is the amount of pollutant that a water body can assimilate without exceeding the pollutant's water quality standard.

Table 2.0. Impaired waters in the Elk River Watershed.

Water Body	HUC	DNR Lake ID # or stream reach #	Listing Year	Affected Use	Pollutant or Stressor	Target Start Date	Target Completion Date
Mayhew Lake	07010203	05-0007-00	2008	Aquatic Recreation	Excessive nutrients	2008	2011
Big Elk Lake	07010203	71-0141-00	2008	Aquatic Recreation	Excessive nutrients	2010	2014
Elk River	07010203	579	2006 & 2008 respectively	Aquatic Life and Aquatic Recreation	Turbidity and pathogens (fecal coliform)	2008	2016

The impairments listed above were based on water quality monitoring conducted by Sherburne Soil and Water Conservation District (SWCD), Benton SWCD, the Minnesota Pollution Control Agency (MPCA), the Briggs Lake Chain Association and the MPCA Citizen Lake and Stream Monitoring Program (CLMP & CSMP) over the last ten years. The most previous ten year data is used to determine whether or not a water body is impaired. Water analysis in all cases was conducted by a laboratory that is certified by the Minnesota Department of Health Laboratory.

This TMDL study addresses four 303d impairments on three water bodies including: bacteria and turbidity impairments on the Elk River between Big Elk Lake and the St. Francis River and nutrient impairments in Mayhew Lake and Big Elk Lake. The purpose of this report is to summarize existing data for each waterbody, identify data gaps in the existing data sets; develop a modeling strategy to address the impairment(s) and develop a monitoring plan to collect the additional data required to fill the identified data gaps and complete the TMDL study for each impaired water.

3.0 Applicable Water Quality Standards

This TMDL addresses exceedances of the State standard for excess nutrients (phosphorus), *E. coli* (previously fecal coliform bacteria) and turbidity of the identified water bodies within the Elk River Watershed located in Central Minnesota within the North Central Hardwoods Forest ecoregion (NCHF). Discussion is provided below in order to define the regulatory context and environmental endpoints for the TMDLs.

Minnesota R. Ch. 7050 identifies the beneficial uses for which surface waters are protected. The impaired waters identified in this report are categorized as Class 2 recreational waters. Class 2 waters are further categorized into subclasses. As such, the waters identified here are considered Class 2B which refers to those State waters that are identified to support aquatic life (warm and cool water fisheries and are not protected for drinking water) and recreation (swimming). The rules are as follows for class 2B surface waters which are addressed in this report:

Excess Nutrients

Nutrient standards for lakes address increases in nutrients and algae also known as the "eutrophication process". Phosphorus is typically the limiting nutrient for aquatic plant and algal growth; while it is an essential nutrient, it is considered a pollutant when it stimulates excessive growth of aquatic plants or algae.

The MPCA has established numerical thresholds based on ecoregions for determination of Minnesota lakes as either impaired or unimpaired. The protected beneficial use for all lakes is aquatic recreation. Table 3.0 outlines the MPCA water quality goals that were used to determine that Mayhew and Big Elk Lake should be placed on the 303 (d) list of impaired waters in Minnesota. New water quality standards became effective in the State rules (Minnesota Water Quality Rule Ch 7050) on March 17th, 2008 and were subsequently approved by US Environmental Protection Agency (EPA) on May 23rd, 2008 (table 3.1). The newly approved standards for nutrients are based on ecoregion and water depth. The changes to the standards also include two indicators of eutrophication that measure lake response to excess phosphorus. The new goals will be used in determining the endpoint goals for both Mayhew Lake and Big Elk Lake. For more information on the MPCA's water quality goals, go to the MPCA website at: http://www.pca.state.mn.us/water/standards/index.html

Table 3.0. MPCA goals for protecting swimming use used to list Big Elk Lake and Mayhew Lake (North Central Hardwood Forests Ecoregion) (MPCA 2007).

Impairment Designation	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
Full Use	**<40**	**<15**	**≥ 1.6**
Review	**40-45**	**N/A**	**N/A**
Impaired	**>45**	**>18**	**<1.1**

Table 3.1 New MPCA goals and standards for protecting Class 2B waters. Values are summer averages (June 1 through September 30) (MPCA 2008).

Ecoregion	TP (µg/L)	Chl-a (µg/L)	Secchi (m)	Applicable Lake Goals
CHF- Aquatic Rec. Use (class 2b) Deep Lakes	**<40**	**<14**	**>2.5**	**Mayhew Lake**
CHF- Aquatic Rec. Use (Class 2b) Shallow lakes[1]	**<60**	**<20**	**>1.0**	**Big Elk Lake**

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

Determining appropriate goals and endpoints for lakes is an essential part of the TMDL process. In this case, Mayhew Lake, according to the MPCA definition, is considered a deep lake and is located in the (NCHF) ecoregion. Therefore, the NCHF ecoregion deep lake standard of 40 µg/L will be set as the goal for Mayhew Lake. Big Elk Lake, on the other hand, is considered a shallow lake and is located in the NCHF ecoregion; as such, the NCHF ecoregion shallow lake standard of 60 µg/L will be set as the goal.

E. coli

High levels of bacteria in water from human or animal fecal material can cause illness in humans if ingested. Bacteriological standards for surface waters are designed to protect swimmers from getting sick if they consume small quantities of water.

At the time when Elk River reach 579 was listed on the impaired waters list, The Minnesota standard for class 2B waters was based on fecal coliform bacteria as follows:

Minn. R. Ch. 7050.0222 Subp. 4 and 5, fecal coliform water quality standard for class 2B and 2C waters states that fecal coliforms shall not exceed 200 organisms per 100 milliliters as a geometric mean of not less than five samples in any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 2,000 organisms per 100 milliliters. The standard applies only between April 1 and October 31.

New water quality standards for bacteria impairments became effective in Minnesota (Water Quality Rule Ch 7050) on March 17th, 2008 and were subsequently approved by US Environmental Protection Agency (EPA) on May 23rd, 2008. The new water quality standards for bacteria replace fecal Coliform bacteria with Escherichia Coli (*E. coli*). Through the process a relationship was built between fecal coliform and *E. coli* levels. The new *E. coli* based standards are shown below with the fecal coliform standard included for comparison.

Table 3.2. 2008 *E. coli* standards shown with the current fecal coliform standard for class 2B waters (MPCA 2008).

Use	Water Type	30-Day Geometric Mean cfu/100 ml		10% of Values not to Exceed cfu/100 ml	
		E. coli	fecal coliform	*E. coli*	fecal coliform
Primary Body Contact (swimming)	Class 2B waters	126	200	1260	2000

All bacterial data collected in Elk River reach 579 prior to 2009 was analyzed for fecal coliform. This data will be converted to the equivalent *E. coli* amount at the ratio of 200 to 126 for TMDL development purposes. All subsequent data will be analyzed for *E. coli.*

Endpoint *E. coli* concentrations must meet the 2008 State water quality standard of a monthly geometric mean of 126 cfu/100 ml and no value exceeding 1,260 cfu/ 100ml for the period of April 1 though October 31.

Turbidity

Turbidity refers to how clear the water is; it is caused by the suspension of sediment, organic matter or algae in the water making it appear green or brown. Too much turbidity limits the beneficial uses of streams in Elk River reach 579 including aquatic life recreation; additionally turbidity in source water areas can increase the cost of treatment for drinking water. Turbidity exceedances in reach 579 appear to be caused by extreme algae blooms.

The standard and goal for turbidity in Class 2B waters is 25 nephelometric turbidity units (NTU). Transparency and TSS values reliably predict turbidity and can serve as surrogates at sites where there are an inadequate number of turbidity observations. For transparency, a transparency tube measurement of less than 20 centimeters indicates a violation of the 25 NTU turbidity standard. For TSS, a measurement of more than 100mg/L in the NCHF ecoregion indicates a violation. For a water body to be listed for turbidity, at least 3 observations and 10% of observations must be in violation of the turbidity standard.

Endpoint turbidity measurements must meet the turbidity standard for Class 2B waters, 25 NTUs.

4.0 Background Information

4.1 GENERAL WATERSHED CHARACTERISTICS

The entire Elk River Watershed is located northwest of the Twin Cities metropolitan area in the NCHF ecoregion and is a major tributary to the Upper Mississippi River. The full drainage area of the Elk River consists of approximately 392,320 acres (613 square miles) of Sherburne County, Benton County, Mille Lacs County, and Morrison County. However; the majority of the Elk River Watershed lies within Benton and Sherburne Counties. The Elk River headwaters are located in northern Benton County, and the river extends south eastward towards the City of Elk River were it outlets into the Mississippi River. The Elk River has a gradient of approximately three feet per mile.

In 1994 a Joint Powers Board, the Elk River Watershed Association was formed as a result of Local Water Planning efforts in Sherburne and Benton Counties. Concerned citizens identified the water quality of the Elk River and lakes in the Elk River Watershed as priorities for improvement. Thus, the two Counties determined that a watershed approach would be the most effective way to improve water quality. A Joint Powers Board was formed by Sherburne and Benton SWCDs and Counties for the purpose of coordinating efforts within the Elk River Watershed.

The total population in the watershed is estimated to be 152,400 based on US Census in 2000. Sherburne County has shown a 54 percent increase in population since 1990 and Benton County has shown a 13 percent increase.

Land use in the northern portion of the watershed is primarily agricultural and feedlot density is high. The high percentage of agricultural land use in riparian areas leads to an extremely high potential to introduce large amounts of phosphorus, sediment, and bacteria to surface waters. Furthermore, the numerous small to medium sized feedlots and riparian pastures offer additional opportunities for manure to enter surface water directly. To this point, the southern portion of the watershed is mainly comprised of irrigated agriculture and urban/residential developments. With the exception of Mayhew Lake, all of the lakes greater than 10 acres are located within Sherburne County. The lake shore property in the watershed tends to be densely populated. Much of this development occurred prior to the adoption of shore land ordinances. Subsequently, many lots are as small as 50 feet in width and most natural vegetation has been removed from the shorelines and replaced with turf grass. Septic systems provide waste water treatment for these areas.

Land use within the Elk River watershed will be influenced over the coming year by its close proximity to two major employment centers; the St. Cloud Metropolitan Area and the “Twin Cities” of Minneapolis and St. Paul. Sherburne County is served by two major transportation corridors, US TH 10 and US TH 101/169, which provide for convenient connections to careers and leisure activities in the major metropolitan area. To this point, most of the growing demand for building permit requests in both the cities and the townships is taking place within the southern portions of the watershed, within Sherburne County.

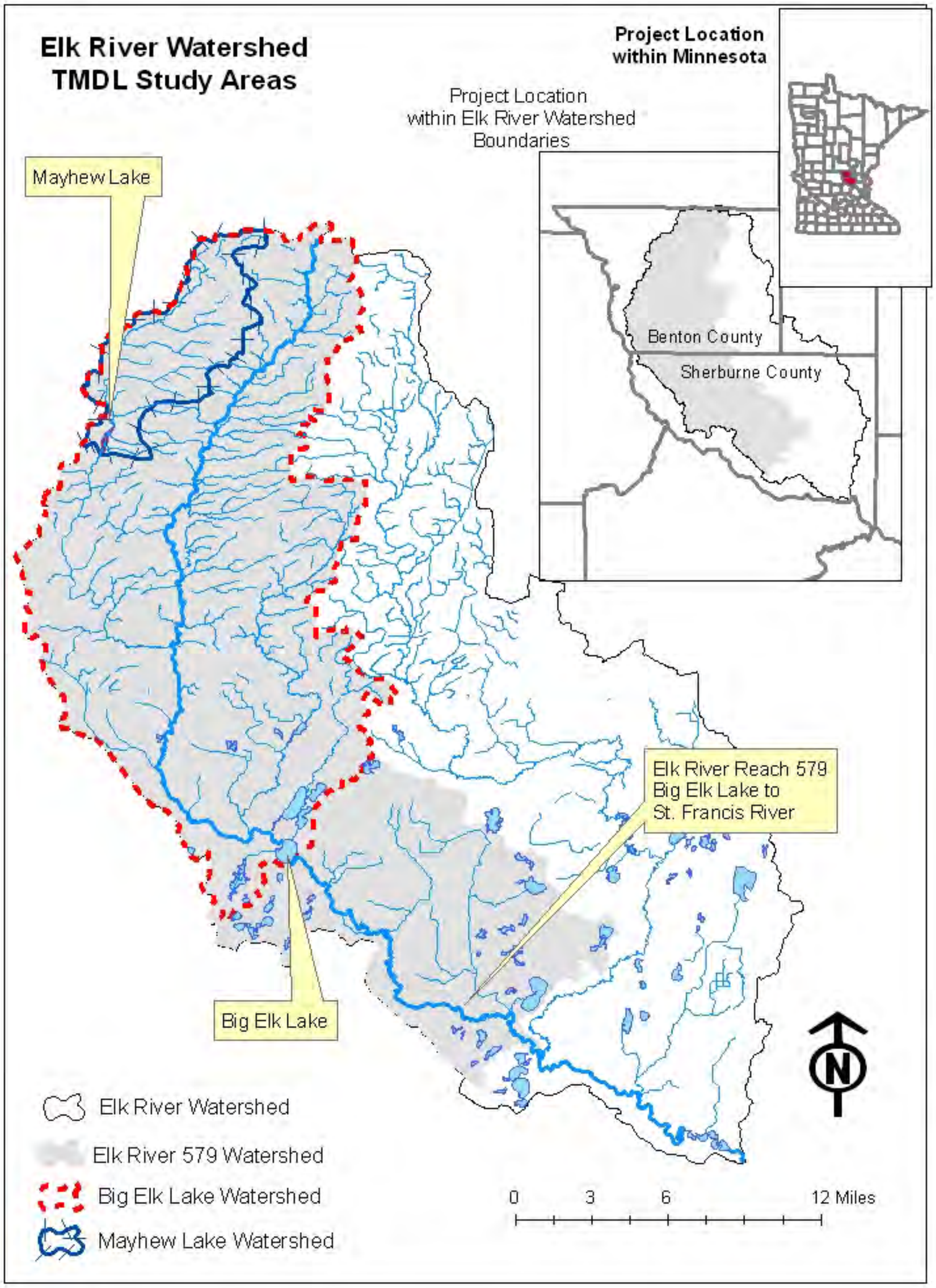
The Elk River offers recreational opportunities for canoeists, anglers, hunters and non-game wildlife viewers close to the Minneapolis- St. Paul Metropolitan area. The Department of Natural Resources (DNR) has identified twenty five potential canoe accesses along the river and there are several lakes with public boat accesses.

In addition to the three water bodies evaluated in this TMDL, there are several other impaired water bodies located within the Elk River Watershed (Table 4.0). TMDLs applying to the waters not covered here will be addressed as funding becomes available.

Table 4.0. Impaired waters located within the Elk River watershed. These impairments are not addressed in this TMDL.

Water Body	**DNR Lake ID or Stream Reach #**	**Year Listed**	**Impairment**	**Target Start Date**	**Target Finish Date**
Julia Lake	71-145	2008	Excess Nutrients (Phosphorus)	2010	2014
Rush Lake	71-147	2008	Excess Nutrients (Phosphorus)	2010	2014
Briggs Lake	71-146	2008	Excess Nutrients (Phosphorus)	2010	2014
Rice Creek	07010203-512	2006	Dissolved oxygen and turbidity	2014	2021
Elk River	07010203-579	2006	aquatic macro invertebrate bioassessments	2008	2016
Rice Creek	07010203-512	2006	Dissolved oxygen, turbidity	2014	1021
Battle Brook	07010203-535	2006	aquatic macro invertebrate bioassessments	2016	2021
Lake Orono	71-013	2008	Excess Nutrients (Phosphorus)	2010	2013
Mayhew Creek	07010203-509	2002	fish and aquatic macro invertebrate bioassessments	2009	2017

Figure 4.0. Elk River Watershed and location of TMDL watersheds.



4.1.1 Subwatersheds

The waters addressed in this TMDL are located within subwatersheds of the Elk River Watershed as depicted above in figure 4.0 and described below.

Elk River reach 579 subwatershed: This reach of the river begins at the outlet of Big Elk Lake and flows generally southeast to its confluence with the St. Francis River just north of the City of Big Lake. The length of the impaired reach is approximately 15 miles. The subwatershed area consists of the entire upper Elk River watershed and extends to the confluence of the St. Francis River. To that point, the drainage area is quite large totaling 214,633 acres (335 square miles).

Mayhew Lake subwatershed: Mayhew Lake has a rather large subwatershed of 17,469 acres (excluding the lake). The large watershed increases the potential to deliver large nutrient loads to the lake. Mayhew Creek flows into the lake from the north and flows out at the south end.

Big Elk Lake subwatershed: The Elk River enters Big Elk Lake on the northwest side and outlets on the southeast. The Briggs Chain of lakes, consisting of Lake Julia, Briggs and Rush Lake, flow into the lake from the northeast via Lilly Creek. Accordingly, the watershed area is very large, consisting of 154,381 acres (241 square miles). The huge watershed which drains to the lake (Elk River and Lilly Creek) contributes to its poor water quality.

The impaired watersheds have been subdivided into 23 minor subwatersheds based on tributary drainage as delineated by the MN DNR. Minor subwatershed size ranges from 3,338 to 36,536 acres. The minor subwatershed boundaries will allow us to identify areas were pollutant loading is the greatest. The ERWSA will then be able to prioritize the minor subwatersheds to focus implementation activities.

4.1.2 Land Use

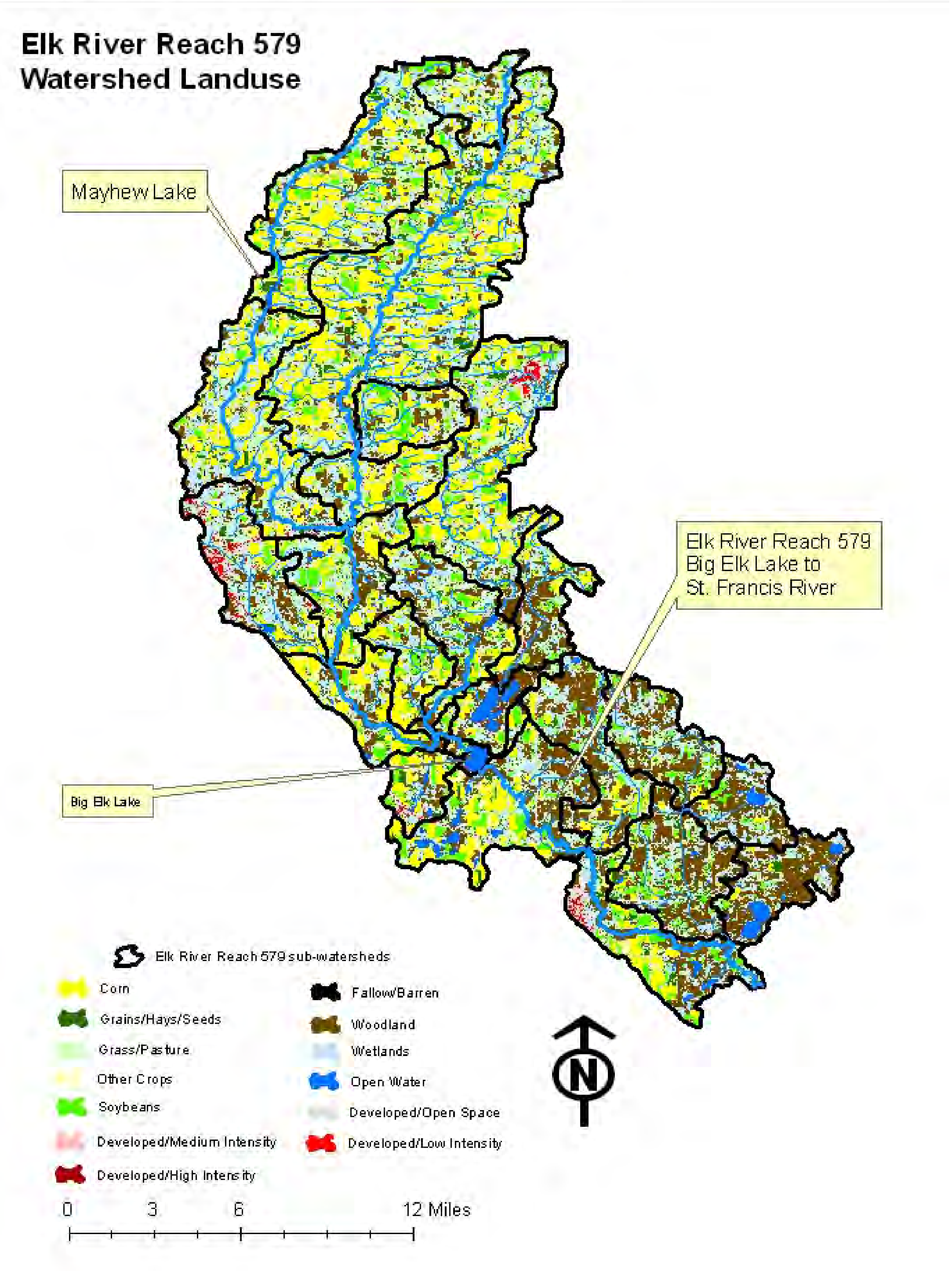
2007 land use data specific to the Elk River reach 579 watershed, including Big Elk and Mayhew Lake, are presented in Table 4.1 and figure 2.1. Agricultural land makes up 45.5 percent of the watershed, urban and rural development makes up approximately 1.0 percent and open space comprises 51.8 percent. Open space is comprised of wetlands, woodland and open space. The remaining land is surface water.

Table 4.1. 2007 Land use within the three TMDL watersheds (USDA 2007 Minnesota Cropland Data Layer).

Land Use	Acres Reach 579	Percentage	Acres Mayhew Lake Watershed*	Percentage	Acres Big Elk Lake Watershed*	Percentage
Corn	48,107	22.4	4,868	27.7	41,995	27.2
Grains/Hays/Seeds	7,486	3.5	875	5.0	5,647	3.7
Grass/Pasture	21,975	10.2	2,287	13.0	16,425	10.6
Soybeans	19,026	8.9	1,831	10.4	13,769	8.9
Other Crops	1,055	0.5	4	0.0	597	0.4
Woodland	49,129	22.9	2,306	13.1	25,475	16.5
Wetlands	45,786	21.3	3,885	22.1	34,261	22.2
Open Water	3,575	1.7	121	0.7	1,842	1.2
Fallow/Barren	280	0.1	6	0.0	233	0.2
Developed/High Intensity	311	0.1	1	0.0	257	0.2
Developed/Medium Intensity	529	0.3	1	0.0	367	0.2
Developed/Low Intensity	1,396	0.7	14	0.7	1,078	0.7
Open Space	15,985	7.4	1,347	7.7	12,398	8.0
Total	**214,639**	**100%**	**17,548**	**100%**	**154,345**	**100%**

*land use calculated independently of Reach 579. Both Mayhew and Big Elk Lake are within Reach 579.

Figure 4.1. Land use in the Elk River 579, Mayhew Lake and Big Elk Lake watersheds.



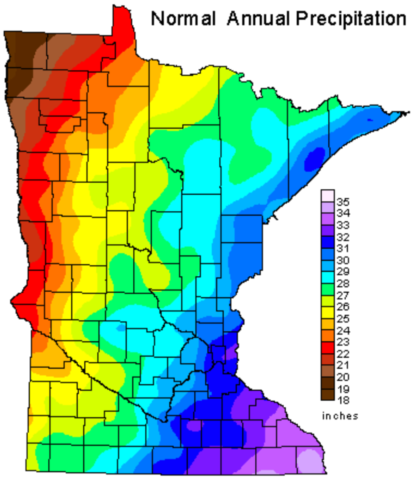
4.1.3 Topography and Soils

Deposits left by retreating glaciers formed the topography and soils of the watershed. The topography and soils of the watershed can be divided into two general areas including glacial till and glacial outwash. Glacial tills associated with moraines and drumlin fields comprise the upper portion of the watershed. Soils are predominantly loamy in this area. On this landscape, soil infiltration rates are low and runoff tends to rapidly concentrate in low areas where intermittent streams carry runoff to main channels. These soils are susceptible to water erosion. The lower part of the watershed consists of sandy outwash, lacustrine sands and sand and gravel deposits associated with river terrace. Upland soils in this portion of the watershed are predominantly coarse textured and have a high infiltration rate. Because of the gently sloping topography and well-drained sandy soils, this part of the watershed is not as susceptible to erosion from water. Wind erosion, however, is a common problem. Because of the rapid movement of water through these soils the shallow ground water is susceptible to pollution from surface sources. Wetlands and lakes occupy low areas throughout the watershed. A wetland is an area that has mostly wet soil, is saturated with water above or just below the surface and is covered with plants that are associated with wet conditions. Wetlands are characterized by soils with high organic content.

4.1.4 Climate and Meteorological Data

Precipitation varies across the Elk River Watershed reach 579 due to the large area it covers. Normal precipitation varies from 27 inches in Sherburne County to 30 inches in Benton County. Average annual precipitation recorded at the St. Cloud Municipal airport (middle of the watershed) is 27.13 inches annually with an average annual snowfall of 47.96 inches (State Climatology Office- Department of Natural Resources 2000). The area has an average growing season length of 152 days (temperature above 32 degrees Fahrenheit).

Figure 4.2. Map showing normal annual precipitation for Minnesota. *(Minnesota State Climatology Office).*



State Climatology Office - DNR Waters
July 2003

Table 4.2 shows the variation in the average annual precipitation by County over the last five years. The average precipitation shown is the average of all rain gauge stations in the Counties. Additional climatological data are summarized below in table 4.3.

Table 4.2. Average annual precipitation (hydrological year: Begins in October) for both counties.

	Sherburne County Average Annual Precipitation (inches)	**Benton County Average Annual Precipitation (inches)**
2007	26.13	21.79
2006	30.97	30.39
2005	31.34	30.59
2004	31.34	27.28
2003	28.97	26.56

Table 4.3. Average annual Temperature (Fahrenheit), Precipitation (inches), and snowfall (inches) from the St. Cloud Municipal Airport (1971-2000).

Month	Average Temp. °F	Ave. Precipitation in.	Ave. Snowfall in.
Jan	8.8	0.76	10.1
Feb	16.1	0.59	7.2
Mar	28.4	1.50	8.5
Apr	43.6	2.13	2.9
May	56.6	2.97	0.2
Jun	65.1	4.51	0.0
Jul	69.8	3.34	0.0
Aug	67.2	3.93	0.0
Sep	57.4	2.93	0.0
Oct	45.3	2.24	0.0
Nov	28.8	1.54	9.1
Dec	14.4	0.69	8.6
Annual	41.8	27.13	47.2

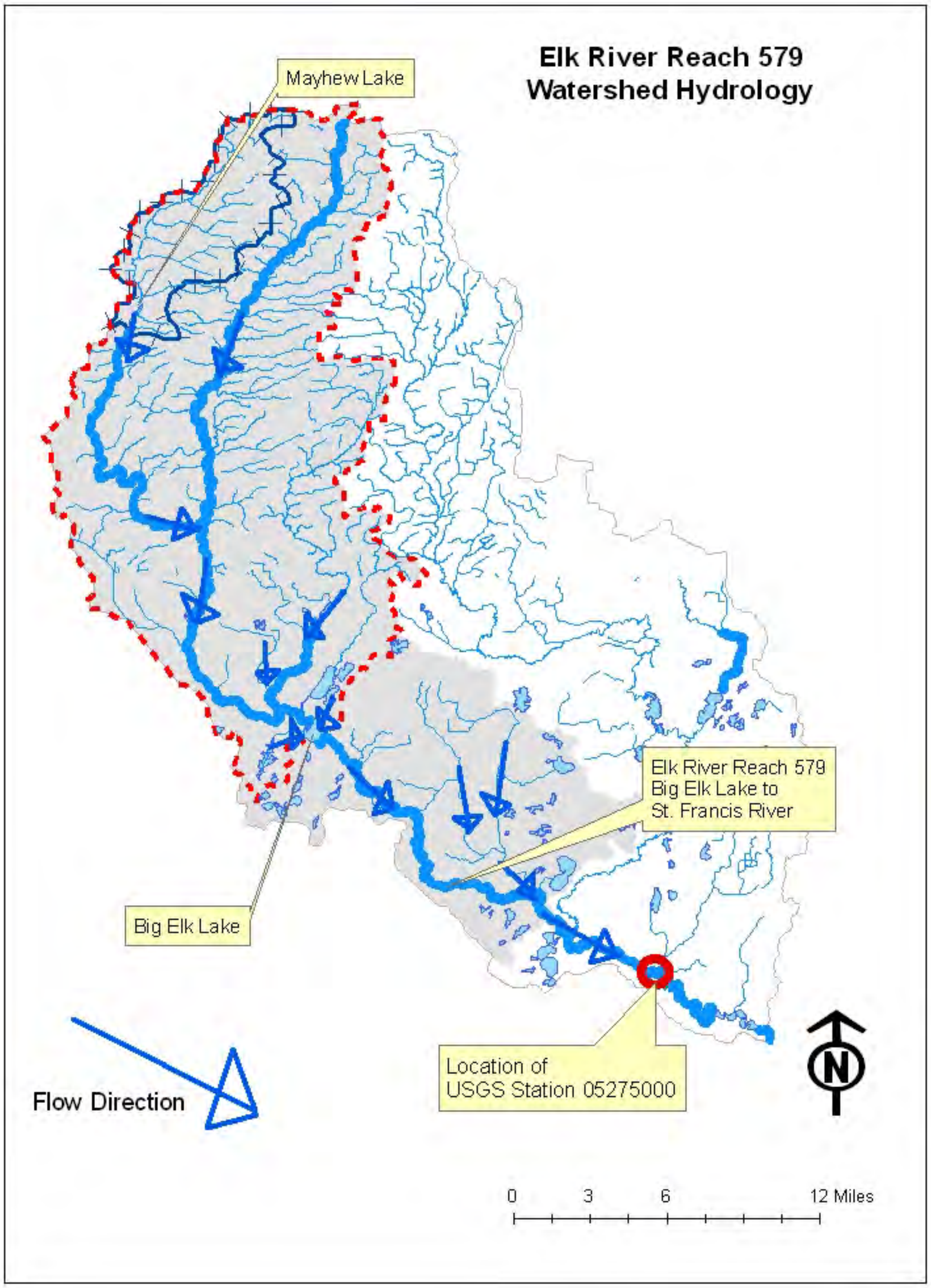
4.1.5 Hydrology

Average daily discharge has been monitored and reported at the USGS station 05275000 located in Big Lake at CSAH 15 (approximately 5 miles below Elk River Reach 579) periodically since 1911 and yearly since 1990. Monthly average flows since 1911 at the USGS station range from 112 cubic feet per second (cfs) in January to 661cfs in April. The maximum average daily flow at the USGS stations was 7,170 cfs on April 16, 1965. The lowest average daily flow was recorded on August 1st, 1934 was 4.0 cfs. The average annual runoff estimated from 1911-2007 is 6.72 inches. The average annual runoff over the last two years (2006 and 2007) was 5.6 and 4.6 respectively (USGS Water Data Report 2007).

Additional flow sites are identified in this report and will be used to develop a local rating curve.

Figure 4.3 displays the basic hydrology of surface water in the watershed and the location of the USGS station. Water also enters the system through groundwater and precipitation runoff from the surrounding watershed.

Figure 4.3. Surface water flow in Elk River reach 579 watershed.


Elk River Reach 579
Watershed Hydrology
Mayhew Lake
Big Elk Lake
Elk River Reach 579
Big Elk Lake to
St. Francis River
Location of
USGS Station 05275000
Flow Direction
N
0
3
6
12 Miles

4.2 ASSESSMENTS OF POINT AND NON-POINT SOURCES

A key component to developing a TMDL is to understand the sources contributing to the impairment. This section provides a brief description of the potential phosphorus sources in the watershed.

4.2.1 Point Source Discharges

Turbidity, *E. coli* bacteria (fecal coliform), and excess nutrients can originate from a wide range of sources including industrial wastewater discharge, municipal wastewater treatment plant effluent, runoff from roads and parking lots, construction activities and concentrated animal feeding operations (CAFOs). The following is an inventory of the MPCA permitted sources in the TMDL watersheds.

Facilities with NPDES Permits

Evaluation of point sources in the MPCA's Environmental Data Access (EDA) website showed four National Pollutant Discharge Elimination System (NPDES) permitted Wastewater Treatment Facilities (WWTFs) are located within the impaired reach of the Elk River. NPDES permit holders discharging to the impaired reach of the Elk River are listed below.

Table 4.4. List of NPDES permitted WWTFs in the study area.

NPDES Permit Holder Name	NPDES Permit Number	Population[1] Served	MPCA Limits	Watershed Location
Foley WWTF	MN0023451-SD-1, -2, -3	2624	FC, TSS	ER 579, BEL
Gilman WWTF	MN6580021-SD-2	228	FC, TSS	ER 579, BEL
Becker WWTF	MN0025666-SD-1	4105	P,TSS	ER 579
Eagle View Commons WWTF	MN0063983	102[2]	N/A	ER 579, BEL

FC= fecal coliform; TSS= total suspended solids; P= phosphorus

ER 579= Elk River reach 579 watershed; BEL= Big Elk Lake watershed; MAY= Mayhew Lake watershed

1 League of MN Cities 2008

2 40 homes are served by the system, calculated according to 2000 census average persons per household for Benton County.

Foley WWTF is a class D facility consisting of two main lift stations and two stabilization ponds (Birch Pond and Golf Pond). Birch pond has a controlled discharge (SD001) which discharges to a marsh into Stony Brook. Stony Brook becomes Rice Creek prior to it's confluence with the

Elk River. The pond has a detention time of 180 days at designed flow and treats up to 161,000 gallons per day (gpd). According to the MPCA permit, SD001 cannot discharge flow in the months of January through March, July and August. This discharge point must meet a fecal coliform limit of 200 colony forming units (cfu) per 100 ml limit as a calendar month geometric average and a total suspended solids (TSS) limit of 45 mg/L as a calendar month average. No phosphorus limit is required although phosphorus concentrations are recorded on the facilities discharge monitoring reports (DMR).

The second stabilization pond, Golf Pond, also has a controlled discharge (SD002) into a ditch to Stony Brook. Golf Pond is designed to treat influent up to 210,300 gpd and has a detention time of 180 days at designed flow. The primary cells of Golf pond also have a manually controlled outlet control structure (SD003) which discharges to Stony Brook. According to the MPCA permit SD002 can not discharge flow in the months of January through March, July and August. SD002 must meet a 200 cfu/ 100ml fecal coliform limit and a TSS limit of 45 mg/L. No phosphorus limit is required although concentrations are recorded on the facilities DMRs. SD003 is not regulated by any limits.

Gilman WWTF consists of a two cell stabilization pond. Both ponds have a detention time of 290 days at an average flow of .045 mgd. This facility treats domestic sewage and discharges to an undammed ditch which flows to Bailey Creek which flows to the Elk River. According to the MPCA permit, the facility must meet a 200 cfu/ 100ml fecal coliform limit, a 45 mg/L TSS limit No P limit is required although P concentrations are recorded on the facilities DMRs. Discharge is prohibited from January through March, July and August.

Becker WWTF is a Class A facility. Becker WWTF consists of two separate trains with a combined final discharge to the Elk River. One train treats water from the industrial park and the second treats domestic flow. Both trains currently use chemical application and a polymer addition for phosphorus and solids removal. Biosolids are mechanically thickened, go through a lime pasteurization process and are land applied. The Becker WWTF is currently designed to treat a combing average wet weather flow (AWW) of 850,000 gallons per day (GPD). The existing system is being proposed for an expanded flow which will allow it to treat an AWW flow of 2,150,000 gpd. Effluent from the discharge has a 1 mg/L Phosphorus limit and 30 mg/L total suspended solids limit as calendar month averages. These limits are effective from January through December.

According to state rule, each facility above is required to meet a discharge limit of 200 cfu/100ml fecal coliform concentration and 1 mg/L phosphorus concentration. All permitted facilities are required to monitor their effluent to ensure that concentrations of specific pollutants remain within levels specified in the discharge permit. The MPCA regularly reviews the Discharge Monitoring reports to determine if violations have occurred.

Eagle View Commons WWTF is a Class C facility consisting of a gravity sewer system that discharges to one lift station, a cast in place tank constructed with three compartments in series with a total tank capacity of 38,779 gallons. One compartment is sized at 19,389 gallons and the other two compartments are sized at 9,695 gallons each. A splitter manhole to split flow between two lined subsurface flow forced aeration wetland treatment cells measuring 10,000 square feet each, a dosing manhole with a dosing siphon which periodically discharges wastewater to one 15,600 square foot unlined wetland that acts as an infiltration bed. This WWTF is designed to serve 40 homes; four bedroom homes with a contribution of 250 gallons per day (gpd) per home. The wetland treatment system has an average annual design flow of 10,000 gpd and a peak daily flow of 16,667 gpd. No commercial or industrial facilities are proposed to be served by the wastewater treatment system.

Impairment contribution: *E. coli*, excess nutrients, turbidity

Entities with Phase II NPDES Permits

Our evaluation of permit holders also revealed NPDES Phase II permits for small municipal separate storm sewer systems (MS4s). The unique permit numbers assigned to these permit holders are as follows:

Table 4.5. List of NPDES II permit holders in the TMDL study area and the impaired water that it drains to.

NPDES Phase II Permit Holder Name	NPDES II Permit Number	Watershed Location
Sherburne County	MS4400155	ER 579, BEL
Big Lake Township	MS4400234	ER 579
City of Big Lake	MS4400249	ER 579
Benton County	MS4400067	ER 579, BEL, MAY
Sauk Rapids City	MS4400118	ER 579, BEL
Sauk Rapids Township	MS4400153	ER 579, BEL
St. Cloud City	MS4400052	ER 579, BEL
Sartell City	MS400048	ER 579, BEL
MNDOT Outstate District	MS4400180	ER 579, BEL
Haven Township	MS4400136	ER 579, BEL
Minden Township	MS400147	ER 579, BEL

Impairment contribution: *E. coli*, excess nutrients, turbidity

Construction Permits

The MPCA issues construction permits for any construction activities disturbing: 1) One acre or more of soil, 2) Less than one acre of soil if that activity is part of a “larger common plan of development or sale” that is greater than one acre or 3) Less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. The Environmental Protection Agency (EPA) estimates a soil loss of 20 to 150 tons per acre per year from stormwater runoff at construction sites. Such sites vary in the number of acres they disturb.

Impairment contribution: excess nutrients, turbidity

Livestock Facilities with NPDES Permits

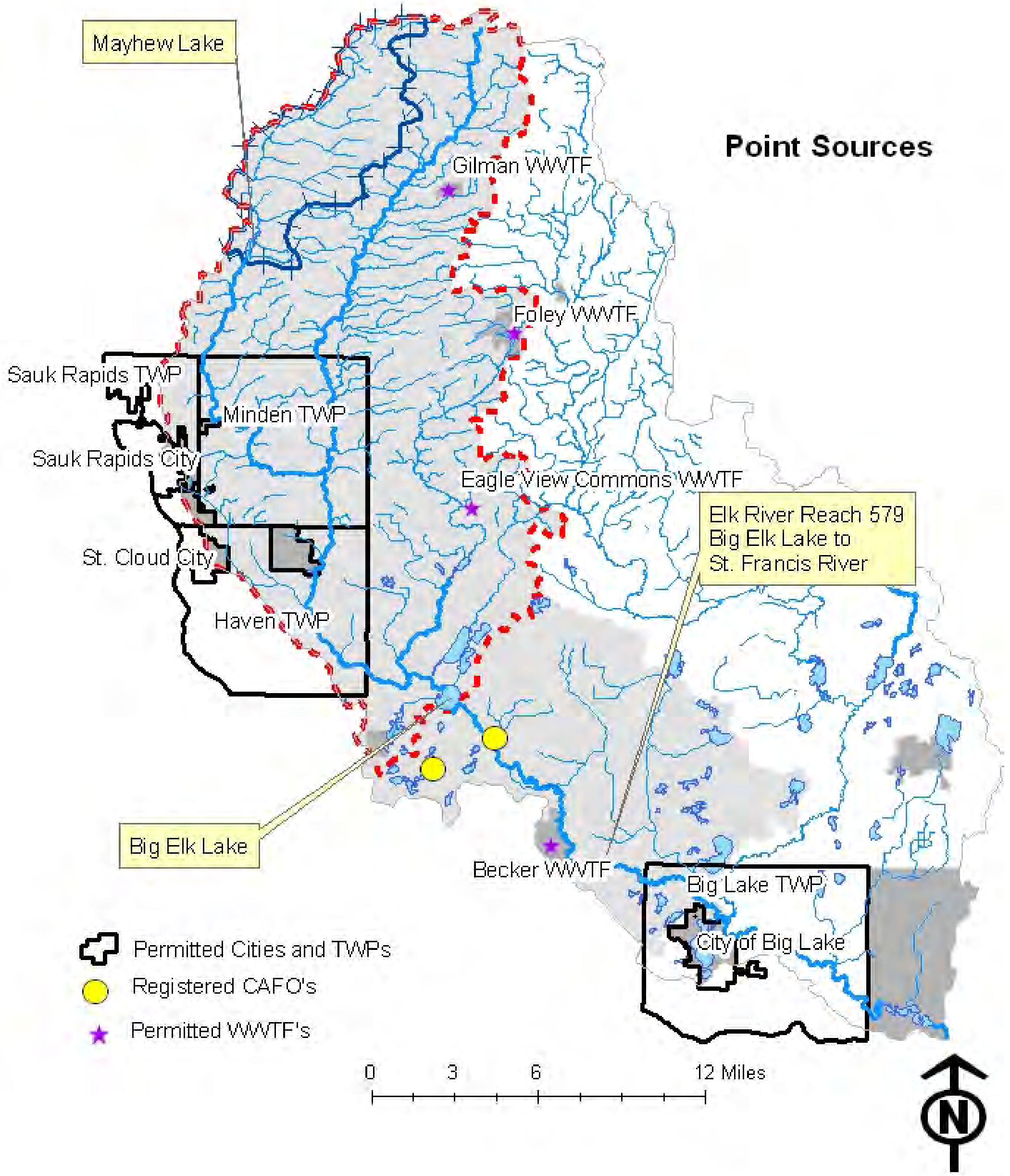
A Confined Animal Feeding Operation (CAFO) is a feedlot having 1,000 or more animal units, or a smaller feedlot with a direct man-made conveyance to surface water. A feedlot designated as a CAFO is required to operate in accordance with a NPDES permit. According to the MPCA Feedlot database there are two CAFOs located in the Sherburne County portion of Elk River reach 579 watershed. The CAFOs represent a total of 1456 Animal Units (AU) comprised of 1060 beef and 396 poultry AUs.

Table 4.6. List of CAFO NPDES permit holders in the TMDL study area that it drains to.

CAFO NPDES Permit Holder	Permit Number	AUs	Watershed Location
Goenner Poultry LLC	New - does not have a permit number yet	396	ER 579
Eiler Bros.	MNG440909	1060	ER 579

Impairment contribution: *E. coli*, excess nutrients

Figure. 4.4. Point source discharges in the impaired reach watersheds.



4.2.2 Non-Point Sources

Below is an inventory of the non-point sources in the Elk River watershed that have been identified as potential sources of nutrients, *E.Coli* or turbidity.

The turbidity impairment in Elk River reach 579 has been identified to be the result of algal blooms caused by excess nutrients from Big Elk Lake. Differences in turbidity can be easily noticed when comparing the Elk River above vs. below Big Elk Lake. Big Elk Lake is addressed in this TMDL for Excess Nutrients (phosphorus). Preliminary indications tell us that with reductions in nutrient loading to the lake, turbidity reductions in Elk River reach 579 will result. As such, many of the sources of excess nutrients identified below are also listed as sources of turbidity.

Atmospheric Deposition

Precipitation contains phosphorus that can ultimately end up in the lakes as a result of direct input on the lake surface or as part of stormwater runoff from the watershed. Although atmospheric inputs must be accounted for in the development of a nutrient budget; direct inputs to the lake surface are impossible to control and will be considered part of the background load.

Impairment contribution: Excess nutrients, turbidity

Internal Phosphorus Release

Internal phosphorus loading in lakes has demonstrated to be an important aspect of the phosphorus budgets of lakes. However, measuring or estimating internal loads can be difficult in lakes that completely or partially mix several times throughout the year; specifically relating to Big Elk Lake. Internal loading for both Mayhew and Big Elk Lake will be estimated and accounted for in the nutrient budget.

Impairment contribution: Excess nutrients, turbidity

Subsurface Sewage Treatment Systems (SSTS)

Failing SSTS, can be a significant source of phosphorus to surface waters. A 1991 Septic Leachate survey conducted on Big Elk Lake and the Briggs chain of lakes concluded that of the 504 residential units around the lakeshores, 10 percent exhibited indications of septic leachate (Water Research & Management, Inc.). There are five homes with SSTS located on the lakeshore of Mayhew Lake. It is difficult to determine whether or not any of them are failing; however, Benton County staff indicates that 30 percent of the SSTS in the County are failing.

In addition to phosphorus, *E.Coli* from humans can reach surface water through the pathways of SSTS. Failing or nonconforming SSTS can be an important source of *E. coli* bacteria, especially during dry periods when these sources continue to discharge and runoff driven sources are not active. Just as inadequate SSTS can contribute to excess nutrients, poorly treated effluent can contain elevated concentrations of *E. coli* and should be considered a threat to public health. All residential areas not connected to city WWTFs should be suspect to bacteria contribution.

Without comprehensive inspections it is difficult to know the amount of phosphorus or *E. coli* loading that can be attributed to failing systems. We will utilize estimate from the Counties, past research conducted by Water Research and Management, Inc. (October 1991) and conservative estimates to calculate approximately the external load that can be attributed to failing SSTS.

Impairment contribution: *E. coli*, excess nutrients, turbidity

Straight-pipe Septic Systems

Straight pipe septic systems are septic systems that deposit untreated raw sewage directly to rivers, lakes, drain tiles or ditches. For comparison, a properly functioning SSTS treats sewage with chemical, physical and biological process using a septic tank and a soil treatment system. Straight-pipe septic systems are illegal and unpermitted, but do exist in the watershed. Benton County estimates that six percent of the septic systems in the Elk River Watershed are straight pipe systems. We will work with Sherburne County in order to determine an estimate of the number of illegal septic systems in the watershed.

Impairment contribution: *E. coli*, excess nutrients, turbidity

Rural and Urban Residential runoff

Runoff from the residential land along riparian property has the potential to be a major source of phosphorus and *E. coli* loading to surface water. Lakeshore homes and other residential areas have the potential to transport materials such as grass clippings, leaves, car wash wastewater and animal waste to surface water. All of these materials contain phosphorus and bacteria which can impair local water quality. Additionally, impervious surfaces in the watershed cause nutrient export from such areas that can rival that of agricultural areas.

Particularly, lake shore property around Big Elk Lake and several lakes located upstream from the lake have dense residential populations. Nutrient loading from these areas will be estimated based upon monitored water quality data and literature nutrient export values for residential land use in Minnesota.

Impairment contribution: *E. coli*, excess nutrients, turbidity

Non-CAFO Livestock Facilities and Riparian Pastures

Runoff from livestock feedlots, pastures and land application of manure have the potential to be significant sources of nutrients and *E. coli*.

There are numerous small to medium sized feedlots and riparian pastures scattered throughout the watershed which offer opportunities for manure to enter surface water directly; however, there is considerable variation in the type and density of livestock facilities across the watershed. The feedlot density is the highest in the upper portion of the watershed were Benton County is listed as having the highest density of broiler chickens and the 5th highest density of dairy cows in the state. To that point, runoff from feedlots may be a significant source of phosphorus and *E. coli* contamination during periods of heavy precipitation. However, many small sized livestock operations have riparian pastures which lead to opportunities for manure to enter surface water directly during dry periods. Pastures of this type in the upper portion of the watershed have been identified to be a significant source of nutrients according to a field reconnaissance conducted in 2008 (see section 5.2).

The MPCA registered feedlot data base lists 190 feedlots and approximately 27,557 AU in the Elk River 579 watershed; 34 feedlots and 4,217.78 AU are listed in the Mayhew Lake Watershed and 176 feedlots with 24,311.6 AU listed in the Big Elk Lake watershed. The registered feedlots are mainly composed of dairy, beef, and swine. Other animals include horse, sheep, turkey, duck and lama.

Impairment contribution: *E. coli*, excess nutrients, turbidity

Agricultural Land Use

A high percentage of the land use in the watershed is agricultural consisting of row crops (corn, soybeans and small grains) and hay. Manure application on row crops and the type of manure application (surface vs. incorporated) of manure can contribute to *E.Coli* in waterways.

A recent survey of 187 soil test results in Benton County revealed that 93% of soil test levels were above 21 ppm total phosphorus, the threshold where the MPCA begins to regulate land application of manure. A survey of 50 poultry manure tests and 30 manure spreader calibrations shows that on average, phosphorus is being applied at 604 pounds per acre with rates as high as 1,479 pounds per acre.

The combination of long, moderately steep slopes, easily erodible sandy loam soil that is inherently high in phosphorus, a high density of feedlots, and predominately agricultural land use in riparian areas leads to an extremely high potential to introduce large amounts of phosphorus, sediment, and bacteria to surface waters.

Impairment contribution: *E. coli*, excess nutrients, turbidity

Wetlands

The correlation between wetlands and water quality is that wetlands act as a sink for nutrients such as phosphorous. However, wetlands can become contaminated with agricultural and/or urban runoff, thus becoming another source of excess phosphorus that may end up in the lake. Wetlands account for approximately 22 percent of the land use in the Elk River 579 watershed (including Big Elk Lake, Mayhew Lake watersheds).

<u>*Impairment contribution*</u>: Excess nutrients, turbidity

Wildlife

Natural background loads for *E. coli* bacteria can be attributed to wildlife.
For this assessment we will focus on deer and geese because they are known contributors of *E. coli* bacteria and are considered good estimates of wildlife densities in general.

Wildlife populations can be estimated utilizing past research and knowledge from the Department of Natural Resources. Deer populations in the Elk River Watershed are estimated to be 15-20 deer per square mile. Goose densities were estimated based on Metro area estimates and were reduced to half of those estimates based on MN DNR input (Fred Bengston pers. Comm.).

Table 4.6. Deer and goose population estimates.

Wildlife	Density (per sq mile)	Watershed Population (est.)
Deer	15-20	5025-6700
Geese	1.4	469

<u>*Impairment contribution*</u>: *E. coli*

In-Stream sources

In-stream erosion sources (stream banks and bed) result from the instability of the stream channel due to high or flashy flow events. The slope of the bank, amount of moisture in the soil, and the cohesiveness of the material all play a role in bank failure. A substantial portion of the sediment derived from banks and beds may have originally come from upland soil eroded years earlier and deposited in riparian areas. Although initial investigations have concluded that in-stream erosion plays a minimal role in the turbidity impairment we will gather the data necessary to support this theory.

<u>*Impairment contribution*</u>: Turbidity

5.0 Review & Analysis of Data

5.1 EXISTING WATERSHED DATA

The Elk River Watershed Association (ERWSA) has collected water quality and hydrologic data in the impaired waters addressed in this report. These data are summarized in this section of the TMDL Phase I Report.

5.1.1 Big Elk Lake

Big Elk Lake is a shallow, 360-acre basin with an average depth of five feet and a maximum depth of nine feet. Big Elk Lake meets the definition of a shallow lake because of its maximum depth, and because its littoral zone covers 100 percent of the basin. Big Elk Lake is a flow through system on the main stem of the Elk River which enters the lake in the northwest corner on river mile 39.7 and exits at the southeast corner of the lake at river mile 38.5. Lily Creek also flows into Big Elk Lake at the north end of the lake, which connects Big Elk Lake to the other lakes on the Briggs Chain of Lakes. Big Elk Lake and its tributaries and monitoring stations are shown in Figure 5.1.

Big Elk Lake has a large contributing watershed of approximately 173,000 acres (270 mi^2), resulting in a watershed to lake area ratio of 480:1. Due to the shallow nature of the lake, the lake volume is relatively small at only 1,540 ac-ft. The large inflow volume from the Elk River and additional tributaries results in a very short residence time for the lake, ranging from less than one to more than 60 days. It is critical to understand the role the Elk River inflows play in the nutrient impairment. To that end, inflows were evaluated in terms of residence time.

A long term record of flow in the Elk River is maintained by the USGS downstream of Big Elk Lake at river mile 9.5 near the City of Elk River. The flow records from the USGS station were used to calculate unit area flow for the watershed. The calculated unit area flow was then applied to the watershed area contributing to Big Elk Lake to generate a long term inflow record to Big Elk Lake. A flow duration curve for the Elk River at the inflow to Big Elk Lake is presented as Figure 5.2. This figure demonstrates the variation in residence time for Big Elk Lake. From this evaluation, we can see that 40% of the time, the residence time in Big Elk Lake is less than one week.

Figure 5.1 Monitoring stations and contributing water bodies for Big Elk Lake

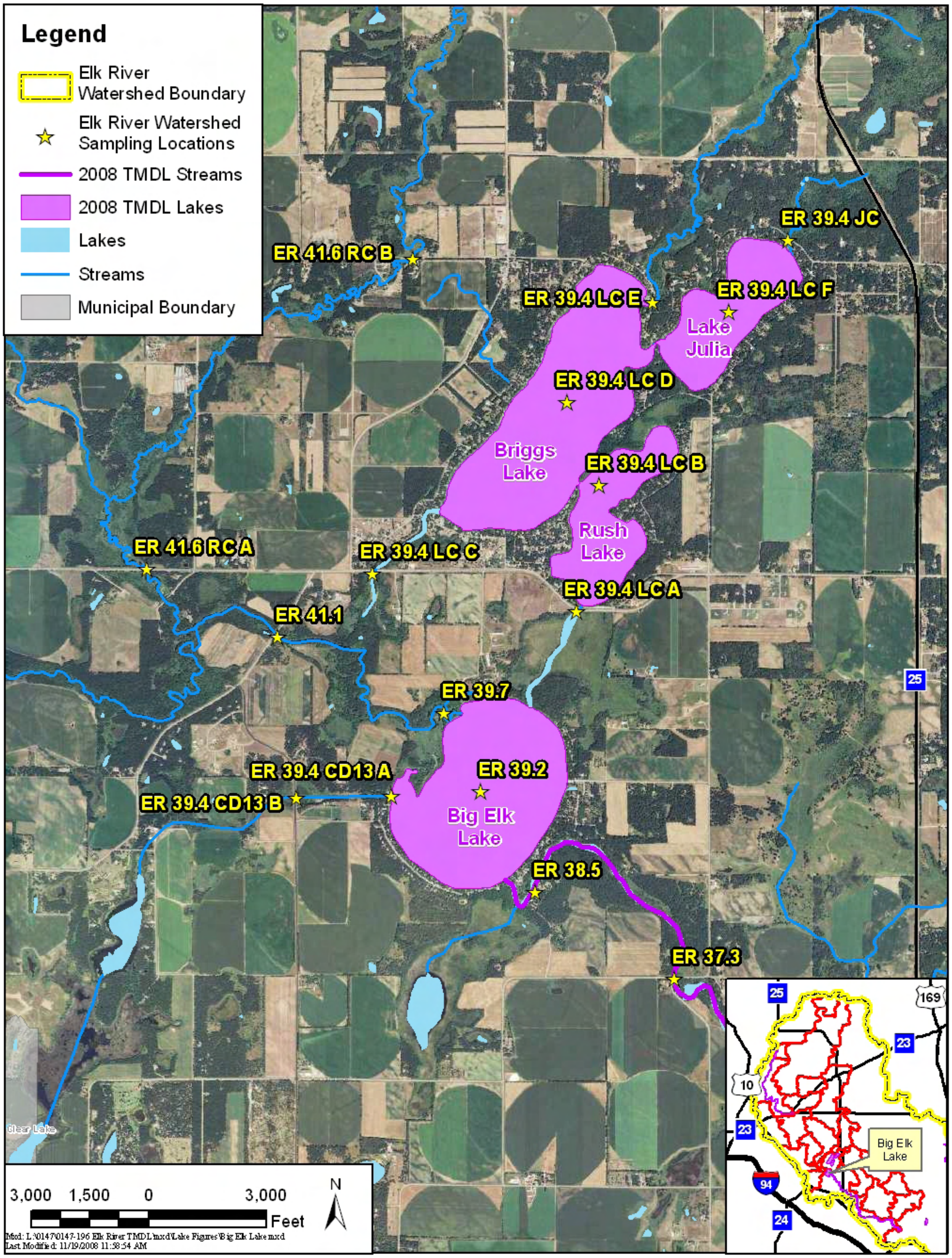
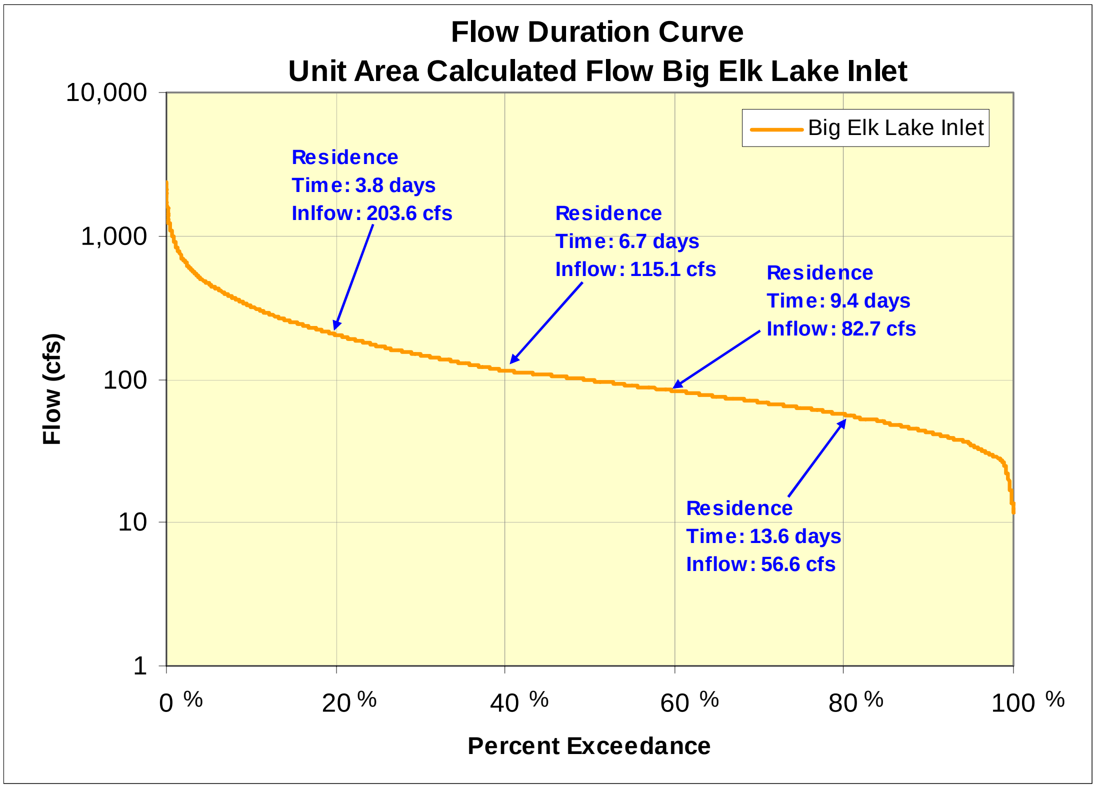


Figure 5.2 Flow duration curve for the Elk River at the inflow to Big Elk Lake



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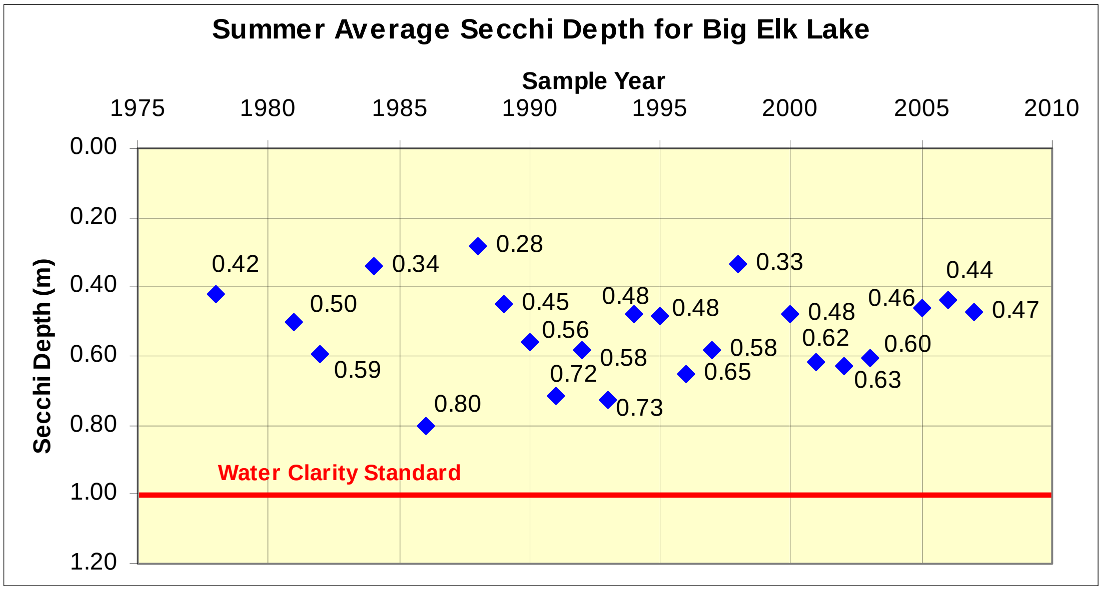
Water quality data for Big Elk Lake was retrieved from the MPCA Electronic Data Access (EDA) website. Water clarity data (i.e. Secchi depth measurements) are available from 1978 through 2007. Total phosphorus and chlorophyll-a data are available from 1981 through 2007. Secchi depth measurements for Big Elk Lake have varied from a low of 0.28 meters in 1988 to a high of 0.80 meters in 1986 (Figure 5.3). Since 2000, annual average Secchi depth has been stable ranging from 0.44 to 0.63 meters. All measured years for water clarity fall below the State standard of 1.0 meters for shallow lakes in the North Central Hardwood Forest ecoregion. The data reveals no significant trend.

Figure 5.3 Summer average Secchi depth readings for Big Elk Lake



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Average summer growing season total phosphorus concentrations have ranged from 128 µg/L in 2006 to 313 µg/L in 1986 and 1989 (Figure 5.4). Total phosphorus concentrations in Big Elk Lake ranged from 290 to 313 µg/L in the 1980s. Monitoring data from four sample years between 1998 and 2007 showed total phosphorus concentrations ranged from 128 to 219 µg/L with an average of 179 µg/L; however, despite the lower total phosphorus concentrations observed in recent years, concentrations have exceeded the State standard of 60 µg/L for shallow lakes of the North Central Hardwood Forests ecoregion in all monitoring years.

Discrete total phosphorus concentrations in Big Elk Lake were compared to inflows from the Elk River. The highest observed total phosphorus concentrations in 2006 and 2007 occurred late in the summer, during low flow conditions.

Average summer growing season chlorophyll-a concentrations have ranged from a low of 49 µg/L in 1993 to 94.5 µg/L in 1998 (Figure 5.5). There has been a moderate amount of observed variation in summer growing season average chlorophyll-a concentrations in Big Elk Lake. Chlorophyll-a concentrations have increased or decreased by more than 50 percent between monitoring years, with no clear trends across monitoring years. Average summer growing season chlorophyll-a concentrations in Big Elk Lake have exceeded the State standard of 20 µg/L for shallow lakes of the North Central Hardwood Forests ecoregion during all monitoring years.

Figure 5.4 Summer average total phosphorus concentrations for Big Elk Lake

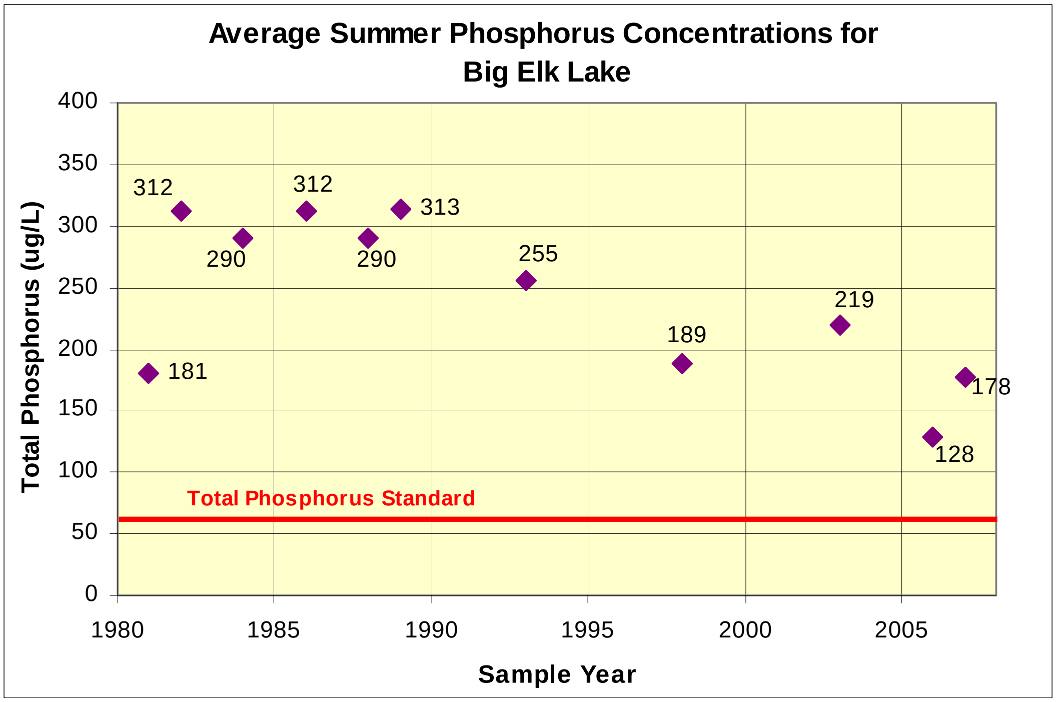

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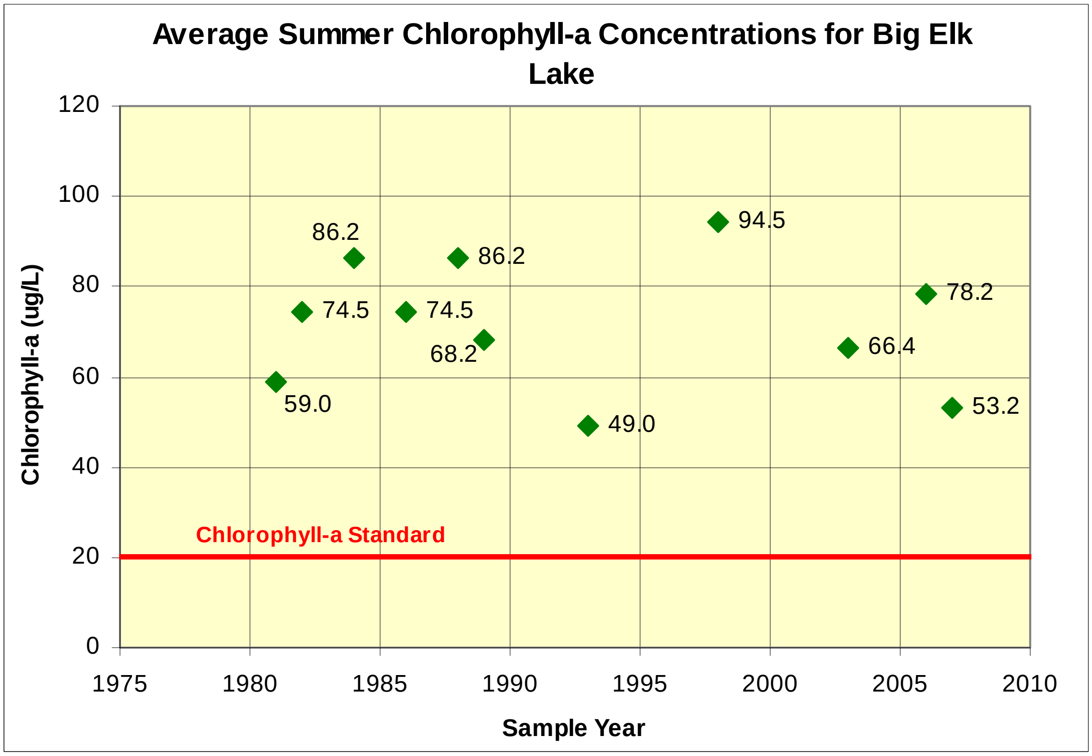
Figure 5.5 Summer average chlorophyll-a concentrations for Big Elk Lake



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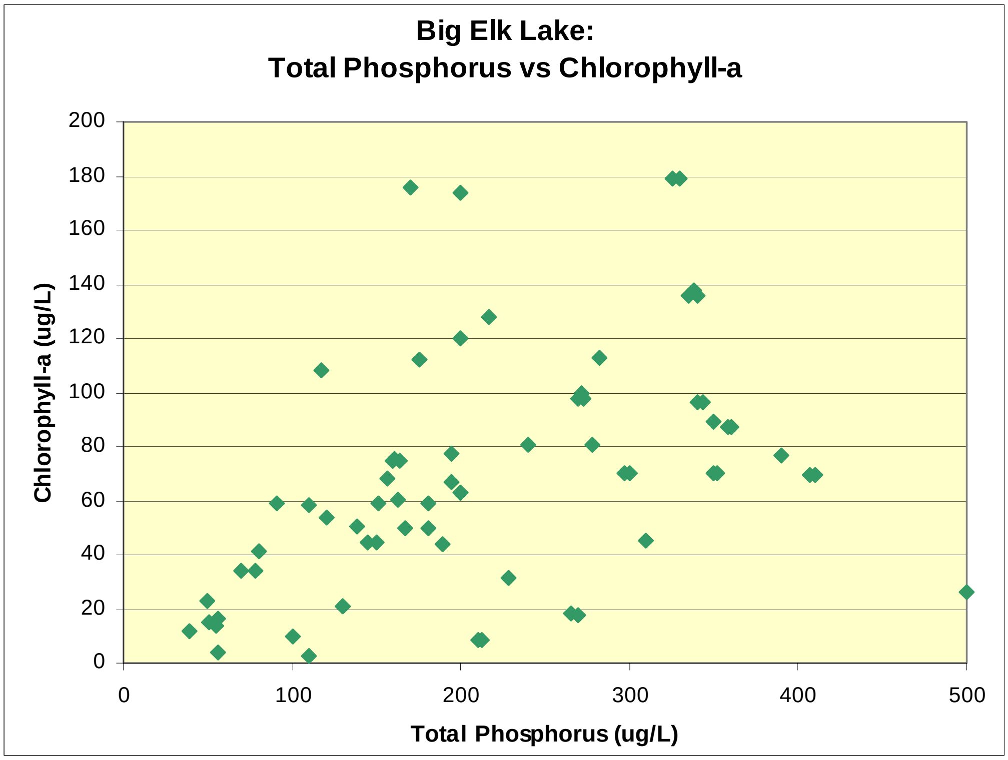
Discrete chlorophyll-a concentrations were compared to discrete total phosphorus concentrations in Big Elk Lake (Figure 5.6). In general, high chlorophyll-a concentrations are associated with high total phosphorus concentrations. Variability is likely due to the residence time of Big Elk Lake relative to generation times for algae.

Figure 5.6 Discrete chlorophyll-a concentrations versus discrete total phosphorus concentrations for Big Elk Lake



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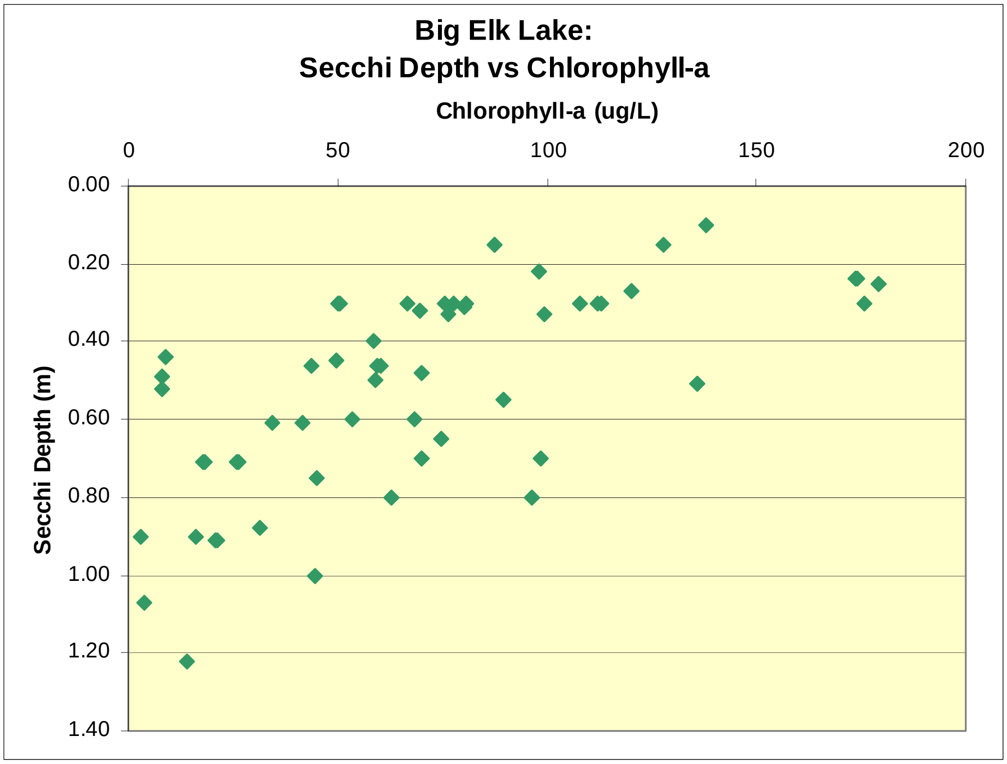
Discrete chlorophyll-a concentrations were also compared to discrete Secchi depth readings in Big Elk Lake (Figure 5.7). This comparison reveals that algal turbidity is likely the main driving factor affecting water clarity in Big Elk Lake, though turbidity from other sources like wind resuspension is also common in shallow lake systems like this one.

Figure 5.7 Discrete chlorophyll-a concentrations versus discrete Secchi depth readings for Big Elk Lake



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A review of the lake management plan developed by the DNR reveals that Big Elk Lake lacks the typical aquatic plant community expected in a shallow lake system. Vegetation surveys conducted by the DNR in 1986 and 1999 indicated that most of the basin is devoid of submerged vegetation. A low number of native submerged species are present in the lake including coontail, sago pondweed and bushy pondweed. These species were mainly limited to depths of 2 to 5 feet in the shallow bays along the north and west shores of the lake near the stream inlets. The exotic species curly leaf pondweed was also observed in both the 1986 and 1999 surveys, but its distribution across the lake is limited. Emergent vegetation is sparse around the lake shore, again limited to the shallow bays and marsh areas near the stream inlets. The emergent species observed by the DNR include sedges, bulrush, arrowhead and needlerush. The lack of healthy aquatic vegetation in the basin is likely due to the high algal turbidity in the lake that limits light transparency. The basin has a long fetch, and with its overall shallow depth, the absence of a stable root system from submerged aquatic vegetation may lead to some internal loading due to wind suspension of silty, organic sediments.

The fish community in Big Elk Lake has been surveyed by the DNR four times from 1980 through 1999. The primary management species in Big Elk Lake are northern pike and walleye. Both species were stocked frequently during the 1960s and 1970s with the last walleye stocking occurring in 1980 and the last northern pike stocking occurring in 1992. The most recent DNR survey indicates that both walleyes and northern pike are successfully reproducing in the system either within the lake itself or within the Elk River. The populations of walleye and northern pike are now self-sustaining and have an adequate forage base provided by the minnow and white sucker community. The panfish population abundance (bluegill, black & white crappie, pumpkinseed and yellow perch) is low, likely due to the lack of stable submerged aquatic vegetation which provides spawning habitat, feeding areas and a refuge from predators. Big Elk Lake does have a significant rough fish community that includes black bullhead and common carp. Due to the shallow, open nature of the basin and lack of submerged structure, Big Elk Lake is suitable for commercial harvest of rough fish. However, past efforts of rough fish removal have not lead to a reduction in the overall abundance of rough fish in the lake, likely due to the connection to the Elk River and the Briggs Chain.

5.1.2 Elk River: Big Elk Lake to the St. Francis River

The Elk River is an 83.4 mile long river with its origin as an intermittent stream in north central Benton County. The Elk River flows south-southeast to its confluence with the Mississippi River in the City of Elk River, Minnesota. The total watershed of the Elk River is 392,482 acres (613.3 mi^2). The reach of the Elk River listed for turbidity and bacteria impairment is a 23.2 mile reach, extending from the outflow of Big Elk Lake at river mile 38.6 to its confluence with the St. Francis River at river mile 15.4 (Figure 5.8). The contributing watershed area to the listed reach of the Elk River includes the 172,848 acre area upstream of Big Elk Lake and an additional 41,791 acres contributing directly to the listed reach for a total of 214,639 acres (335.4 mi^2).

The United States Geological Survey (USGS) has maintained a permanent flow gauging station on the Elk River at river mile 9.5 for over 30 years. The flow record at the USGS station contains daily flow data from 1977 through 2008. This station is downstream of the St. Francis River and outside of the reach listed for bacteria and turbidity impairment. However the station is only five miles downstream of the listed reach and this long term flow data set will be suitable for use during the modeling of the listed reach in conjunction with data collected from the listed reach. A flow duration curve for the USGS daily Elk River flow is provided as Figure 5.9. The 50th percentile flow for the Elk River at the USGS station is 203 cubic feet per second (cfs).

Figure 5.8 **Monitoring stations along the reach of the Elk River listed for bacteria and turbidity impairment**

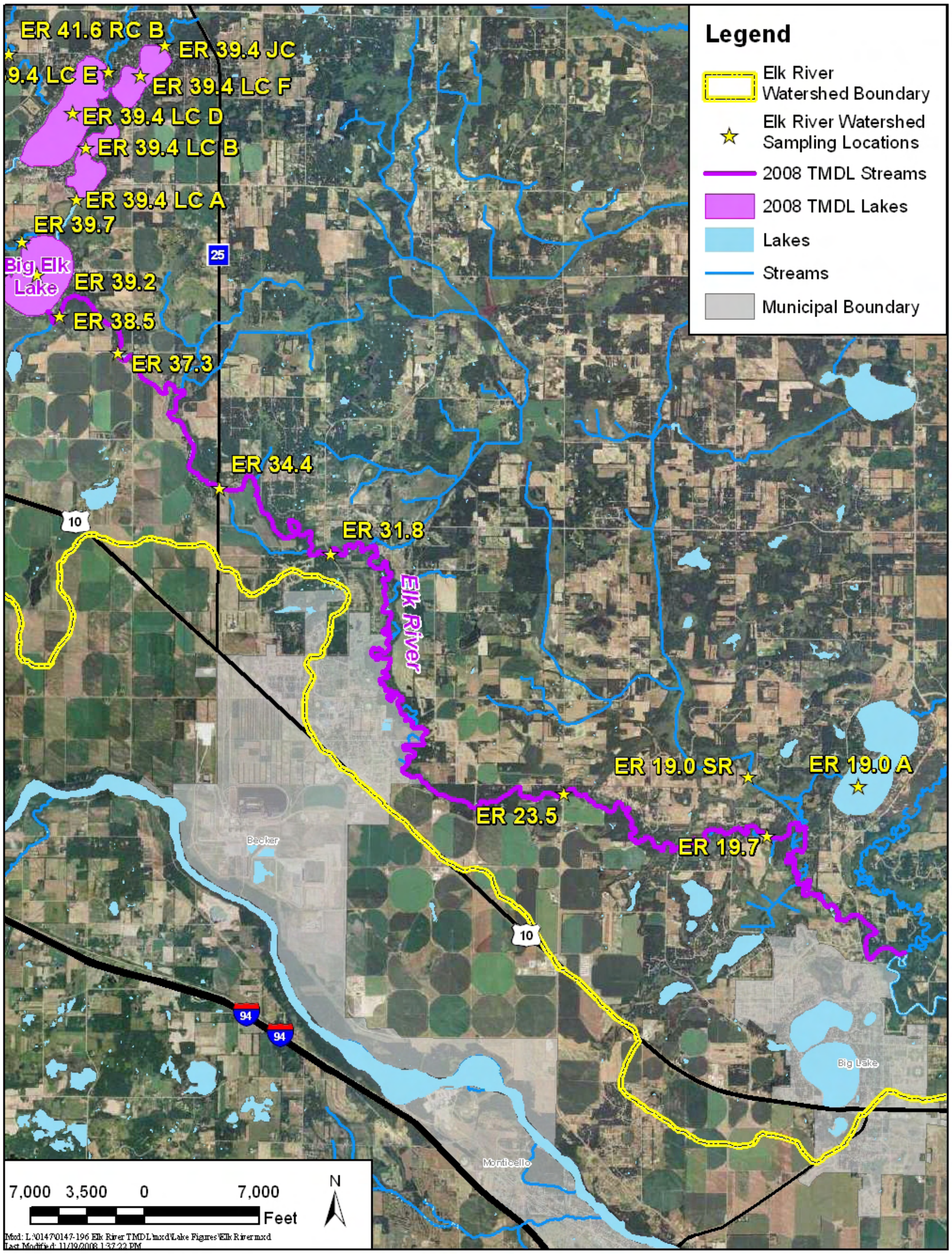
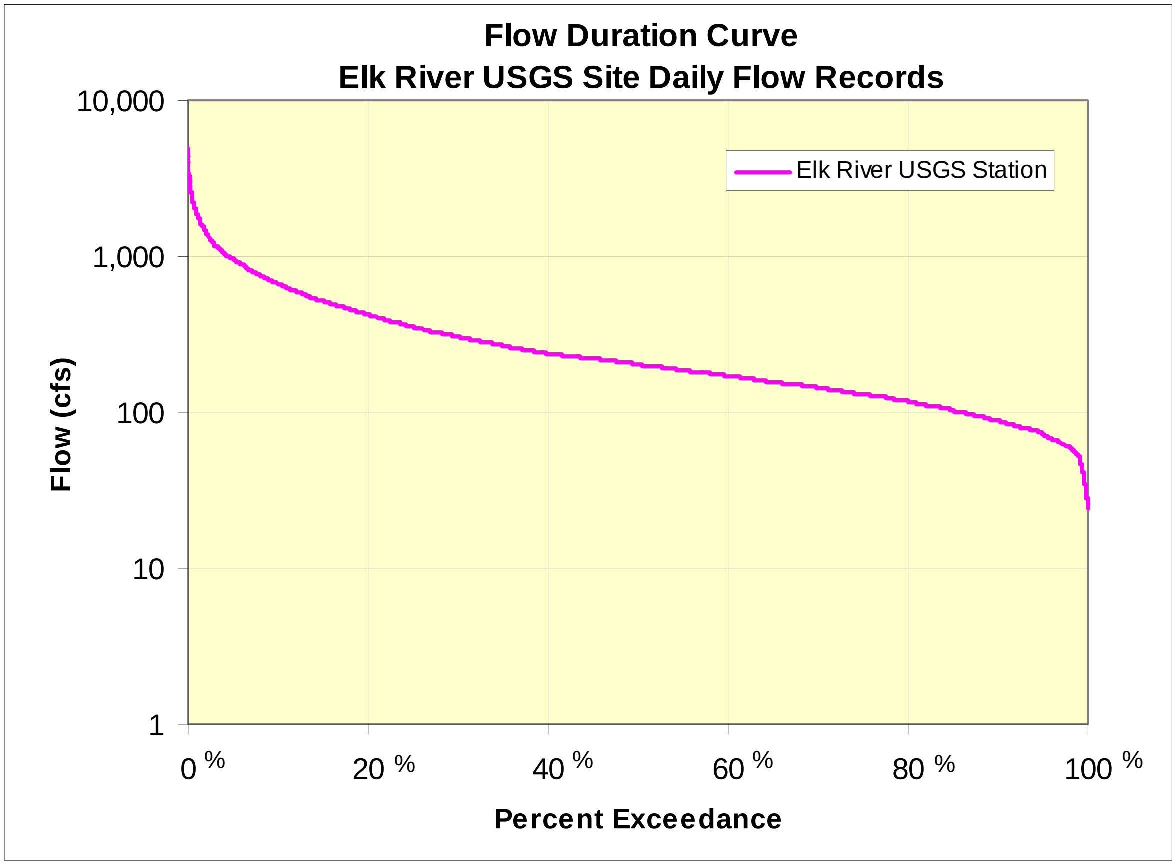


Figure 5.9 Elk River flow duration curve, river mile 9.5



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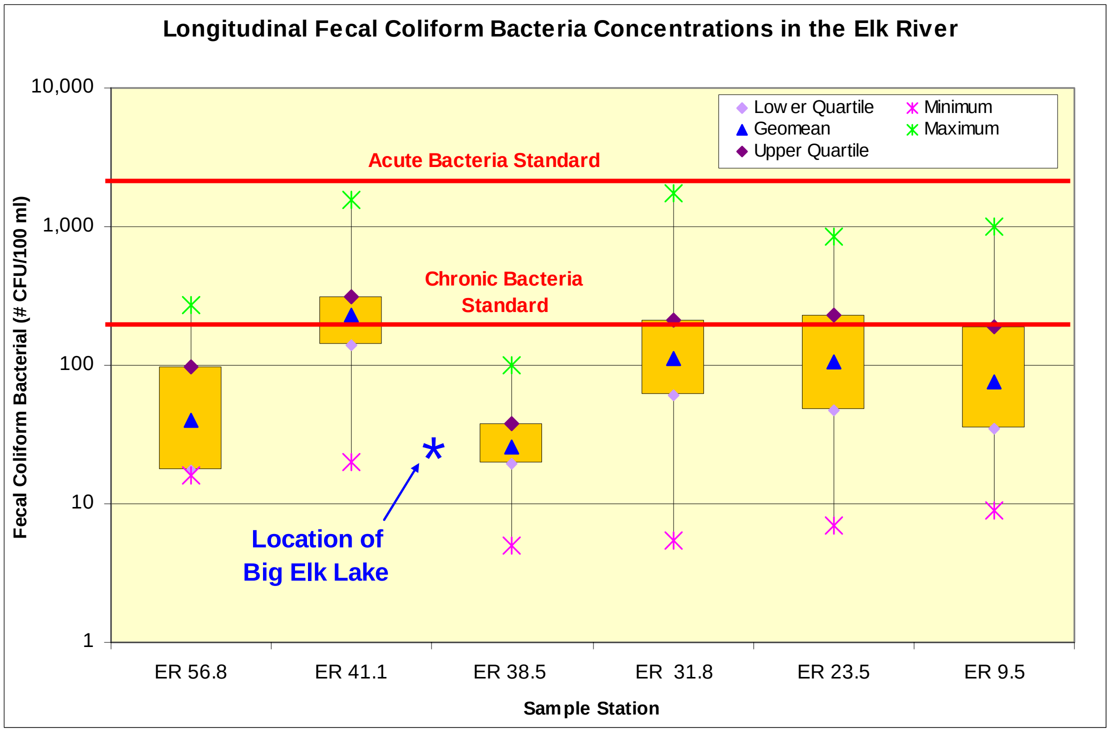
Bacteria concentrations as fecal coliform were measured at six stations along the main stem of the Elk River, two stations upstream of Big Elk Lake, three stations downstream of Big Elk Lake within the listed reach and one station downstream of the St. Francis River outside of the listed reach. Box plots displaying the geometric mean fecal coliform bacteria concentrations, as well as the range of observed values from each station are presented in Figure 5.10. The chronic (200 CFU/100ml) and acute (2,000 CFU/100ml) standards for fecal coliform are displayed on this graph. The geometric mean does not exceed the State chronic standard at any of the six sample stations.

Figure 5.10 Box plots of longitudinal fecal coliform bacteria concentrations in the Elk River.



T:\0147\196 Elk River TMDL\Elk River Water Quality Data\Mainstem Elk WQ Data.xls\Fecal Coliform Charts

A summary of the discrete fecal coliform samples by month for the three sample stations within the listed reach of the Elk River are presented in Table 5.1. Eleven of the fifteen exceedances of the State chronic standard occur in August and September. Approximately 20 percent of all collected samples exceed the State chronic standard. No samples from the three sample stations within the listed reach exceed the State acute standard.

Table 5.1 Summary of fecal coliform bacteria samples for three monitoring stations within the listed reach of the Elk River

Sample Month	Total Samples (n)	# > 200 CFU/100mL	# >2,000 CFU/100mL
May	8	0	0
June	15	3	0
July	12	1	0
August	18	7	0
September	11	4	0

The standard measure of turbidity in a body of water is the use of nephelometric turbidity units or NTUs. The turbidity standard for Class 2B waters is 25 NTUs; a sample value greater than 25 NTUs is considered a violation of the standard. However, surrogates for turbidity are often collected, and can be reliably used to predict turbidity. Surrogates may include total suspended solids (TSS) samples or transparency tube readings. Most of the turbidity data collected along the Elk River has been in the form of transparency tube readings. A transparency tube measurement of less than 20 cm is considered a violation of the 25 NTU standard. For a reach to be listed for turbidity impairment based on transparency readings, there must be a minimum of thirty (30) observations **and** ten (10) percent of the total observations must be below 20 cm in violation of the turbidity standard.

Transparency data is available for ten stations along the Elk River, six stations upstream of Big Elk Lake and four stations downstream of Big Elk Lake within the listed reach. Longitudinal transparency data for the Elk River is presented by river mile from upstream to downstream (Figure 5.11). Stations ER 56.8 through Station ER 41.1 are upstream of Elk Lake and outside of the reach listed for turbidity impairment. The median transparency value for these samples is 60 or greater. Station ER 47.4, ER 44.5 and ER 41.1 do have three or more values below 20 cm. However, the number of samples below 20 cm is not greater than 10% of the total sample measurements and therefore the reach is not considered impaired for turbidity. Sampling stations within the listed reach are Stations ER 38.5, ER 37.3, ER 34.3 and ER 31.8. The median transparency value for observations from these stations ranges from 22 to 25 cm, approaching a violation of the turbidity standard as an average. For each station within the listed reach there are greater than 20 readings below 20 cm in violation of the turbidity standard. For these stations readings below 20 cm represent from 34 to 45 percent of all observations (Table 5.2).

Figure 5.11 Longitudinal transparency tube readings in the Elk River.

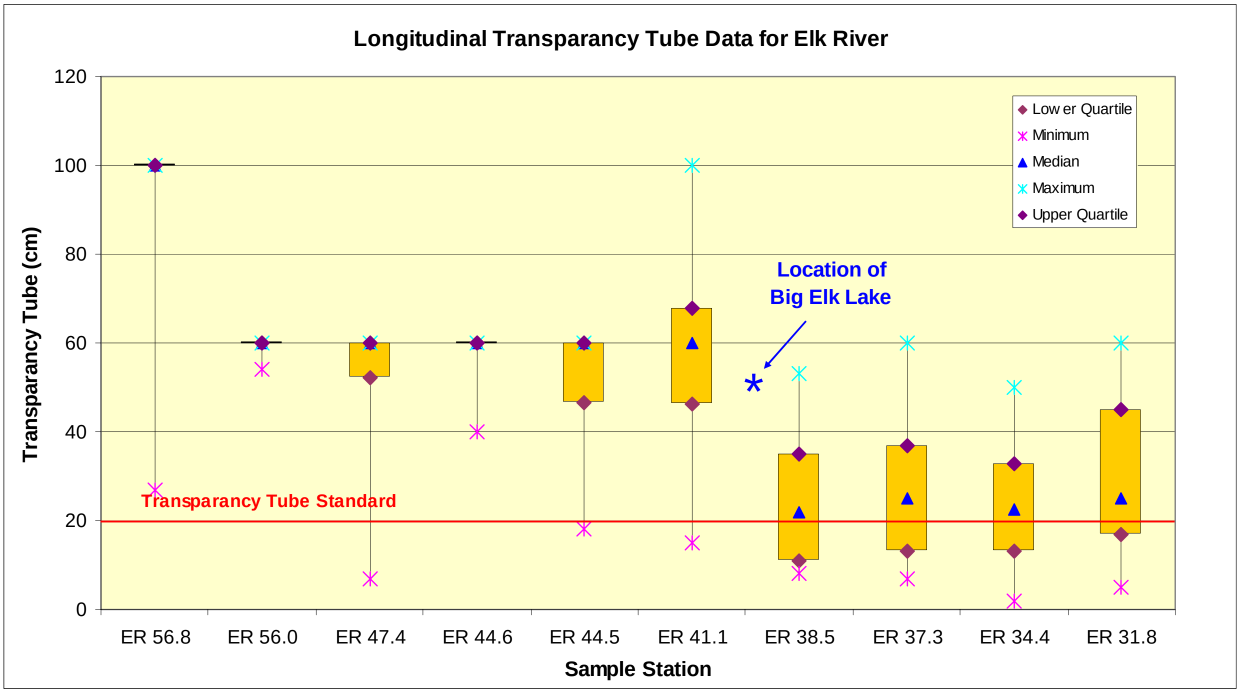


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Table 5.2 Summary of transparency tube readings for the Elk River upstream of Big Elk Lake and within the listed reach

Location	Sample N	# > 20 cm	% > 20 cm	# < 20 cm	% < 20 cm
Upstream of Big Elk Lake	391	376	96%	15	4%
Listed Reach of Elk River	396	239	60%	157	40%

Displaying the transparency data longitudinally helps to illustrate the influence Big Elk Lake has on the water clarity within the Elk River. Big Elk Lake is a hyper-eutrophic system with total phosphorus and chlorophyll-a concentrations well above the state water quality standards. Water clarity, measured by Secchi depth, is typically 0.5 meters or less within Big Elk Lake. Flows from the Elk River entering Big Elk Lake are typically clear and low in turbidity (see Figure 5.11). Watershed and instream sources of turbidity upstream of the lake are not likely contributing to the turbidity downstream of the lake. Instead, nutrient sources in the upper watershed coupled with the lake dynamics are the driving factor in the turbidity impairment in the Elk River downstream of Big Elk Lake. The high nutrient and chlorophyll-a concentrations in the lake lead to high algal turbidity within the lake which is discharged to Elk River. Data and observations also indicate that algae thrive in the listed reach of the Elk River.

5.1.3 Mayhew Lake

Mayhew Lake is a 130 acre basin located in the upper northwest corner of the Elk River watershed. Mayhew Lake is oriented as a long and narrow basin that is relatively shallow with an average depth of 13 feet and maximum depth of 20 feet (Figure 5.12). Mayhew Lake has a littoral zone covering 64 acres, or 49 percent of the basin. Mayhew Creek flows into Mayhew Lake at the northeast end of the basin and serves as the outflow point to Mayhew Lake at the southwest end of the basin. There are two other unnamed tributaries that flow into the east end of Mayhew Lake. Mayhew Lake has a contributing watershed area of 18,521 acres, resulting in a watershed to lake area ratio of 142:1. This indicates Mayhew Lake has a short residence time.

Water quality data for Mayhew Lake was retrieved from the MPCA EDA website. Water clarity data (i.e., Secchi depth measurements) are available between 1993 through 2005. Total phosphorus and chlorophyll-a data are available from 1995 through 2005. Mean Secchi depth measurements for Mayhew Lake have varied from a low of 0.64 meters in 1995 to a high of 0.80 meters in 2005 (Figure 5.13). The most recent years of water clarity measurements, 2003 through 2005, show an improvement in lake water clarity; however, some of the data seemed to have been entered with incorrect units. For the purpose of Figure 5.13, values that appeared to have been misentered were corrected. Water clarity measurements in 1993 and 1995 were below the State standard of 1.4 meters for lakes in the North Central Hardwood Forest ecoregion; however, mean water clarity values were above the State standard for the years of 2003 through 2005.

Figure 5.12 Monitoring stations and inflow tributaries for Mayhew Lake

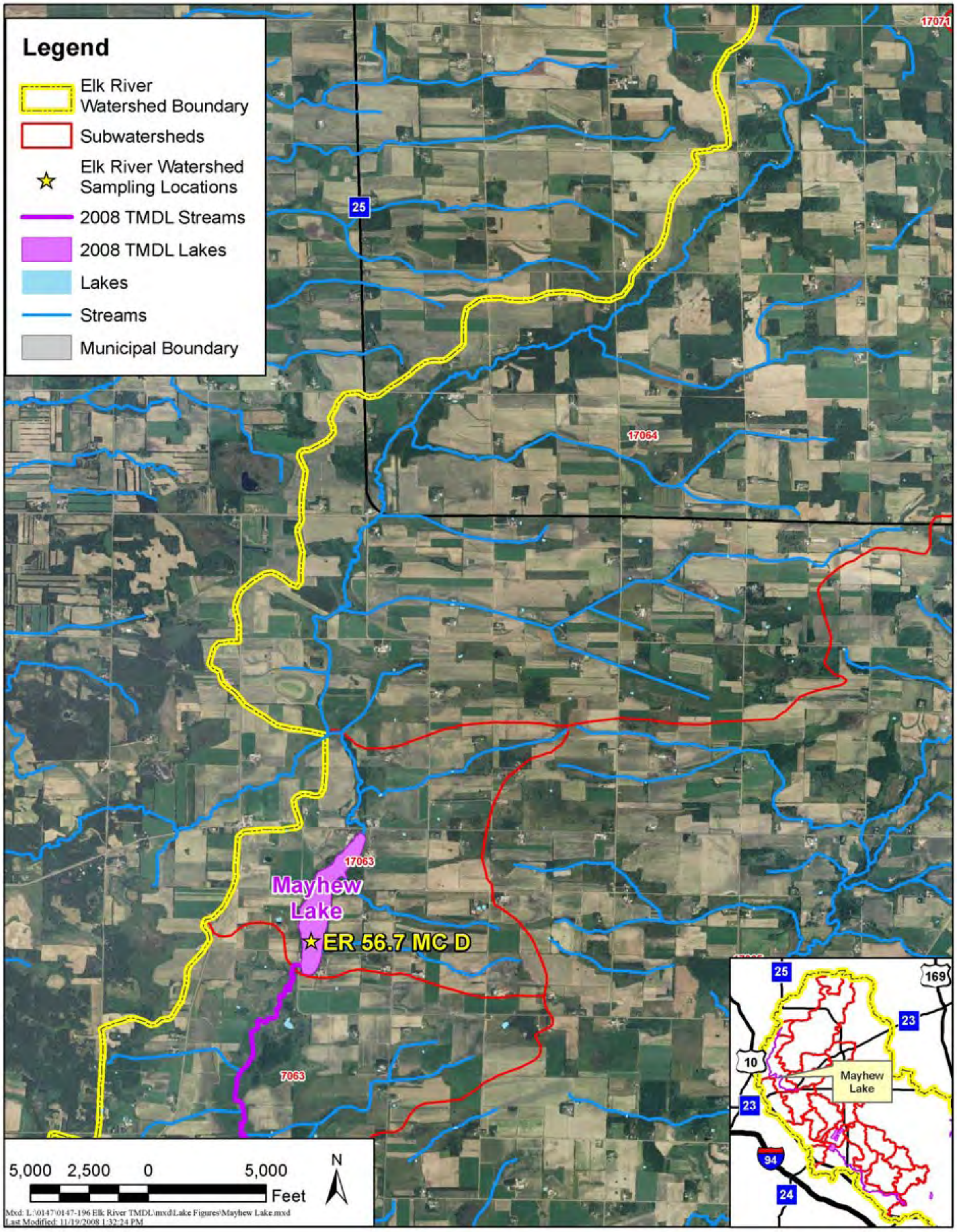
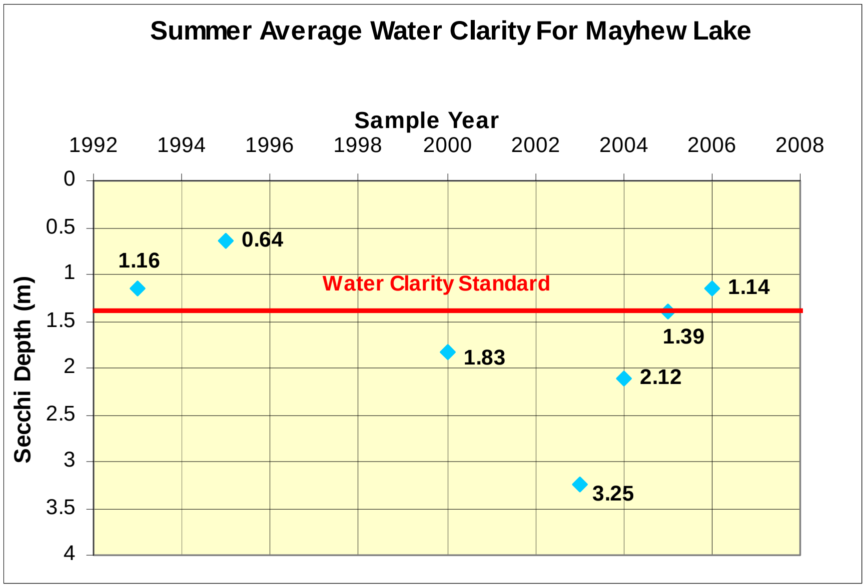


Figure 5.13 Summer average Secchi depth readings in Mayhew Lake



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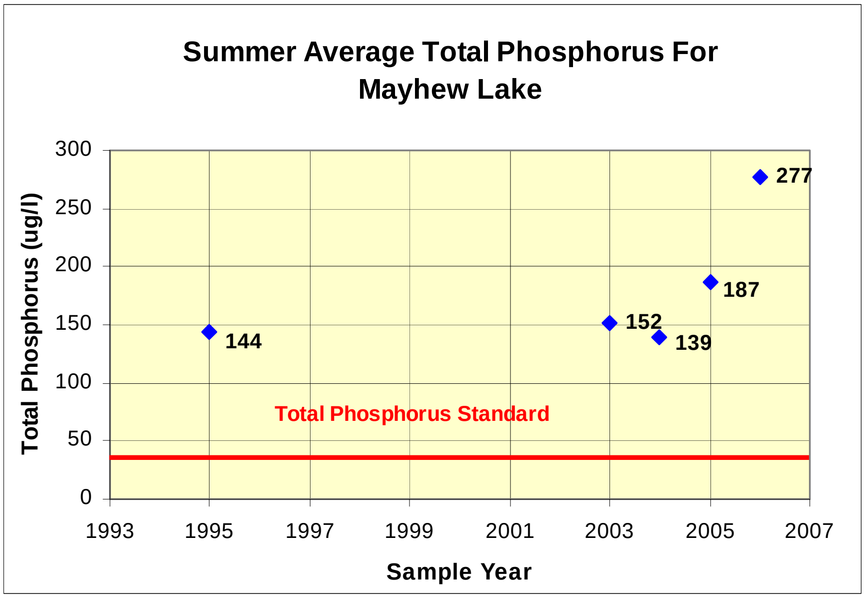
Average summer growing season total phosphorus has remained stable, ranging from 139 µg/L to 187 µg/L (Figure 5.14). The reported increase in lake water clarity values observed in 2003 through 2005 did not correlate with observed total phosphorus concentrations in Mayhew Lake. Total phosphorus concentrations in Mayhew Lake have exceeded the State standard of 40 µg/L for lakes of the North Central Hardwood Forests ecoregion in all monitoring years.

Figure 5.14 Summer average total phosphorus concentrations in Mayhew Lake



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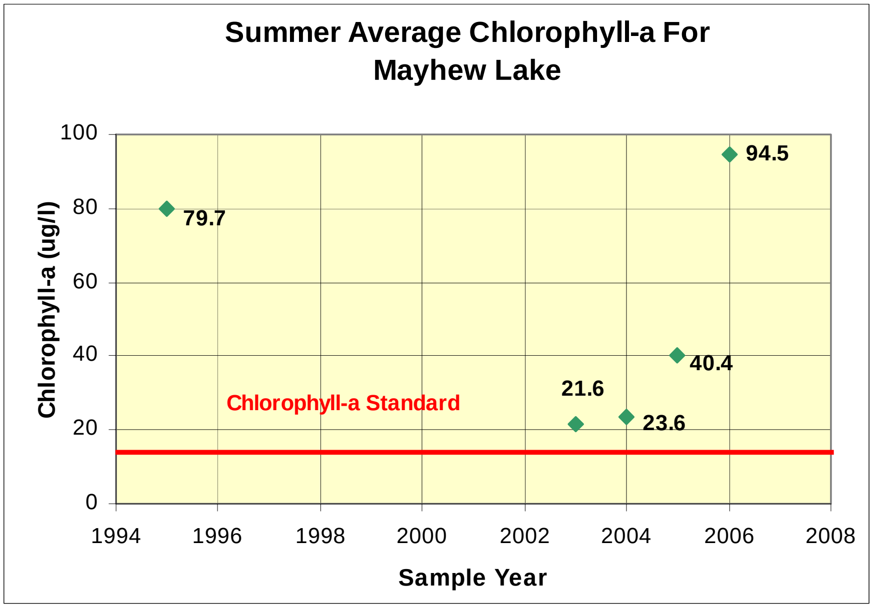
Average summer growing season chlorophyll-a concentrations followed a pattern more closely related to the water clarity measurements than did the total phosphorus concentrations. The highest observed average chlorophyll-a concentration was 79.7 µg/L in 1995 (Figure 5.15). For 2003 through 2005, chlorophyll-a concentrations ranged from 21.6 µg/L to 47.0 µg/L. The corresponding improvement in both chlorophyll-a concentrations and observed water clarity values indicates that algal turbidity is likely the factor limiting water clarity. However, despite the improvement in chlorophyll-a concentrations in Mayhew Lake from 2003 through 2005, concentrations have exceeded the State standard of 14 µg/L for lakes of the North Central Hardwood Forests ecoregion in all monitoring years.

In 1995 a lake assessment study was conducted in a joint effort by the MPCA, DNR and the Benton County Department of Development and the Soil and Water Conservation District (SWCD). The study determined that watershed sources are the major contributing factor of increased nutrient loading to Mayhew Lake. The Mayhew Lake watershed is dominated by agricultural land uses. The study determined that there are four feed lots in the immediate direct watershed to the lake and up to 50 feed lots in the overall watershed. Based on this report livestock are likely a major watershed source contributing nutrients to Mayhew Lake.

There are a limited number of residents along Mayhew Lake and it was estimated that septic systems do not contribute a significant nutrient load to the lake. The Benton County SWCD has initiated efforts to work with land owners in the Mayhew Lake watershed and has been successful in implementing nutrient reduction Best Management Practices (BMPs) in the watershed. Continuing and increasing this effort will be an important component in improving the water quality in Mayhew Lake.

Figure 5.15 Summer average chlorophyll-a concentrations in Mayhew Lake for four monitoring years from 1995 through 2005



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A review of the lake management plan developed by the DNR reveals that the fish community of Mayhew Lake has fluctuated over time. Mayhew Lake has produced a stable black crappie fishery but populations of species such as walleye, bluegill or northern pike have been less stable. Walleyes do not naturally reproduce within Mayhew Lake, populations have been sustained with various levels of stocking efforts overtime. The current stocking plan includes stocking fingerling walleyes during odd numbered years. Based on the DNR assessment, bluegill and largemouth bass populations are below goal in the lake due to a lack of suitable submerged vegetation to provide the necessary habitat. The most recent fish community survey indicated that the northern pike population is larger than desirable. However, the large northern pike population may be providing an effective top down control on panfish (i.e., yellow perch, bluegill), in turn limiting the grazing pressure of panfish on the zooplankton community which can limit algae growth.

The DNR indicates that common carp have a significant presence within the lake, even though catch rates for carp are low. Carp are not easily sampled by gear traditionally used for DNR population estimates, and it is common for carp to be more prevalent in a lake than is indicated by the DNR surveys. Common carp can present significant management problems, especially in shallow, eutrophic basins such as Mayhew Lake. Carp are a long lived species, with adults reaching ages of more than 50 years in some systems. This allows carp to sustain a population in a system for years even if breeding conditions are not favorable. When the proper conditions are present, carp spawn with overwhelming success and compete for resources with other species. Common carp are bottom-feeders that uproot aquatic macrophytes during feeding and spawning, re-suspending bottom sediments and nutrients. These activities can lead to increased nutrients in the water column, ultimately resulting in increased nuisance algal blooms. Addressing the presence of common carp in Mayhew Lake may be an important factor when attempting to improve water quality within the lake.

Mayhew Lake lacks the typical aquatic plant community expected in a shallow lake system. The DNR lake management plan states that the greatest depth of submerged plant growth was three feet. Based on a review of the lake depth contours, this indicates the area of the lake with submerged plant growth is very limited. Additionally, livestock may access the lake in certain pastured areas which has altered shoreline conditions causing the loss of emergent vegetation as well as bank erosion.

Improved water clarity within the lake would likely increase the percentage of the lake with submerged plant growth. An increase in the submerged aquatic plant base in Mayhew Lake would help to consume and remove nutrients in the water column as well as provide additional habitat for fish and wildlife.

5.2 RISK ASSESSMENT & WATERSHED RECONNAISSANCE

As part of the Phase I Report for this TMDL, a risk assessment and watershed channel reconnaissance were performed to identify

- The risk of nutrient and sediment transport in the watershed and
- The type and spatial extent of nutrient and sediment sources from channel erosion and mass wasting.

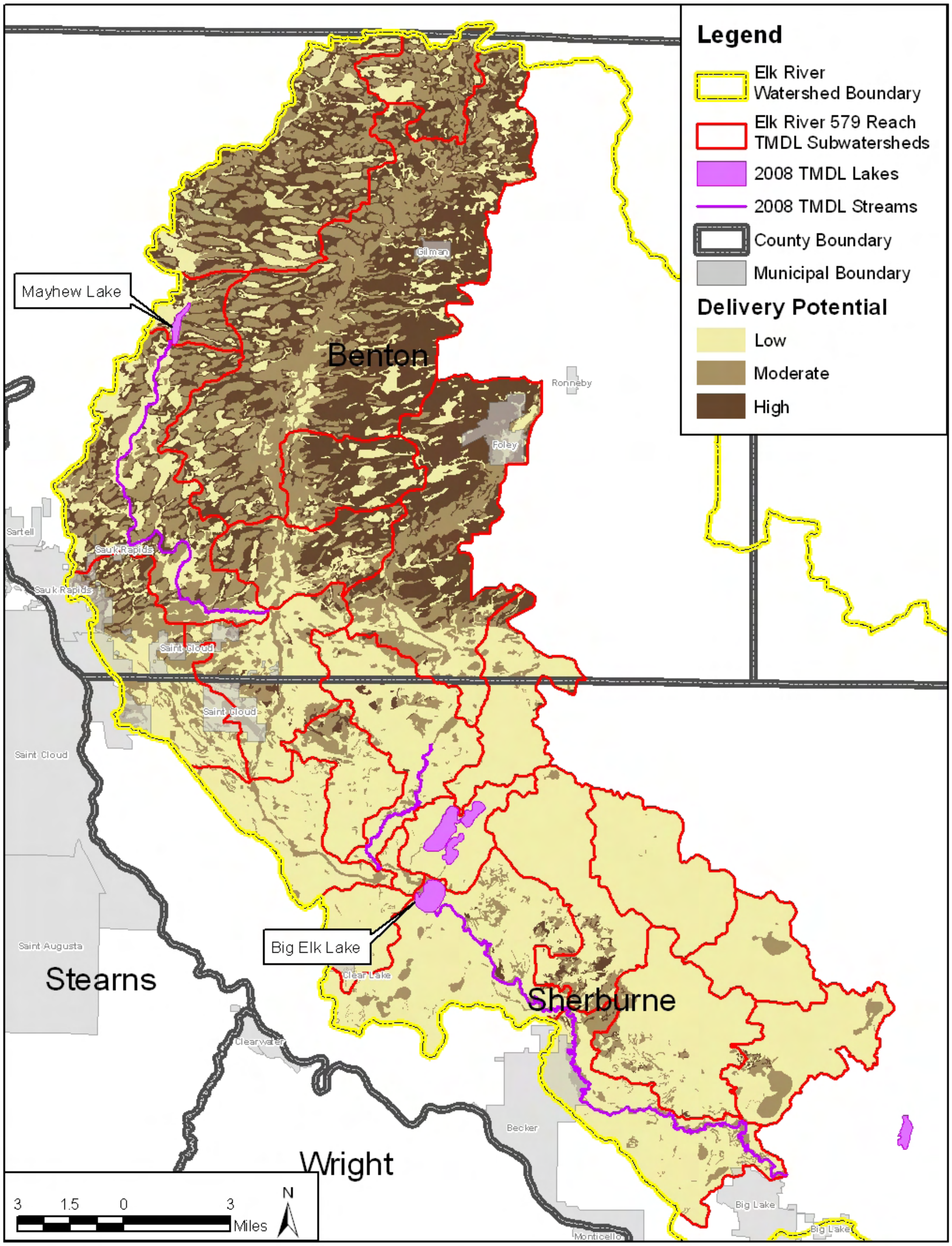
Watershed sources of nutrients and sediments are related to land cover, land use, soil type, and land slope. The Elk River watershed is drained by a dense system of natural and human-made channels and streams. According to the DNR 24K stream network map, there are 656 miles of channels ranging in size from first order to fifth order in that part of the watershed that is upstream of and tributary to the Impaired Waters. This network of channels is a potential conveyance of nutrient and sediment load from the watershed. In addition, streambank erosion and failure could be an additional source of sediment and nutrients to downstream waterbodies.

The purpose of the risk assessment was to use existing data such as land use, land cover, soil type, and slope to identify areas which pose a high risk of nutrient and sediment export to impaired waters. The purpose of the watershed reconnaissance was to provide an initial screening of the channel network, to better understand current channel conditions and to determine if those conditions suggest that in-stream sources of sediment and nutrients were likely to be significant. The outcome of the reconnaissance is an identification of those channels where additional, more detailed analysis should be done to better quantify in-stream sources, and those channels which likely were not significant contributors of sediment and nutrients.

5.2.1 Risk Assessment

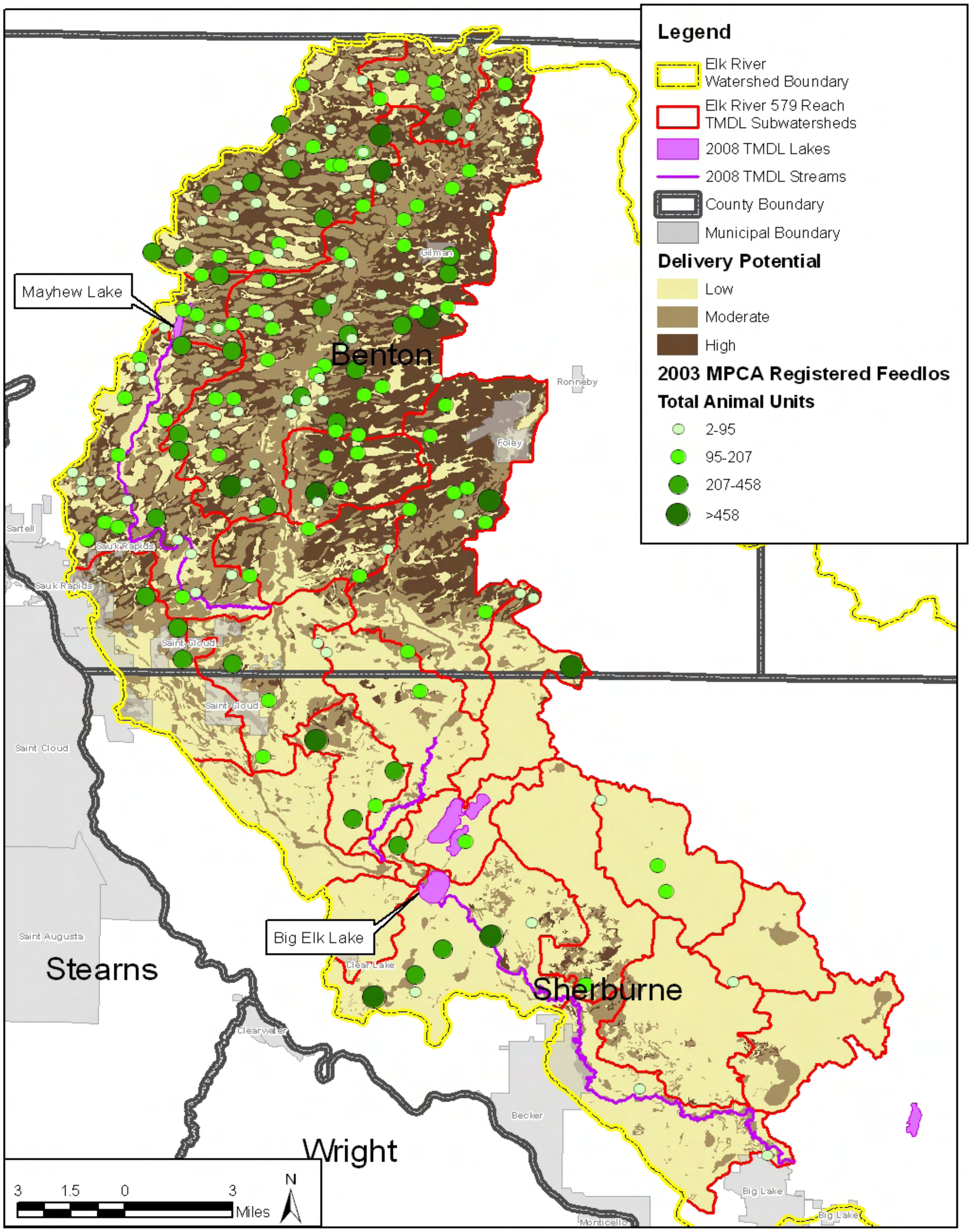
Watershed nutrient and sediment delivery potential was evaluated using runoff potential and erodibility (Figure 5.16). This information was derived from the GIS based Surgo Soils data layers. The results show that the highest delivery potential in the watershed was the watershed upstream of Big Elk Lake, predominantly the area in Benton County.

Figure 5.16 Nutrient and sediment delivery potential



Delivery potential was then evaluated in terms of dominant land use, and the presence of feed lots (Figure 5.17). It is not surprising that agricultural land uses dominate the areas of high delivery potential, given the dominant land use within the watershed is agriculture.

Figure 5.17 MPCA Feed Lot Inventory and high delivery potential



5.2.2 Watershed Reconnaissance Process

The reconnaissance was a field survey of 117 locations in the watershed, evaluating channels ranging from first order tributaries to fifth order rivers (Elk River). To determine the survey locations, a GIS analysis assigned a stream order to each channel in the DNR 24K stream network in the impaired watershed. This network includes both natural streams and human-made channels and ditches. The GIS shapefile was created by the DNR from USGS topographic maps. The stream network shapefile was then intersected with the MNDOT road network shapefile to identify the locations of channel road crossings. Maps of the impaired watershed were then produced displaying the stream network by stream order and highlighting each channel road crossing.

The field survey focused on channel crossings because they tend to be high impact areas with greater stress. Velocities upstream and downstream of culvert crossings tend to be higher than elsewhere in the stream, leading to a greater risk of erosion and bank failure. Overland flow from the impervious road surface and outfalls from storm sewers or road ditches are sources of additional stress. If erosion and bank failure were likely to occur on a stream due to soil type, peak velocity or flow, it would likely be evident at un-stabilized crossings.

The field survey was performed by a team of ten people on September 30, 2008. Each member of the reconnaissance team was assigned either a stream (Mayhew Creek, Elk River) or a major roadway to survey. At each crossing encountered on the stream or major roadway, the team member evaluated stream condition upstream and downstream of the crossing using a standardized bank erosion severity evaluation tool developed by the Natural Resources Conservation Service (NRCS 1983). Adjacent land use, riparian vegetation and conditions, and other data were also recorded for each crossing. Figures 5.18 and 5.19 show the monitoring locations. Table 5.3 shows the summary data recorded at each location.

Table 5.3 Reconnaissance location summary data

• Road name	• Upstream and downstream riparian conditions
• Location number	• Approximate stream width
• Location description	• Type of crossing (culvert, open bottom, etc.)
• Evaluator	• Upstream and downstream adjacent land use
• Date	• General segment description
• Coordinates or map location	• Potential sources of nutrients, bacteria, sediment
• Weather	• Upstream and downstream photos
• Sketch	

Figure 5.18 Stream crossing investigated as potential turbidity sources in the Elk River Watershed upstream of Big Elk Lake in September 2008

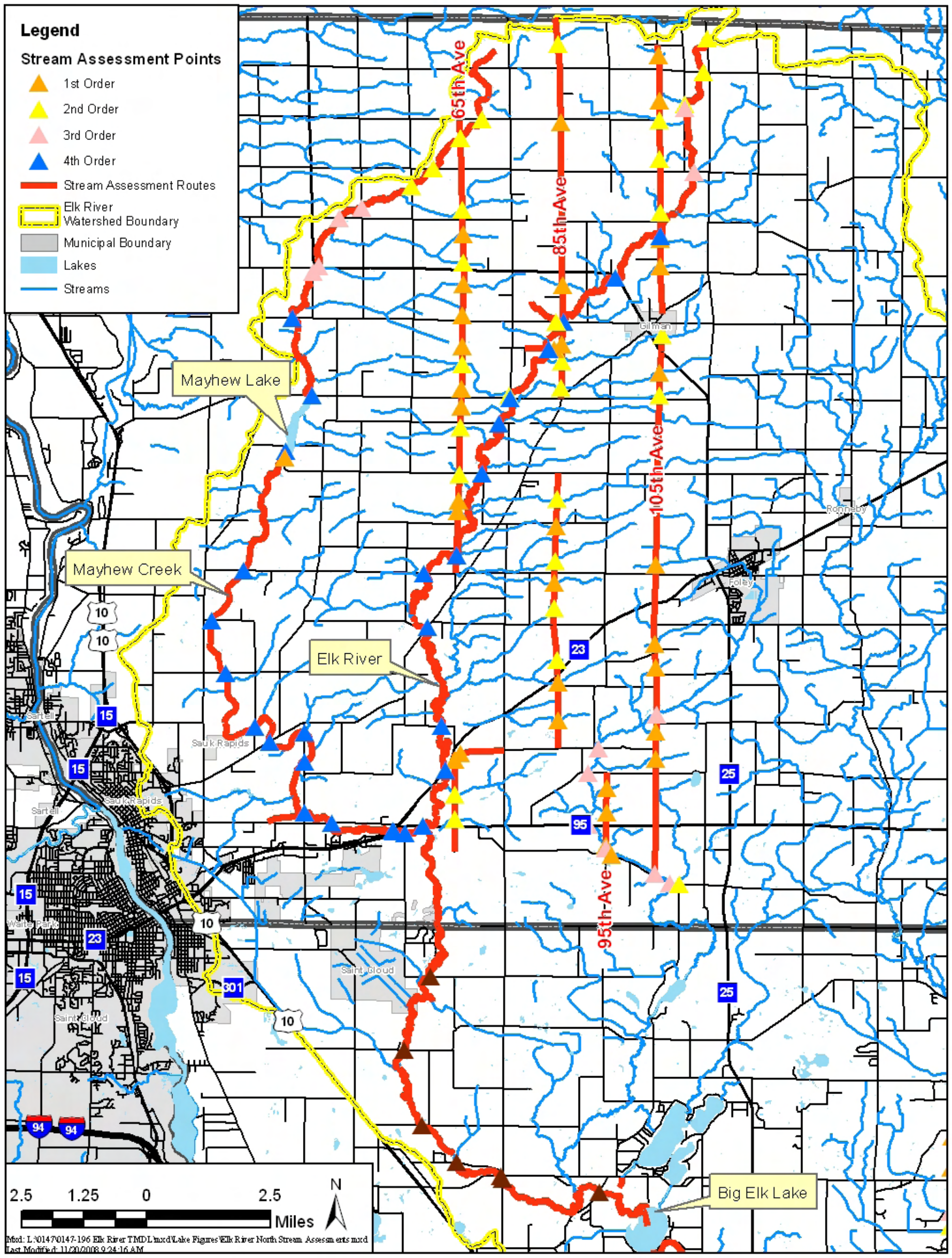
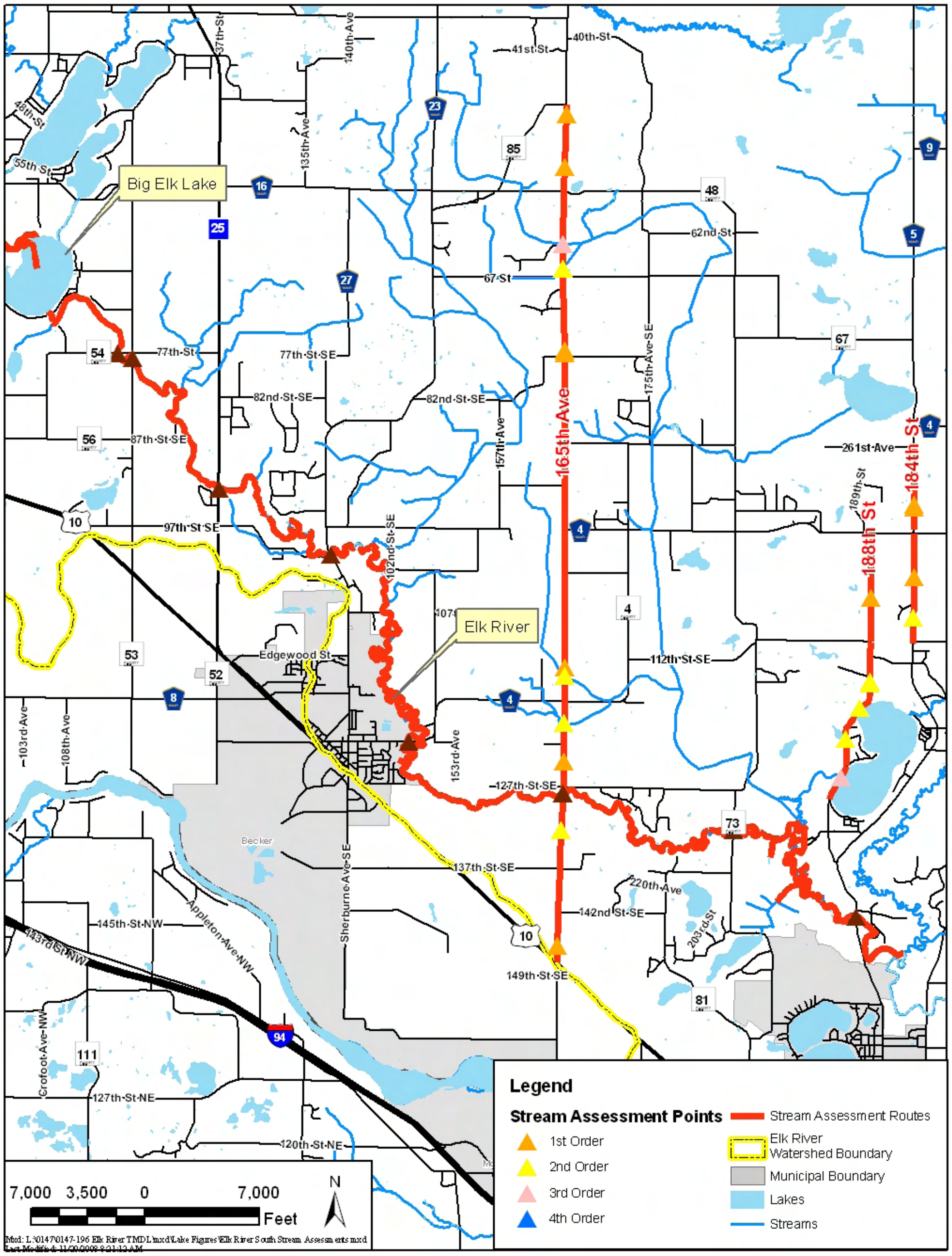


Figure 5.19 Stream crossing investigated as potential turbidity sources in the Elk River Watershed downstream of Big Elk Lake in September 2008



The team member also recorded locations of observed feed lots, locations where animals had access to the channel, areas with minimal buffers, and any other features that might be a significant source of nutrients or sediment.

Table 5.4 below shows the bank condition severity rating standardized bank erosion severity evaluation tool developed by the Natural Resources Conservation Service (NRCS 1983). Each of six factors is scored, and the results are summed into a cumulative rating. The cumulative rating is then used to select an annual recession (bank loss) rate to estimate the volume of material lost annually from the streambank.

For this reconnaissance, the field crew made observations both upstream and downstream of the crossing. If conditions were dissimilar, then the severity rating was performed separately for each side of the crossing, and the crossing condition was assumed to be the worst condition of the two. The field crew also generally estimated the amount of erosion upstream and downstream, choosing between “Spot erosion,” “25-50% erosion,” and “+50% erosion.”

Table 5.4 Bank condition severity rating

Bank Stability:
• Do not appear to be eroding - 0 • Erosion evident - 1 • Erosion and cracking present - 2 • Slumps and clumps sloughing off - 3
Bank Condition:
• Some bare bank, few rills, no vegetative overhang - 0 • Predominantly bare, some rills, moderate vegetative overhang - 1 • Bare, rills, severe vegetative overhang, exposed roots - 2 • Bare, rills and gullies, severe vegetative overhang, falling trees – 3
Vegetation / Cover On Banks:
• Predominantly perennials or rock-covered - 0 • Annuals / perennials mixed or about 40% bare - 1 • Annuals or about 70% bare - 2 • Predominantly bare - 3
Bank / Channel Shape:
• V - Shaped channel, sloped banks - 0 • Steep V - Shaped channel, near vertical banks - 1 • Vertical Banks, U - Shaped channel – 2 • U - Shaped channel, undercut banks, meandering channel - 3
Channel Bottom:
• Channel in bedrock / noneroding - 0 • Soil bottom, gravels or cobbles, minor erosion - 1 • Silt bottom, evidence of active downcutting - 2
Deposition:
• No evidence of recent deposition - 1 • Evidence of recent deposits, silt bars - 0

Cumulative Rating:
• Slight (0-4) Moderate (5-8) Severe (9+)

5.2.3 Findings

Over half the 117 locations surveyed exhibited little or no erosion, shown in Table 5.5 with the cumulative rating of “Slight.” Most of the first order channels that were evaluated exhibited little or no erosion. Many of these first order channels appear to be seasonal or ephemeral. In several cases no channel was found, indicating either hydrologic conditions had changed since the USGS quad map was prepared or the channel had been filled in or vegetated over. Many second and third order channels likewise showed only minor erosion, with significant erosion occurring generally only where pasture animals had access to the stream or at significant road crossings.

Table 5.5 Bank condition severity cumulative rating

Severity	Number	Percent
Slight	62	54%
Moderate	39	34%
Severe	13	11%
No rating	3	
	117	

Mayhew Creek and Elk River, fourth and fifth order streams, tended to have more instances of observed erosion and higher severity of erosion, although significant erosion was found at only a handful of locations. Table 5.6 and 5.7 further summarize the study results.

Table 5.6 Locations observed to have 25% or more of streambank erosion by stream order

Order	25% or More of Streambank Eroded	Spot or Minimal Erosion	Total
1	3	32	35
2	6	24	30
3	4	9	13
4	10	16	26
5	3	10	13
Total	26	91	117

Table 5.7 Bank condition severity cumulative rating by stream order

Stream Order	Bank Condition Severity Cumulative Rating													Total
	Slight					Moderate				Severe				
	0	1	2	3	4	5	6	7	8	9	10	11	14	
1	10	8	3	2	2	2	3	1	1	1				33
2	1	8	5	4	2	3	1	2	2		2			30
3	1	2	1	2		1	3		1	1	1			13
4	1	2	3	3	2	1	6	3		1	2	1		25
5						8			1		2	1	1	13
Total	13	20	12	11	6	15	13	6	5	3	7	2	1	114

The reconnaissance findings suggest that although the watershed that is tributary to the Impaired Waters is drained by an extensive network of channels, it does not appear that streambank erosion from the first, second, and third order streams is a significant source of downstream sediment and nutrients. The reconnaissance found and noted locations where animal access to the channel may be causing localized streambank erosion, although at some of those locations the channel appears stable (Table 5.8). Minimal buffers observed in some locations may be inadequate to filter runoff from adjacent agricultural or pasturage uses. However, these problems were noted at fewer than 10 percent of the locations evaluated.

Table 5.8 Bank condition severity cumulative rating by observed animal access to channel

Cumulative Rating	Severity Rating	Observed Access to Channel	No Observed Access to Channel	Total
Slight	0	1	12	13
	1	1	19	20
	2		12	12
	3		11	11
	4	1	5	6
Moderate	5	2	13	15
	6	1	12	13
	7		6	6
	8	1	4	5
Severe	9	2	1	3
	10	1	6	7
	11	1	1	2
	14		1	1
	N/A	1	2	3
	Total	12	105	117

5.2.4 Recommendation for Additional Data

Based on the findings of this reconnaissance, a full stream assessment of the channel network does not appear warranted. However, the following are recommendations for additional data collection:

1. Many, but not all, observed locations where animals could access the stream exhibited some erosion. Channels, especially second order or higher, adjacent to known feed lots should be surveyed to determine the extent of impact to channel stability.
2. Elk River downstream of Big Elk Lake appeared to be actively undercutting. A more thorough stream assessment should be performed to document existing conditions and to identify needs for stream stabilization.

6.0 Modeling Strategy

6.1 NUTRIENT IMPAIRMENT IN BIG ELK LAKE; TURBIDITY IMPAIRMENT IN THE ELK RIVER

Big Elk Lake is a flow-through lake on the main stem of the Elk River located at river mile 39.2. Big Elk Lake is impaired for nutrients and it is suspected that the nutrient impairment is a major driver in the turbidity impairment on the Elk River. The reach of the Elk River listed for turbidity impairment begins at the outflow of Big Elk Lake at river mile 38.5 and extends down to the confluence with the St. Francis River at river mile 15.5.

A watershed reconnaissance was performed on September 30th, 2008 to evaluate the relative roles of in-stream sources of turbidity and watershed nutrient and turbidity sources to the impairments. The watershed reconnaissance revealed that riparian livestock and other agricultural land uses likely contribute a large nutrient load to Big Elk Lake via the upper reach of the Elk River. The algal blooms are driven by nutrient concentrations and hydraulic residence time of the lake, which is driven by inflows from the Elk River. The reconnaissance also confirmed that algal turbidity from Big Elk Lake is driving the turbidity impairment in the listed reach of the Elk River. In-stream turbidity sources were not significant. As a result of the close linkage between the individual impairments, the modeling strategy for Big Elk Lake and the Elk River should be integrated into a framework that assesses both.

The Water Quality Analysis Simulation Program (WASP) is a U.S. EPA dynamic compartment modeling program for aquatic systems, allowing the user to investigate one, two, or three dimensional systems. There are separate modules within WASP that can be used to address various contaminant categories such as eutrophication, organic chemicals or mercury. Parameters such as CBOD, dissolved oxygen, nitrogen, phosphorus, algae, detritus, and sediment diagenesis can be modeled with the WASP Eutrophication Module, which will be used to address the Big Elk Lake impairment and to quantify the turbidity load to the Elk River from Big Elk Lake.

The equations solved by WASP are based on the key principle of the conservation of mass, meaning that the mass of each modeled water quality constituent must be accounted for within the model. Within the WASP frame work spatial and temporal variability can be accounted for, as well as transport patterns, loading patterns and chemical interactions. The advantages of the WASP model framework include the ease of development of input datasets, which can simply be cut and pasted into the model or can be queried from a linked database. Additionally, the WASP

model can be easily integrated with hydrodynamic models/input files and a virtually unlimited number of plots, spatial grids and/or model result files can be produced by the program.
We propose to model eutrophication in Big Elk Lake to simulate phytoplankton growth due to excess nutrients from point and non point sources. The model results will then be used to quantify the turbidity load to the Elk River from Big Elk Lake due to upper watershed nutrients. Inputs to the WASP model will include continuous flow rate from Elk River and Briggs Chain and nutrient concentrations from these sources measured during Phase II of the TMDL study. Ungauged watershed loads will be modeled using a unit area load method similar to that used to partition watershed loads for allocation.

WASP will be calibrated to in-lake water quality data collected during Phase II of this project in 2009. First, the model will be calibrated to match lake levels and residence times; then the nutrients will be calibrated.

Section 303(d) of the Federal Clean Water Act and EPA's regulations in 40 CFR 130.7 require the consideration of seasonal variation of conditions affecting the constituent of concern and inclusion of a Margin of Safety (MOS) in the development of a TMDL. Projection simulations will be run for the summer critical conditions to represent the required seasonality and conservative modeling assumptions provide the MOS for lake eutrophication models.

Watershed nutrient and turbidity sources will be partitioned to sources in the upper and lower watershed using a unit area load method which draws upon water quality data collected within the watershed, land use, watershed data, point source data and the results of the Risk Assessment and Watershed Reconnaissance.

The turbidity TMDL for the Elk River will be established using a load duration curve method, relying on the long-term USGS gauging station at Elk River as well as continuous flow data collected during Phase II.

6.2 NUTRIENT IMPAIRMENT IN MAYHEW LAKE

Mayhew Lake is located in the upper, northwest corner of the Elk River watershed and lies within the upper portion of its sub-watershed. Mayhew Creek forms the inflow and outflow to Mayhew Lake. In addition to Mayhew Creek, there are two un-named tributaries that flow into Mayhew Lake from the east.

Modeling of the nutrient impairment in Mayhew Lake will be completed using a suite of tools focused on analyzing the internal and external loads as well as the lake response to these loads. Watershed modeling will be completed using the unit area load method to identify watershed sources of phosphorus to the lake. The unit area load model will be calibrated to the existing water quality data and extrapolated to the unmonitored portions of the watershed. Internal loading will be modeled using an anoxic factor and release rate (Nürnberg 2004). Lake response modeling will be completed using the BATHTUB modeling suite including FLUX for calculating watershed loads.

6.3 BACTERIA IMPAIRMENT IN THE ELK RIVER

We propose using a load duration curve to set the bacteria TMDL for the Elk River between Big Elk Lake and the St. Francis River. This approach is similar to that used in the Carver County Bacteria TMDLs approved by the EPA in March of 2007. The basic approach is to quantify the sources of bacteria in the watershed, calculate the potential bacteria loads from each source (i.e. human, cow, deer, etc.), and then determine the potential for loads from each source that reach the receiving water under wet and dry (or seasonal) conditions.

The bacteria source assessment will include a source description and quantification. Bacteria sources will be quantified using available data from

- county feed lot inventories,
- DNR studies on wildlife populations, and
- county and census information on human population.

Literature values will be used to calculate potential bacteria loads from each source (i.e. human, cow, squirrel, etc.).

To link water quality targets and sources and estimate load reductions, bacteria delivery potential will be modeled by evaluating watershed practices, flow conditions, and water quality data. The data analysis will include a load duration curve.

7.0 2009 Monitoring Plan

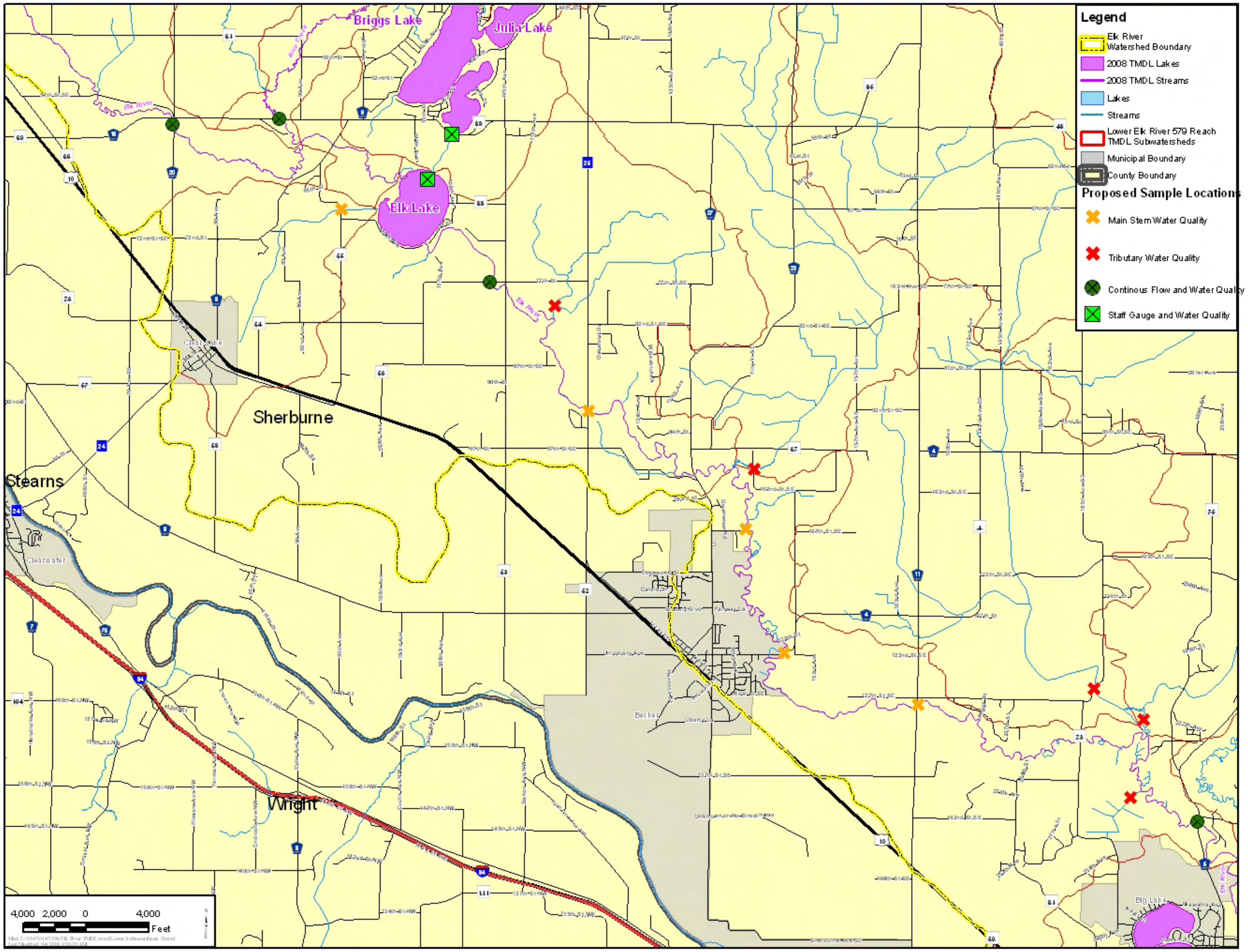
The overall Phase II monitoring plan including locations, schedule, parameters, etc is summarized in Table 7.1 and Figure 7.1 and described in greater detail in the following sections.

Table 7.1 Monitoring Plan

Water	Impairement	Stations	Sample Frequency	Sample Frequency	Parameters	Number of Samples
Mayhew Inflows	Nutrients	3	Every two weeks during flow season (April- Oct 09)	8	TSS, TP, OP, Nitrogen Series, flow, Field Parameters	24
Mayhew Lake	**Nutrients**	1	Monthly (May-Oct 09)	6	TP (2), OP (2), TKN, DO/ Temp Profiles, Surface Chla, Secchi, bottom iron	6
Big Elk Lake	**Nutrients**	1	Every two weeks, (April- Oct 09)	16	TP (2), OP (2), TKN, DO/ Temp Profiles, Surface Chla, VSS, TSS, Secchi, bottom iron	16
Elk River Inflow to Big Elk Lake	**Turbidity, nutrients**	2	Every two weeks during flow season (April- Oct 09)	16	TSS, VSS, DO, TP, OP, Nitrogen Series, field parameters, turbidity tube, Flow (continuous & discrete)	32
Other Big Elk Lake Tribs	**Nutrients, Turb**, biota	2	Every two weeks during flow season (April- Oct 09)	22	TSS, VSS, TDS, DO, TDS, TP, OP, chla, Nitrog. series, field parameters, Turbidity Tube, Flow (discrete & stage readings more frequenly)	44
Elk River Tribs	Nutrients, Turb	5	Every two weeks during flow season (April- Oct 09)	22	TSS, DO, TP, OP, Nitrog. series, *E. Coli*, flow, turbidity tube, field parameters	110
Elk River	**Bact, turbidity**	6	Every two weeks during flow season (April- Oct 09)	22	TSS, VSS, TDS, DO, TP, OP, TKN, NO2+NO3, Chlorophyll, *E. Coli*, Field parameters, flow, turbidity tube	132
T:\0147\196 Elk River TMDL\[Monitoring Plan.xls]Field Efforts_A						
Field Parameters: DO, Temp, Conductivity, pH						

We realize that the monitoring stations selected may not be ideal due to safety, access and logistics and understand there may need to be some modification to the stations. We expect that this will be a collaborative decision process to ensure that even as stations are moved, we will still have all the data needed to set the TMDL upon completion of data collection.

Figure 7.1 Monitoring Plan, Sampling Locations



7.1 BIG ELK LAKE

Measuring the hydrology of Big Elk Lake is key to understanding how the nutrient sources affect both in lake water quality and water quality downstream in Elk River. There are several inflow sources to Big Elk Lake, including the Elk River and the tributary from Briggs Chain of Lakes that contribute nutrient loads to Big Elk Lake. Additional data is needed to quantify the relationship between inflow nutrient concentrations and the corresponding concentrations of nutrients, chlorophyll-a and water clarity in Big Elk Lake.

Continuous flow monitoring stations will be established at the following locations to assist with the nutrient modeling for Big Elk Lake:

- Continuous flow monitoring station at River Mile 44.6 on the Elk River
- Continuous flow monitoring station at River Mile 41.6 on Rice Creek
- Staff Gauge flow station on the inflow tributary to Elk Lake from the Briggs Chain

Flow data collected from these inflow monitoring stations gathered during the TMDL study will be used to further refine the existing hydrological and water quality data sets for Big Elk Lake. For example, if during early spring, the inflow rate to the lake from the Elk River is 200 cfs, the samples should be collected every 4 days. This should cluster water quality samples in the spring, and provide a flow-weighted concentration. This will allow us to observe the quickly changing conditions in the lake during high flow and evaluate the downstream impacts. In-lake data will be collected at similar intervals to inflow data. Sample locations are shown in Figure 7.1, parameters and frequency for both in-lake and inflow sample locations are shown in Table 7.1.

7.2 ELK RIVER

Sample locations on the Elk River and its tributaries were selected based on subwatershed boundaries to maximize coverage. Sample locations are shown in Figure 7.1, parameters and frequency are shown in Table 7.1. The TMDL study will also include establishing continuous flow monitoring stations at the following locations within the listed reach of the Elk River:

- Downstream of Big Elk Lake at River Mile 37.3
- Upstream of the St. Francis River at approximately River Mile 16

Flow data from these monitoring stations will be used in conjunction with the long term flow record at the USGS flow monitoring station to develop a sound understanding of the flow conditions within the listed reach.

Additionally, in-stream sources of turbidity along the main stem of the Elk River will be quantified at 8 stations using the Wisconsin Method.

7.3 MAYHEW LAKE

A continuous flow gauging station will be established on Mayhew Creek during the 2009 monitoring season at the outflow. In addition to continuous flow at the lake outflow, water quality data and discrete flow will be collected at lake inflows bi-weekly from April through October while flow is greater than zero. Two of the three stations are ephemeral streams and are expected to dry up during the monitoring season. In-lake sampling will be conducted monthly at the established monitoring station. Sample locations are shown in Figure 7.1, parameters and frequency are shown in Table 7.1.

7.4 ROLES AND RESPONSIBILITIES

Several organizations including the MPCA, ERWSA and Wenck Associates are involved in the development of the Elk River Watershed TMDLs. As such, we will lay out the roles and responsibilities of each organization/individual as they are described in the work plan.

<u>MPCA Technical Staff:</u> The MPCA Technical Staff will assist the ERWSA staff with several aspects of Phase II as described below and in the work plan.
Assist with high flow gauging, developing rating curves and flow records to be used in model calibration/validation.
Supply data from field work including continuous flow data and continuous monitoring.
Review and approve reports as needed.
Attend public involvement and technical meetings.
Coordinate necessary MPCA involvement including review and approval of work plans.

MPCA Technical staff will also assist with other monitoring investigations, such as the in-stream sediment quantification, as needed.

Technical Staff includes but is not limited to: Phil Votruba, Maggie Leach, Chuck Johnson, Mark Evenson and Greg VanEeckhout.

<u>ERWSA:</u> During Phase II the ERWSA will be responsible for a majority of the monitoring activities as identified in the work plan as follows:
Data collection and sampling (bi-weekly sampling and flow gauging).
Regular data review, QA/QC of field sheets and follow up with MVTL Laboratories to ensure data quality.
Compile the remaining data collected in Phase II, submit to STORET and Wenck.
Establish a stakeholder group, hold stakeholder and technical meetings.
Prepare semi-annual reports and other administrative documentation to the MPCA as required.
Prepare Phase II report and submit to MPCA.

ERWSA staff will coordinate with the MPCA and Wenck to complete Phase II of the TMLDL. Staff (watershed coordinator) will also assist the MPCA in the in-stream sediment quantification. Staff will submit all data to the MPCA for STORET data entry and submit data as needed to Wenck Staff.

ERWSA Staff duties are primarily the responsibility of Tiffany Determan, Watershed Coordinator. Staff also includes Mark Basiletti and Gerry Maciej.

Wenck Associates, Inc.: During Phase II, Wenck staff will provide technical assistance and guidance as defined in the work plan as follows:
Review, interpret and summarize data. Run models identified in Section 6.0 of this report.
Provide report of findings including assimilative capacity and sources.
Participate in project technical meetings and stakeholder meetings.

Wenck will council MPCA and ERWSA staff on selecting a representative reach of the impaired portion of the Elk River to quantify in-stream sources of turbidity. The ERWSA and MPCA will conduct the remaining field work required to quantify in-stream sources in the listed reach of the Elk River using the NRCS Direct Volume Measurement Method (Wisconsin Method) on the representative reach. Because of the MPCA technical staffs familiarity with this work, it is anticipated that one two-person crew will be required for one field day. Field staff will provide Wenck with the data collected.

Per the work plan, ERWSA will complete the Phase II report, while Wenck Associated, Inc. will complete the final TMDL report.

Wenck associated staff includes but is not limited to: Rebecca Kluckhohn, Diane Spector, Jeff Madejczyk, Pam Massaro, Ed Matthiessen, Jordan Shuck, Wes Boll.

8.0 Sampling Protocol

8.1 INTRODUCTION

The sampling protocol documentation below was taken from the Quality Assurance Protection Plan (QAPP) and formatted to suit this Phase I TMDL report. For a more thorough documentation of sampling protocol please refer to the Elk River Bacteria and Turbidity and Big Elk Lake and Mayhew Lake Nutrients TMDL Project QAPP (2009).

8.2 SAMPLING METHODS

All field work for this project, including water sample collection and delivery within the required time frame to MVTL Laboratories, Inc. will be conducted by ERWSA staff. A certified laboratory will conduct all water sample analyses.

Water chemistry field duplicates will be collected 10% of the time for lake and stream samples. All samples will be collected using approved methods and sampling devices. Samples will be transferred from sample collection devices to pre-cleaned polyethylene or glass bottles. Bacteriological samples will be collected in sterile polypropylene bottles. Project staff will be responsible for collecting and transporting or shipping the samples to MVTL which provides the pre-cleaned bottles and the sterile bacteriological bottles. Sampling protocol used throughout this project will follow procedures as outlined by the QAPP.

8.2.1 Grab Samples

Physical parameters will be assessed on-site by use of a multi-probe, meter, or other device.

Water quality samples will be collected using clean polyethylene bottles of appropriate size to provide the laboratory with sufficient sample to perform the requested analyses and reanalysis, if necessary. Amber glass bottles will be used to collect samples for chlorophyll-a analysis. All samples are to be preserved as required, labeled with a unique identifier, and placed in a cooler on ice. Sample information is logged on field data sheets.

Grab sampling is to be conducted using the container type and size appropriate for each particular analysis. In-stream samples are collected at mid-depth near or at the thalweg to obtain a well mixed sample. The method used for any particular sampling event depends on several factors including flow rate, stream depth and width, and accessibility.

Regardless of collection method, the grab sample is stored and transported in a clean, labeled container. The clean container supplied by the analyzing laboratory is not rinsed before the sample is collected.

Variations of the grab sampling method which may be use as needed are described below.

8.2.2 Wading and Hand Collection

If the stream is safe to wade, the sample collector will wade to the center of the stream with a sample bottle. The sample collector faces upstream taking care not to disturb any stream bottom debris or sediment which may contaminate the sample. The sample bottle is inverted and dipped below the surface, then turned upright to collect the sample while holding the bottle about one foot below the water surface. When considering wading, the general rule is that if stream depth (in feet) multiplied by its velocity (feet/second) is greater than the sampler's height (in feet), then the sampler WILL NOT WADE.

8.2.3 Reach Pole Collection

When wading conditions are not safe in smaller streams, a grab sample may be collected using a reach pole. With the reach pole the sample bottle is fitted into a wire cage attached to the end of a long, telescoping reach pole. The sample bottle is inverted and dipped below the surface, then turned upright to collect the sample while holding the bottle about one foot below the water surface.

An alternative method is to use a 1-L polyethylene bottle affixed to the end of the reach pole to collect sample water which is then transferred to the sample bottles on shore. With this method the sampler bottle is triple rinsed with site water before taking samples for laboratory analysis.

8.2.4 Bridge and Rope Collection

For larger rivers where the sampling station is adjacent to a bridge, a grab sample may be collected using a Van Dorn (or equivalent) sampler lowered from the bridge deck near the river thalweg. The Van Dorn sampler is lowered to the river surface and plunged into the water to approximate mid-depth. The sampler is then raised to the bridge deck, and the grab sample is poured into the sample container. The Van Dorn sampler is triple-rinsed with site water before collection of the final sample, however, the sample bottle is not rinsed.

8.3 COLIFORM BACTERIA SAMPLING

8.3.1 Sample Collection, Preservation, and Storage

Because sterile conditions must be maintained during collection, preservation, storage, and analysis of indicator bacteria samples, specific procedures have been developed that must be strictly followed. These procedures vary with types of sampling equipment and source of sample (surface water, ground water, treated water, or waste water).

8.3.2 Surface-Water Sample Collection

The areal and temporal distribution of indicator bacteria in surface water can be as variable as the distribution of suspended sediment because bacteria commonly are associated with solid particles. The methods to collect bacteria samples are similar to that of the methods for collecting suspended sediment.

8.3.3 Hand-Dip Method

If the stream depth and (or) velocity is not sufficient to use a depth-and-width integrating method, the sample will be collected using the hand-dip method. Niskin, ZoBell, and Wheaton samplers hold a sterilizable bottle or bag. The collection of a hand-dipped sample procedure is as follows:

1. Open a sterile, narrow-mouth borosilicate glass or plastic bottle; grasp the bottle near the base, with hand and arm on downstream side of bottle.
2. Without rinsing, plunge the bottle opening downward, below the water surface. Allow the bottle to fill with the opening pointed slightly upward into the current.
3. Remove the bottle with the opening pointed upward from the water and tightly cap it, allowing about 2.5 to 5 cm of headspace. This procedure minimizes collection of surface film and avoids contact with the streambed.

8.3.4 Sample Preservation and Storage

After collection, the samples will be immediately chilled in an ice chest or refrigerator at ≤ 6°C. Analysis is to begin as quickly as possible, preferably within 1 hour but not more than 24 hours after sample collection, to minimize changes in the concentration of indicator bacteria.

8.3.5 Preserving Sample Cleanliness

The rope, used to lower the sampler, is to be coiled inside of a bucket. While pulling the sampler up, the rope will be recoiled into the bucket. This will keep the rope from being contaminated by substances from the bridge deck.

When lowering and raising the sampler the rope should not rub against the side of the bridge. Such rubbing knocks material from the bridge into the sampler, and can contaminate the sample.

8.4 CHLOROPHYLL-A SAMPLING

Two liter samples will be collected with the two meter depth-integrated sampler. Sample bottles will be immediately placed in ice cooler (ice to 4°C) after collection. Samples will be kept out of sunlight.

Filtering is to take place as soon as possible after sample collection. Portable equipment facilitates the implementation of this procedure on shore or back at the office. The chlorophyll-a sampling procedure to be followed is outlined below:

- Set up filtering equipment. This will include placing a filter (0.45 µ, glass-fiber) on the funnel base with a forceps and twisting on the funnel. The funnel drains into a two liter vacuum flask.

- Measure out a known quantity of sample in a graduate (50 – 1,000 mL) depending on the observed population of algae in the lake. Filter enough sample so the filter is just a light green color.
- Pour sample into filter funnel and begin filtering sample through apparatus described above.
- After known sample has been filtered, use a squirt bottle of deionized water to wash down any algae that may be clinging to the side of the funnel. Continue filtering until filter looks dry.
- Remove vacuum and take apart filter funnel apparatus.
- Fold filter in half with forceps (do not touch with fingers) and place in Petri dish.
- Close Petri dish and write the following information on the Petri dish with a permanent marker.

    - Lake name and ID number
    - Site location
    - Date and time of sample
    - Amount of sample filtered

- Wrap Petri dishes with aluminum foil and place sample in special dry ice cooler which contains about 5 – 15 lbs. of dry ice and transport to laboratory as soon as possible.

8.5 TRANSPARENCY TUBE FIELD SAMPLING PROTOCOL

Water sample will be collected in a clean bucket or bottle at mid-stream and depth.

1. Wading or From Stream Bank.

If staff cannot sample safely, only a visual observation will be made that day (Appearance). If a sample from mid-stream and depth is not possible, stagnant water will be avoided and sample will be collected as far from the shoreline as is safe. The sampler is not to stir up the bottom. The sampler will face upstream as the bucket is filled. The sampler is to avoid collecting sediment from the stream bottom or materials from the water surface.

2. From Atop a Bridge or Culvert.

With a rope tied to its handle, the sampler is to lower a bucket down to the stream and collect water. Tube readings are to be taken in open conditions avoiding direct sunlight. The sampler will pour the water from the bucket into the tube until the symbol on the bottom is no longer visible. While looking down into the tube, the valve is opened at the bottom to slowly release water until you can JUST begin to make out the symbol on the bottom. Note this depth. Water is released a bit more water until the symbol is just visible. This depth is noted. The average of the two depths is recorded on the data sheet to the nearest centimeter. If the symbol is still visible when the tube is full, > 60 cm is indicated on the data sheet.

8.6 RECORDS, FIELD INSTRUMENTS, AND QUALITY ASSURANCE

Field-measurement data and other field information will be recorded, either on paper or electronically, while in the field. Field measurement data, methods, equipment and calibration information will be recorded on field forms and in instrument log books. Field conditions will be recorded as noted below.

Stream Stage
Water level will be estimated or recorded from a stream gauge each time a sample is collected.
L=low; N=normal; H=high

Appearance
The appearance will be recorded during each sample event. The one number that best describes the appearance of stream water within one meter of the sampling site as described below:

1A = Clear – crystal clear, transparent water
1B = Tea-colored – transparent water which has been discolored by dissolved organic matter (lignin) from up–stream bogs or wetlands
2 = Cloudy – is not quite crystal clear; is cloudy, white, or gray
3 = Muddy – cloudy brown due to high sediment levels
4 = Green – due to algae growth; indicative of excess nutrients released into the stream
5 = Muddy AND Green – a combination of cloudy brown from high sediment levels and green from algae growth

Recreational Suitability
During each sampling event the number that best describes the samplers opinion of how suitable the stream water is for recreation and enjoyment will be recorded.

1 = Beautiful, could not be better
2 = Very minor aesthetic problems. Excellent for body-contact recreation, e.g., swimming, wading, frog–catching
3 = Body-contact recreation and aesthetic enjoyment slightly impaired
4 = Recreation potential and level of enjoyment of the stream substantially reduced, e.g., you would not swim but would boat or canoe
5 = Swimming and aesthetic enjoyment of the stream is nearly impossible

8.7 THE SECCHI DISK

Excessive waves, wind, or sunlight may jeopardize Secchi Disk readings. To minimize these effects, secchi readings will be taken during calm days that are partly cloudy to sunny. The boat is to be anchored at the sampling station to avoid boat drift and the Secchi disk will be lowered off the shady side of the boat. If the Secchi disk drifts too fast for an accurate reading, i.e., the line is not vertical in the water, the disk should be weighted make it sink faster and the reading should be taken on the downwind side of the boat. If none of these techniques work, the measurement will not be taken that day as it would not be a good representation of lake clarity conditions on that day.

Weather conditions are also recorded along with the Secchi disk reading.

- **Measurement Methods**

1. Slowly lower the disk into the water to the point where it just disappears.
2. Place a clothespin on the line where it meets the water surface, or mark the point on the line in some other way.
3. Continue lowering the disk a few more inches, and then slowly raise it until it just becomes visible again. Mark this spot with another clothespin or hold the rope here between your fingers.
4. The spot halfway between the two marks represents the average Secchi Disk reading. Mark the spot by moving the clothespin or other marker to the spot.
5. Carefully measure or count the distance from the disk to the marked spot. Record the distance to the nearest tenth of a foot or meter.

- **QA/QC Considerations**

The Secchi Disk reading is subjective because of differences in people’s vision and weather conditions. There is no QA/QC check that can be used to "calibrate" the different readings. The slight differences in vision generally are considered insignificant. Some of the error caused by the subjectivity of this measurement can be reduced by having the same person make the measurement each time.

9.0 References

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