Assessment Report of Selected Lakes Within the North Fork Crow River Watershed Upper Mississippi River Basin

Minnesota Pollution Control Agency

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North Fork Crow River Watershed
Upper Mississippi River Basin
Intensive Watershed Monitoring 2009

Minnesota Pollution Control Agency
Water Monitoring Section
Lakes and Streams Monitoring Unit

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Executive Summary

The Minnesota Pollution Control Agency (MPCA) conducts and supports lake monitoring for a variety of objectives. Staff within the MPCA's Lakes and Streams Monitoring Unit sample approximately 100 lakes per year, coordinate citizen volunteer monitoring through the Citizen Lake Monitoring Program, and manage Surface Water Assessment Grants given to local groups to monitor lake and stream water quality. Watershed-based monitoring emphasizes large lakes (500 acres or greater) whenever possible. All water quality data from these activities are compared to state water quality standards to determine if a given lake is fully supporting or not supporting standards set for recreational use (e.g., swimming, wading, etc.). Lakes not supporting aquatic recreational use are termed "impaired" and are placed on a list biennially. This list is formally termed the 303(d) list (referencing the section within the federal Clean Water Act that requires us to assess for condition); it is also commonly called the "Impaired Waters List". A lake placed on the Impaired Waters List is required to be intensively researched through a Total Maximum Daily Load (TMDL) study to determine the source and extent of the pollution problem. The study also requires the development of a restoration plan. For unimpaired waters, a protection plan will be developed following the assessment process. It should be noted that a great deal of lake monitoring is also carried out by various other MPCA staff and local groups who are undertaking TMDL studies or other, special projects.

This report details the assessment of lakes within the North Fork Crow River Hydrologic Unit Code (HUC)-8 watershed. The North Fork Crow River watershed is made up of nineteen HUC-11 intensively monitored watersheds. A general description at the eight-digit HUC level is provided, followed by discussions for each 11-digit HUC that has one or more assessed lakes. A full list of the assessed lakes, including their morphometric characteristics, within the North Fork Crow River watershed is located in Appendix A.

Many of the North Fork Crow River watershed lakes possessing assessment level data were determined to be non-supporting of recreational use. Of the 68 lakes that had complete datasets available for assessment, 28 were considered to be supporting aquatic recreation use and 40 were not supporting aquatic recreation use. Because of the high number of lakes in the North Fork Crow River, in depth discussions were not possible for all 68 lakes; however a subset of large or otherwise prominent lakes in each HUC-11 were discussed further.

Introduction

Intensive Watershed Monitoring Approach

MPCA conducts and supports lake monitoring for a variety of objectives. One of our key responsibilities per the federal Clean Water Act is to monitor and assess lakes in Minnesota to determine whether or not these lakes support their designated uses. This type of monitoring is commonly referred to as condition monitoring. While the MPCA conducts its own lake monitoring, local partners (SWCDs, watershed districts, etc.) and citizens play a critical role in helping us because their efforts greatly expand our overall capacity to conduct condition monitoring. To this end, the MPCA coordinates citizen volunteer monitoring through the Citizen Lake Monitoring Program (CLMP), and manages Surface Water Assessment Grants given to local groups to monitor lake water quality. All of the data from these activities are combined with our own lake monitoring data to assess the condition of Minnesota lakes. Lake condition monitoring activities are focused on assessing the recreational use-support of lakes and identifying trends over time. The MPCA also assesses lakes for aquatic consumption use-support, based on fish-tissue and water-column concentrations of toxic pollutants.

The primary organizing approach to MPCA's condition monitoring is the "major" watershed (eight-digit hydrologic unit code). There are 81 major watersheds in Minnesota, and the MPCA has established a schedule for intensively monitoring six-eight of them annually. With this strategy, the MPCA and its partners will cycle through all 81 watersheds every ten years. The MPCA began aligning its stream condition monitoring to this watershed approach in 2007. Lake monitoring was brought into this framework in 2009. The year 2017 will mark the final year of the first ten-year cycle. The watershed approach provides a unifying focus on the water resources within a watershed as the starting point for water quality assessment, planning, and results measures. By intensively monitoring lakes and streams within a given watershed at the same time, the lake and stream data can be considered together to provide a comprehensive picture of water quality status and a determination can be made regarding how best to proceed with development of restoration and protection strategies.

Even when pooling MPCA, local group and citizen resources, we are not able to monitor all lakes in Minnesota. The primary focus of MPCA monitoring is lakes $\geq$500 acres in size ("large lakes"). These resources typically have public access points, they generally provide the greatest aquatic recreational opportunity to Minnesota's citizens, and these lakes collectively represent 72 percent of the total lake area (greater than ten acres) within Minnesota. Though our primary focus is on monitoring larger lakes, we are also committed to directly monitoring, or supporting the monitoring of, at least 25 percent of Minnesota's lakes between 100-499 acres ("small lakes"). In most years, we monitor a mix of large and small lakes, and provide grant funding to local groups to monitor lakes that fall in the 10-499 acre range. Currently, we are fully meeting the "large" lake goal, and we are greatly exceeding the "small" lake monitoring goal.

MPCA lake monitoring activities were not yet in sync with the watershed approach in 2008; the year MPCA intensively monitored streams in the North Fork Crow River watershed to assess their condition. MPCA monitoring of large lakes within the North Fork Crow River watershed was concluded in 2009. This report will describe all available lake data collected within the past ten years by partner agencies, grantees, and citizen volunteers found in STORET for the North Fork Crow watershed. Trophic status, thermal stratification, temporal trends, model-predicted phosphorus and assessment status are noted for all lakes with sufficient data. Further detail on concepts and terms in this report can be found in the Guide to Lake Protection and Management: (http://www.pca.state.mn.us/water/lakeprotection.html).

Lake monitoring and data storage

The MPCA collects water quality data for lakes from May through September for each of the applicable years. Data collected from June through September is used to assess the lake's condition while May data is collected to observe lake conditions near the spring turn over and compare this with the remaining seasonal data. Lake surface samples were collected with an integrated sampler, a polyvinyl chloride (PVC) tube two meters (6.6 feet) in length with an inside diameter of 3.2 centimeters (1.24 inches). Depth total phosphorous (TP) samples were collected with a Kemmerer sampler. A summary of data follows (Appendix B).

For lakes sampled by the MPCA, sampling procedures were employed as described in the MPCA Standard Operating Procedure for Lake Water Quality document, which can be found at: http://www.pca.state.mn.us/publications/wq-s1-16.pdf. Samples collected by the MPCA were sent to the Minnesota Department of Health using Environmental Protection Agency-approved methods for laboratory analysis. Samples were analyzed for nutrients, color, solids, pH, alkalinity, conductivity, and chlorophyll-*a* (chl-*a*). Temperature and dissolved oxygen (DO) profiles and Secchi disk transparency measurements were also taken. Historical DO and temperature profiles were used for water column analysis in the absence of more recent data.

Data collected by MPCA and submitted to MPCA by external partners is placed in the United States Environmental Protection Agency's data warehouse, STORET. MPCA makes this data available to the public through the Environment Data Access webpage (http://www.pca.state.mn.us/index.php/topics/environmental-data/eda-environmental-data-access/eda-surface-water-searches/eda-surface-water-data-home.html). Individual lake summaries are also available via the MPCA webpage at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/lake-water-quality-data-search.html.

Lake morphometry and mixing

Lake area, depth, and mixing have a significant influence on lake processes and water quality. Lake depths of 4.5 meters (15 feet) or less are often well suited for macrophyte (rooted plant) growth and this portion of the lake is referred to as the *littoral* area. Shallow lakes are often well-suited for macrophyte growth and it is not uncommon for emergent and submergent plants to be found across much of the lake. These plant beds are a natural part of the ecology of these lakes and are important to protect.

The size (area) of the lake as compared to the size of its watershed can be an important factor as well; whereby lakes with small watershed areas relative to their surface area often receive low water and nutrient loading and absent significant sources of nutrients in their watershed, often have good water quality. In contrast, lakes that have large watersheds relative to their surface area often receive high water and nutrient loading, which may result in poor water quality. Modeling, as described in the next section, can help predict the response of the lake.

Thermal stratification (formation of distinct temperature layers), in which deep lakes (maximum depths of nine meters or more) often stratify (form layers) during the summer months and are referred to as *dimictic*

(Figure 1). These lakes fully mix or turn over twice per year; typically in spring and fall. Lakes with large surface area and shallow depth (maximum depths of five meters or less) in contrast, typically do not stratify and are often referred to as *polymictic*. Lakes, with moderate depths, may stratify intermittently during calm periods, but mix during heavy winds and during spring and fall. Measurement of temperature throughout the water column (surface to bottom) at selected intervals (e.g. every meter) can be used to determine whether the lake is well-mixed or stratified. The depth of the thermocline (zone of maximum change in temperature over the depth interval) can also be determined. In general, dimictic lakes have an upper, well-mixed layer (epilimnion) that is warm and has high oxygen concentrations. In contrast, the lower layer (hypolimnion) is much cooler and often has little or no oxygen. This low oxygen environment in the hypolimnion is conducive to phosphorus being released from the lake sediments. During stratification, dense colder hypolimnion waters are separated from the nutrient-hungry algae in the epilimnion. Intermittently (weakly) stratified polymictic lakes are mixed in high winds and during spring and fall. Mixing events allow the nutrient rich sediments to be re-suspended and are available to algae.

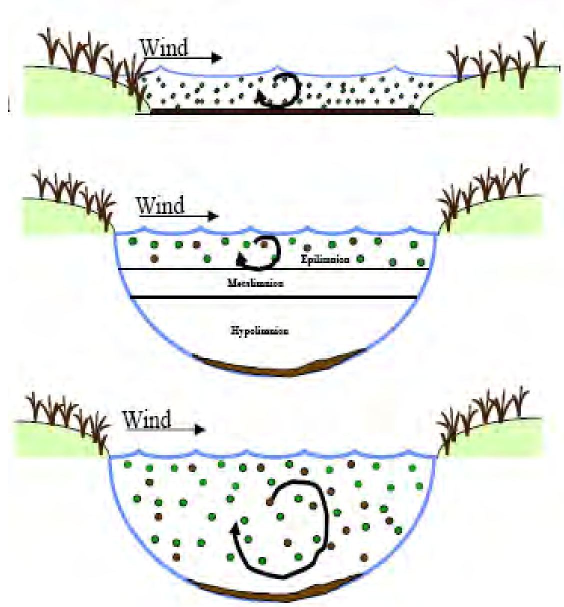
Minnesota's lake standards differentiate among deep and shallow lakes. Shallow lakes are defined as those with maximum depths of 4.5 meters (15 feet) or less or where 80% or more of the lake is littoral ($\leq$ 4.5 meters). As noted above shallow lakes are often well mixed and may have extensive growths of macrophytes. In contrast, deep lakes will often stratify during the summer and often have less surface area that can support macrophyte growth.

Figure 1: Lake stratification

Polymictic Lake
Shallow, no layers,
Mixes continuously
Spring, Summer & Fall

Dimictic Lake
Deep, form layers,
Mixes Spring/Fall

Intermittently Stratified
Moderately deep
Mixes during high winds
Spring, Summer, & Fall



Data analysis and modeling

A standard approach to data analysis is applied to all fully assessed lakes. The major steps are as follows:

1. Dissolved oxygen and temperature data from the most recent one or two years is reviewed and may be charted as well. Profile data are used to determine whether the lake stratifies, depth of thermocline and presence or absence of oxygen in the bottom waters. This step is essential for characterizing the lake and aids in determining whether internal recycling of phosphorus may be a significant contributor to phosphorus loading during summer months. This evaluation also helps determine the proportion of the water column that may be available for fish habitation during the summer.

2. Total phosphorus (TP), chlorophyll-a (chl-*a*) and Secchi transparency data from the two most recent summers are evaluated. In most instances monthly data will be charted to look for correspondence among the TP, chl-*a*, and Secchi measures (also referred to as trophic status measures). Charting the data also allows for patterns to be observed that may help indicate whether internal recycling and/or shifts in the biology of the lake (macrophyte growth/senescence, zooplankton cropping of algae etc.) may be important factors in moderating the trophic status of the lake.

3. Long-term trends based on available summer-mean TP, chl-*a*, and Secchi are assessed when possible. These data are typically charted and analyzed for trends. If statistically-based CLMP trend analysis was conducted that will be noted as well. If a trend is noted and the investigator is aware of potential causes for the trend that will be noted as well.
4. Numerous complex mathematical models are available for estimating nutrient and water budgets for lakes. These models can be used to relate the flow of water and nutrients from a lake's watershed to observed conditions in the lake. Alternatively, they may be used for estimating changes in the quality of the lake as a result of altering nutrient inputs to the lake (e.g., changing land uses in the watershed) or altering the flow or amount of water that enters the lake. To analyze the most recent water quality of lakes within the North Fork Crow River watershed, the Minnesota Lake Eutrophication Analysis Procedures (MINLEAP) model (Wilson and Walker, 1989) was used. MINLEAP was developed by MPCA staff based on an analysis of data collected from the ecoregion reference lakes. It is intended to be used as a screening tool for estimating lake conditions with minimal input data and is described in detail in Wilson and Walker (1989). For the analysis of lakes within the North Fork Crow River watershed, MINLEAP was applied as a basis for comparing the observed TP, chl-*a*, and Secchi values with those predicted by the model based on the lake depth and size and the size of the watershed. Individual results for each of the assessed lakes will be discussed in the lake summary portion of the HUC-11 watershed sections within this report. Complete MINLEAP results can be found in Appendix B.

In addition to fully assessed lakes there are often numerous lakes that do not have sufficient data for assessment. In these instances existing data (TP, chl-*a*, and Secchi) will be summarized and noted in summary tables. In some instances no data other than remote sensed Secchi may be available. This data will be summarized or noted as appropriate. In most instances there will be little or no discussion of lakes that are not fully assessed; however summary data will be compiled so that more comprehensive characterizations of lake condition at the HUC-11 and HUC-8 scales can be made.

303 (d) Assessment

The federal Clean Water Act requires states to adopt water quality standards to protect waters from pollution. These standards define how much of a pollutant can be in the water and still allow it to meet designated uses, such as drinking water, fishing and swimming. The standards are set on a wide range of pollutants, including bacteria, nutrients, turbidity and mercury. A water body is "impaired" if it fails to meet one or more water quality standards.

Under Section 303(d) Impaired Waters List of the Clean Water Act, the state is required to asses all waters of the state to determine if they meet water quality standards. Waters that do not meet standards are added to the 303(d) Impaired Waters List and updated every even-numbered year. If a water resource is listed, an investigative study termed a Total Maximum Daily Load (TMDL) is conducted to determine the sources and magnitude of the pollution problem, and to set pollutant reduction goals needed to restore the waters. The MPCA is responsible for monitoring surface waters, assessing condition of lakes and streams, creating the 303(d) Impaired Waters List, and conducting or overseeing TMDL studies in Minnesota.

TP, chl-*a*, and Secchi transparency are used to determine if a lake meets aquatic recreational use standards (ARUS). Minnesota's ecoregion-based eutrophication standards are listed in Table 1. For a lake to be assessed as impaired it must exceed the causative variable (TP) and one or more of the response variables: chl-*a* and Secchi transparency. The North Central Hardwood Forests (NCHF) and Western Corn Belt Plains (WCBP) ecoregion standards were used for assessing lakes in the North Fork Crow River watershed. The appropriate standards are based on which ecoregion the lake is located in and whether the lake is considered deep or shallow. Individual assessments for each of the lakes will be discussed in the lake summary portion of the HUC-11 watershed sections within this report.

Table 1: Minnesota lake eutrophication standards by ecoregion and lake type (Heiskary and Wilson, 2005) and 2010 303(d) assessment values.

Ecoregion	TP	Chl-*a*	Secchi
	ppb	ppb	meters
NLF – Lake trout (Class 2A)	< 12	< 3	> 4.8
NLF – Stream trout (Class 2A)	< 20	< 6	> 2.5
NLF – Aquatic Rec. Use (Class 2B)	< 30	< 9	> 2.0
NCHF – Stream trout (Class 2a)	< 20	< 6	> 2.5
NCHF – Aquatic Rec. Use (Class 2b)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
WCBP & NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
WCBP & NGP – Aquatic Rec. Use (Class 2b) Shallow lakes	< 90	< 30	> 0.7

North Fork Crow River Watershed Background

The major watersheds in Minnesota are classified with the 8-digit HUC system. This is a standardized watershed classification system developed by United States Geological Survey (USGS) in the mid1970s. Hydrologic units are watershed boundaries organized in a nested hierarchy by size. An eight-digit code uniquely identifies each of the four levels of classification within four two-digit fields. The first two digits identify the water-resources region; the first four digits identify the sub-region; the first six digits identify the accounting unit, and the addition of two more digits for the cataloging unit completes the eight-digit code (Seaber, P.R., et al. 1987).

HUC-8 watershed characteristics

The North Fork Crow River watershed covers a 382,361 hectare (ha; 944,836 acre) area in central Minnesota within the Upper Mississippi River Basin. A majority of the watershed lies within the NCHF ecoregion with a small portion residing in the WCBP ecoregion (Figure 2). The watershed drains to the southeast into the Mississippi River via the Crow River near Dayton, MN. Agriculture accounts for the majority of land use activities within the watershed and the relative percentage of cultivated use is slightly above the typical range for the NCHF ecoregion (Table 3). Watershed areas were calculated based on the HUC-11 watershed coverage provided by the Natural Resource Conservation Service (1999). The distribution of registered feedlots and surface discharging National Pollution Elimination Discharge System (NPDES) permitted facilities are found in Figure X.

The North Fork Crow River watershed is comprised of nineteen 11 digit HUC minor watersheds (Figure 3 and Table 4). Seventeen of these HUC-11 watersheds have lakes that have sufficient monitoring data to allow assessment. A majority of the soil types within the watershed are transitional forest-prairie soils. The soils are predominantly from the Central Iowa and Minnesota Till Prairies major land resource area. These soils tend to be well to poorly drained loamy soils. Erosion control is commonly a problem as well as drainage. The landscape is a level to gently rolling area (USDA 2006).

A summary of the morphometric characteristics of the lakes with sufficient data to allow for assessment within the North Fork Crow River watershed is presented in Table 2. Of the 250 total lakes (> 10 acres) within the HUC-8 watershed, 35 percent have some data and 27 percent have been assessed for aquatic recreation use (Table 4 and Figure 4).

Table 2: Assessed lakes within the North Fork Crow River Watershed sorted by Lake ID

Lake ID	Lake Name	County	Ecoregion	Area	Max Depth	Mean Depth	Littoral Area	Watershed Area
				Hectares	Meters	Meters	%	Hectares
27-0169-00	Cowley	HENNEPIN	NCHF	19	2.1			
27-0191-01	West Sarah	HENNEPIN	NCHF	138		3.8		2227
27-0191-02	East Sarah	HENNEPIN	NCHF	80		4.5		2227
27-0199-00	Hafften	HENNEPIN	NCHF	16	13.4	3.8	61	
34-0044-00	Diamond	KANDIYOHI	NCHF	628	8.2	4.8	41	7280
34-0062-00	Calhoun	KANDIYOHI	NCHF	251	4.0	1.2	100	3066
34-0066-00	Long	KANDIYOHI	NCHF	127	13.7	5.0	44	
34-0079-00	Green	KANDIYOHI	NCHF	2,239	34.1	8.2	38	37,716
34-0119-00	Elkhorn	KANDIYOHI	NCHF	28		5.1	35	
34-0154-00	Nest	KANDIYOHI	NCHF	396	12.2	4.2	56	31,842
34-0158-01	Mud	KANDIYOHI	NCHF	360	1.2		100	25,922
34-0158-02	Mud	KANDIYOHI	NCHF	329	1.8		100	25,922
34-0158-03	Crow River Mill Pond (East	KANDIYOHI	NCHF	13	4.2		100	25,922
34-0158-04	Crow River Mill Pond (Mid)	KANDIYOHI	NCHF	8	4.2		100	25,922
43-0073-00	Hook	MCLEOD	NCHF	131	5.5	1.9	99	
47-0002-00	Francis	MEEKER	NCHF	425	5.8	2.4	95	4,496
47-0015-00	Jennie	MEEKER	NCHF	428	4.3	2.5	100	5,001
47-0026-00	Long	MEEKER	NCHF	66	8.5		66	
47-0032-00	Spring	MEEKER	NCHF	80	9.1		76	
47-0038-00	Big Swan	MEEKER	NCHF	261	9.8	4.6	54	20,363
47-0046-00	Washington	MEEKER	NCHF	979	5.2	2.4	93	9,136
47-0050-00	Manuella	MEEKER	NCHF	117	15.5	6.3	37	
47-0064-00	Erie	MEEKER	NCHF	75	10.4	3.4	46	
47-0068-00	Stella	MEEKER	NCHF	241	22.9	5.3	51	3,069
47-0082-00	Dunns	MEEKER	NCHF	63	6.1	3.5	61	2,260
47-0088-00	Richardson	MEEKER	NCHF	48	14.3	6.0	41	2,057
47-0119-00	Minnie-Belle	MEEKER	WCBP	240	14.9	8.0	31	783
47-0134-02	Ripley (west portion)	MEEKER	WCBP	241		3.0		3,343
47-0177-00	Long	MEEKER	WCBP	282	3.4	1.8	100	7,353
47-0183-00	Hope	MEEKER	WCBP	118		1.6	100	1,856
61-0023-00	Grove	POPE	NCHF	144	9.5		69	
73-0144-00	Pirz	STEARNS	NCHF	27				
73-0196-00	Rice	STEARNS	NCHF	613	12.5	4.8	58	70,075
73-0200-01	Mud	STEARNS	NCHF	55	1.5		100	74,488

Table 2: Assessed lakes within the North Fork Crow River Watershed sorted by Lake ID, continued

Lake ID	Lake Name	County	Ecoregion	Area	Max Depth	Mean Depth	Littoral Area	Watershed Area
				Hectares	Meters	Meters	%	Hectares
73-0200-02	Koronis (main lake)	STEARNS	NCHF	1,191	39.0	8.9		74,542
86-0001-00	Foster	WRIGHT	NCHF	52	3.0		100	1,214
86-0009-00	Martha	WRIGHT	NCHF	40	6.7	2.5	74	
86-0011-00	Charlotte	WRIGHT	NCHF	95	14.0	6.5	40	1,776
86-0023-00	Beebe	WRIGHT	NCHF	120	8.2	3.6	61	389
86-0031-00	Pelican	WRIGHT	NCHF	945	2.7	1.9		9,344
86-0041-00	Dean	WRIGHT	NCHF	70	7.0	3.1	72	672
86-0046-00	Crawford	WRIGHT	NCHF	43	5.8	0.8	98	
86-0051-00	Constance	WRIGHT	NCHF	67	7.0	3.8	54	375
86-0053-02	Pulaski (main bay)	WRIGHT	NCHF	291		11.1		1,349
86-0086-00	Fountain	WRIGHT	NCHF	171	4.6			
86-0090-00	Buffalo	WRIGHT	NCHF	620	10.1	4.3	49	12,473
86-0106-00	Little Waverly	WRIGHT	NCHF	135	3.0	1.9	100	
86-0107-00	Deer	WRIGHT	NCHF	69	8.2	2.6	77	
86-0112-00	Malardi	WRIGHT	NCHF	39				
86-0114-00	Waverly	WRIGHT	NCHF	197	19.8	7.5	29	
86-0120-00	Ramsey	WRIGHT	NCHF	124	24.4	5.9	49	
86-0134-01	Upper Maple	WRIGHT	NCHF	293	3.0	5.1		1,192
86-0182-00	Rock	WRIGHT	NCHF	73	11.3	4.1	57	
86-0184-00	Dutch	WRIGHT	NCHF	63	9.1		73	
86-0188-00	Emma	WRIGHT	NCHF	73	4.3		100	
86-0190-00	Ann	WRIGHT	NCHF	151	5.8	3.1	76	
86-0193-00	Mary	WRIGHT	NCHF	74	14.0	5.5	47	195
86-0199-00	Howard	WRIGHT	NCHF	295	11.0	4.9	44	1,726
86-0217-00	Granite	WRIGHT	NCHF	143	10.4	5.5	32	
86-0221-00	Camp	WRIGHT	NCHF	48	15.9	5.9	38	
86-0250-00	Smith	WRIGHT	NCHF	74	1.5			
86-0263-00	Cokato	WRIGHT	NCHF	221	15.9	6.6	34	11,855
86-0264-00	Brooks	WRIGHT	NCHF	39	6.4	3.5	62	
86-0273-00	French	WRIGHT	NCHF	137	16.5	5.0	47	
86-0279-00	West Lake Sylvia	WRIGHT	NCHF	360	26.8	9.5	33	3,241
86-0288-00	John	WRIGHT	NCHF	160	8.5	3.4	86	1,452
86-0289-00	East Lake Sylvia	WRIGHT	NCHF	271	23.8	9.9	26	2,051
86-0293-00	Collinwood	WRIGHT	NCHF	253	8.5	3.6	60	13,185

Table 3: North Fork Crow River HUC-8 overall land use comparison for the North Central Hardwood Forest and Western Corn Belt Plains ecoregions

Land Use (%)	North Fork Crow River WS[1]	NCHF ecoregion	WCBP ecoregion
Developed	6	2-9	0-16
Cultivated (Ag)	55	22-50	42-75
Pasture & Open	18	11-25	0-7
Forest	10	6-25	0-15
Water & Wetland	11	14-30	3-26

[1]National Land Cover Database www.mrlc.gov/index.php

Table 4: North Fork Crow River HUC-11 watershed units, upstream to downstream

HUC-11 Units	Area (Hectares)	Percent of HUC-8	Number of assessed lakes
Upper North Fork Crow River	74,130	19	5
Raymond Lake	4,672	1	0
Upper Middle Fork Crow River	25,242	7	5
Central Middle Fork Crow River	21,628	6	4
Lower Middle Fork Crow River	24,827	6	1
Long Lake Outlet	12,578	3	2
Jewett Creek	17,629	5	1
Litchfield	5,978	2	2
Middle North Fork Crow River	23,669	6	0
Washington Creek	17,914	5	4
Collinwood Creek	20,812	5	7
Sucker Creek	12,043	3	3
Twelve Mile Creek	15,190	4	6
Mill Creek	15,144	4	5
Louzers Lake Outlet	8,054	2	1
Lower North Fork Crow River	49,967	13	12
Sarah Creek	2,227	1	2
St. Michael	13,817	4	3
Crow River	18,559	5	5

Figure 2: Minnesota's EPA mapped ecoregions and North Fork Crow River watershed location

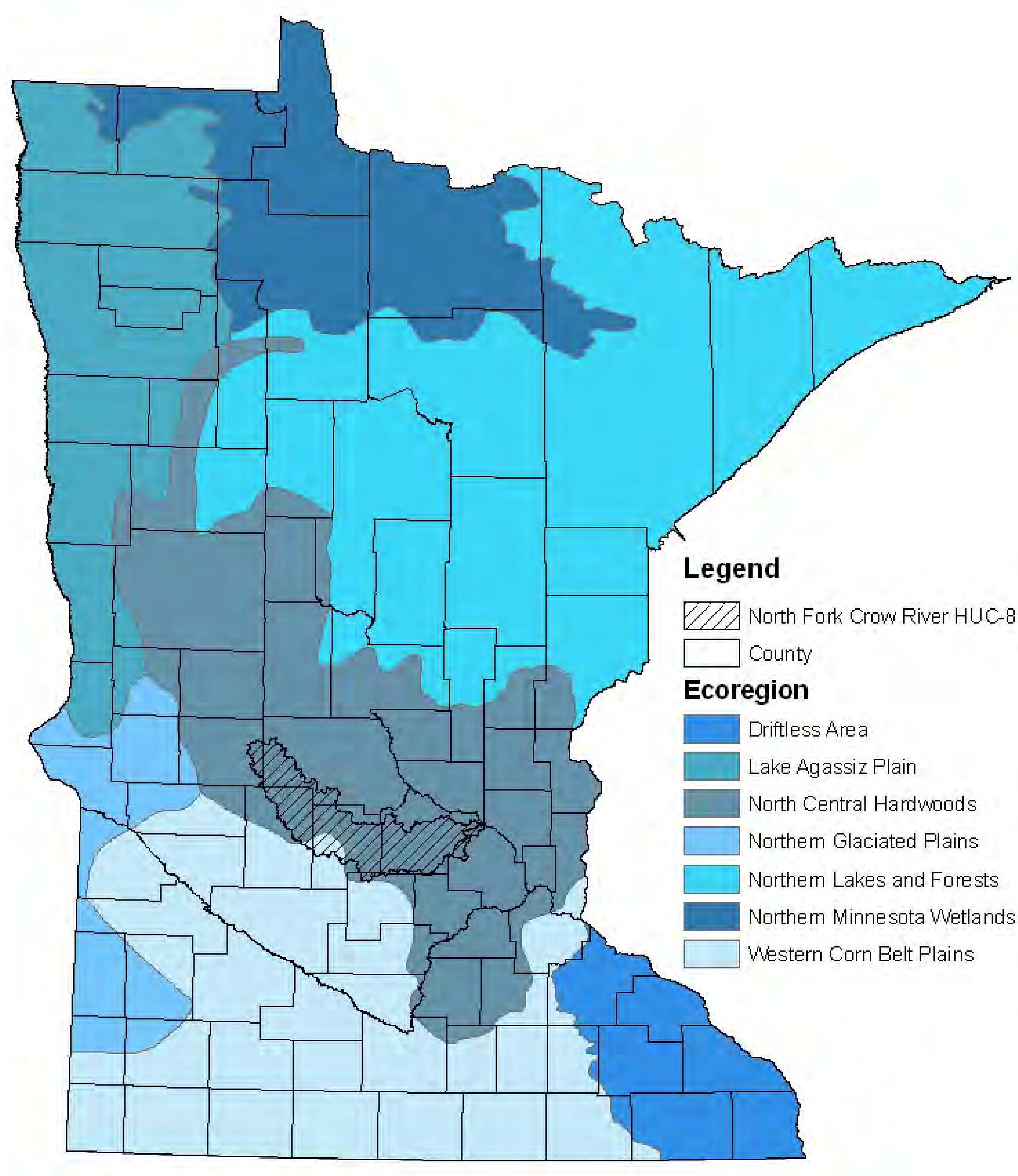


Figure 3: North Fork Crow River HUC-11 watershed boundaries

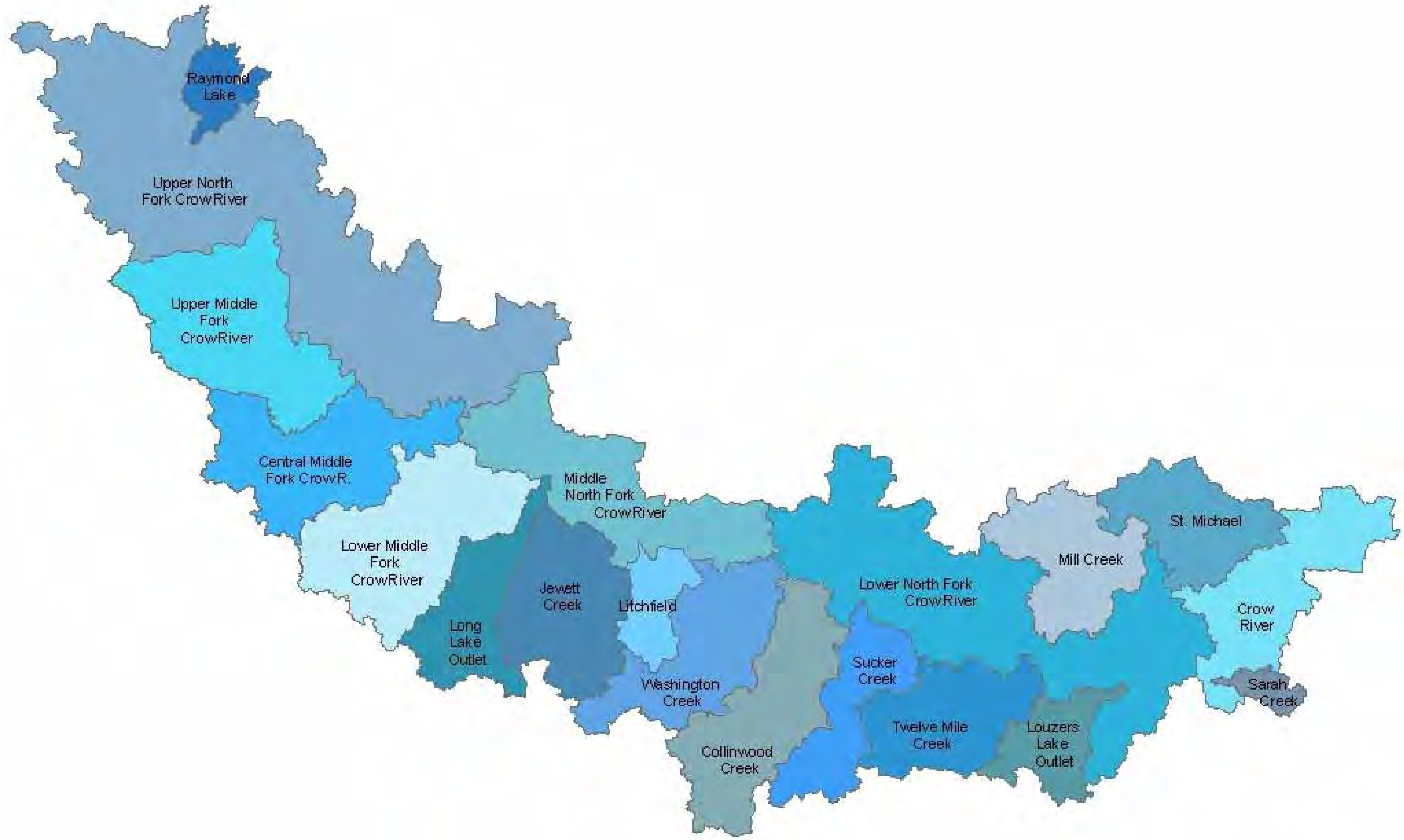


Figure 4: North Fork Crow River HUC-11 watershed boundaries, surface water and monitoring coverage

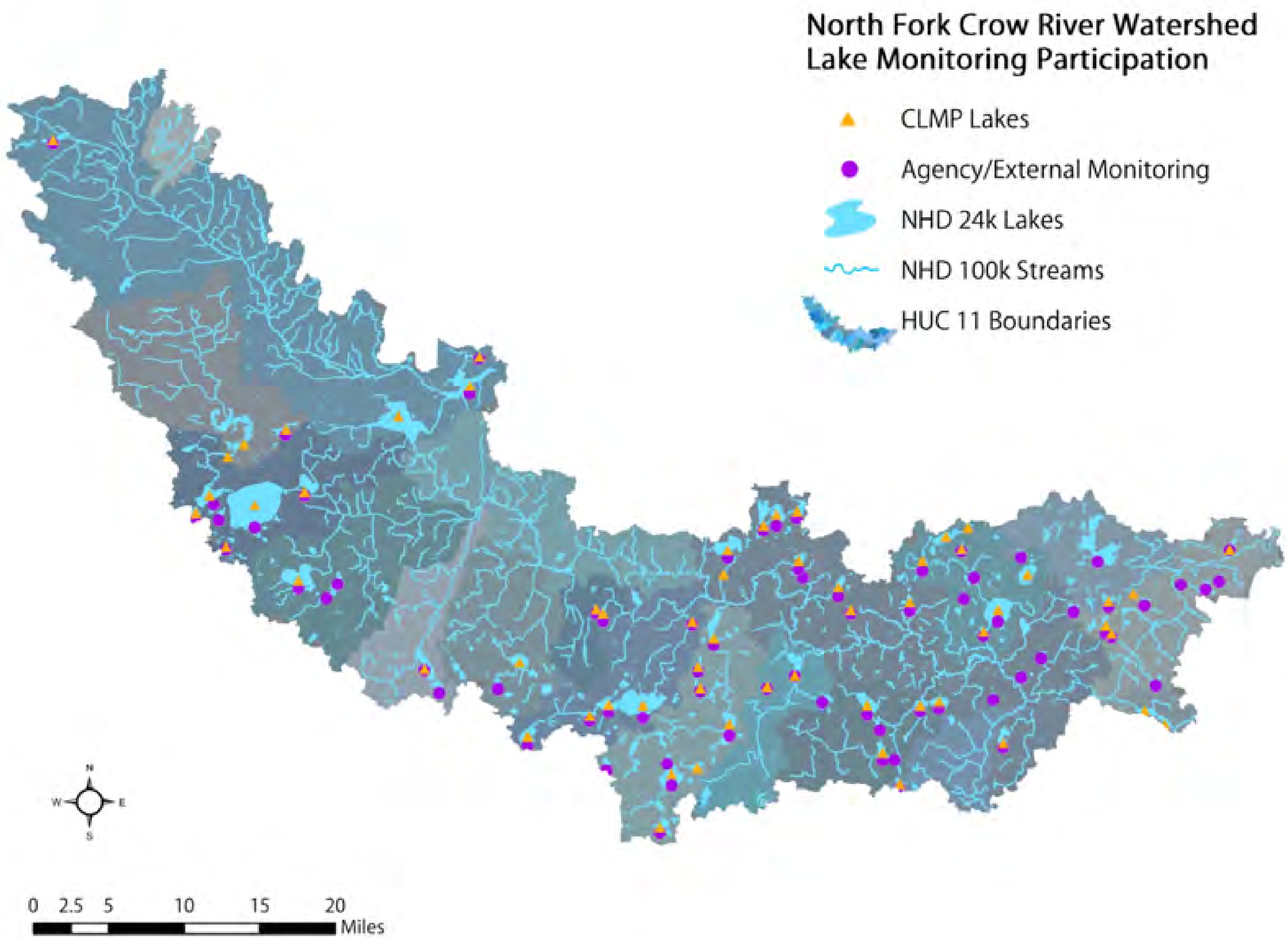
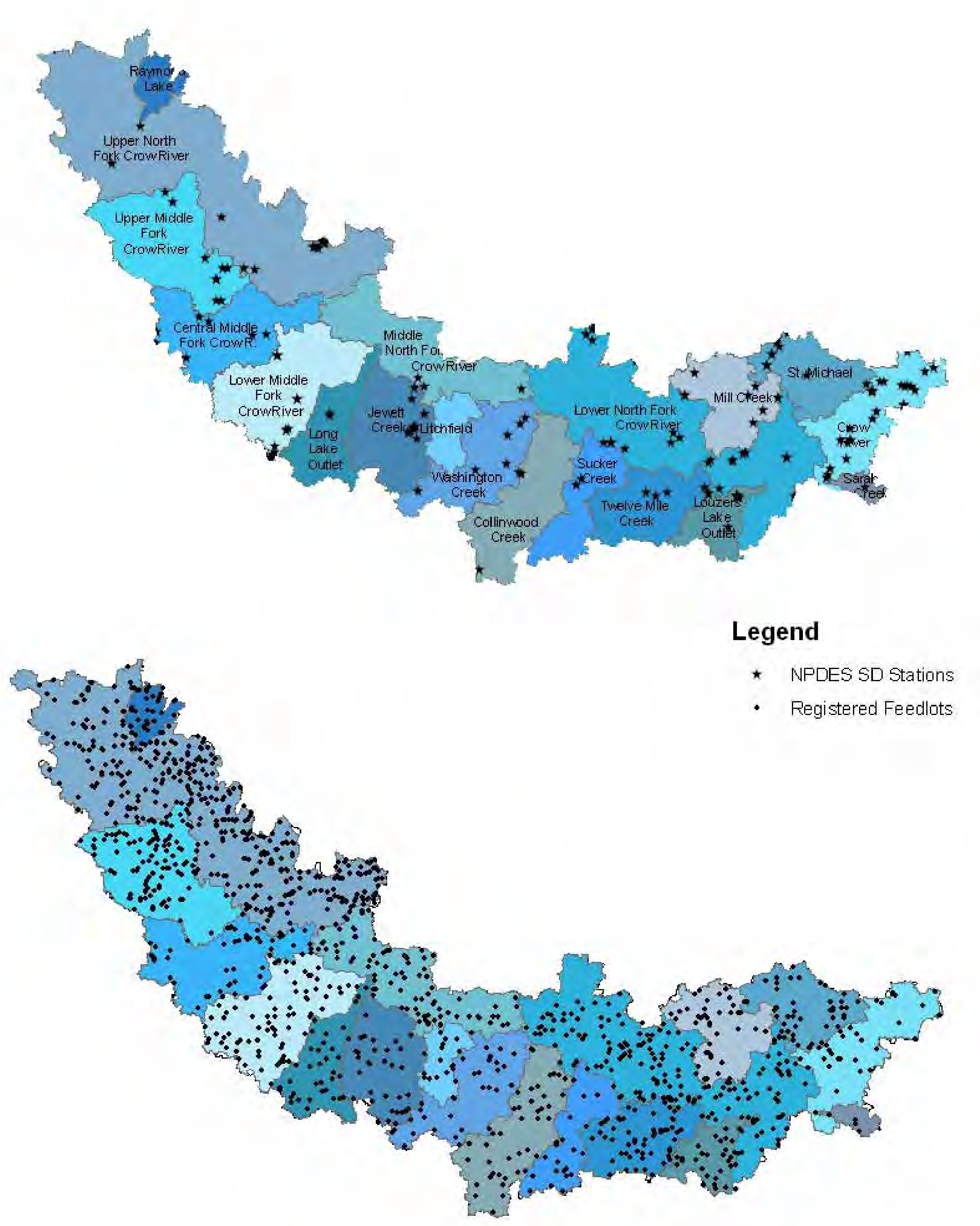


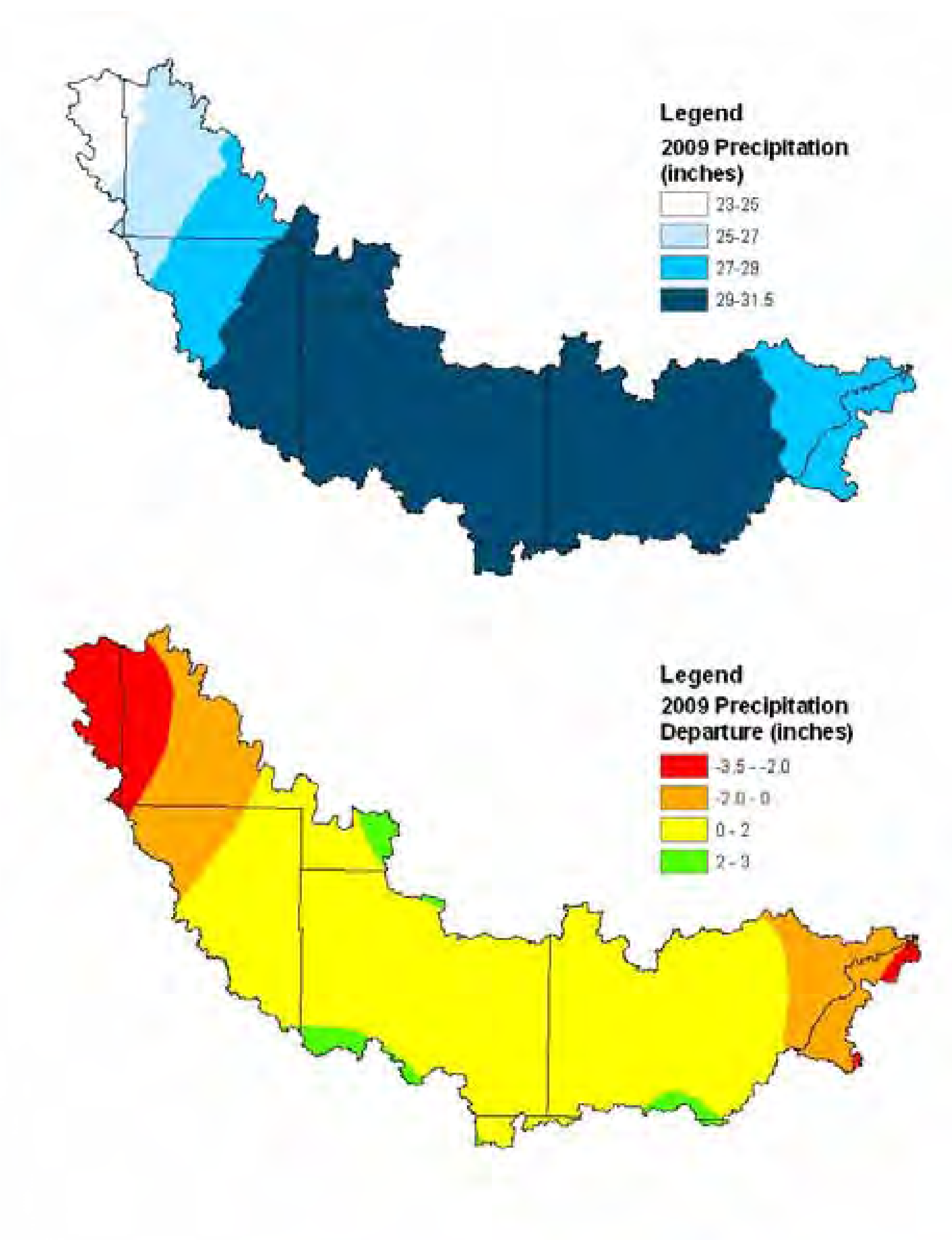
Figure 5: North Fork Crow River watershed NPDES and registered feedlot distribution by HUC-11



Climatic Conditions

Rain gauge records indicate normal conditions throughout the watershed in water year 2009 (October 2008 through September 2009). The majority of the watershed received 29 to 32 inches of rain over the summer. While overall precipitation was normal, the headwaters region of the watershed was dry in 2009 (Figure 6).

Figure 6: 2009 Minnesota water year precipitation and departure from normal for the North Fork Crow River watershed (State Climatological Office – DNR Waters)



HUC-11 Lake Assessment

The North Fork Crow River HUC-8 watershed is comprised of nineteen HUC-11 watershed units (Figure 3 & Table 4). Each individual watershed has had varying amounts of surface water monitoring. Lake assessment results are presented for the HUC-11 watershed units within the North Fork Crow River watershed where monitoring was conducted (17 of 19). This scale provides a robust assessment of water quality condition in the watershed unit and is a practical size for the development, management, and implementation of effective TMDLs and protection strategies. Raymond Lake HUC-11 and Middle North Fork Crow River HUC-11 watershed did not have lakes greater than 100 acres with sufficient data to assess. For that reason, those two watersheds will be excluded from the following discussion. The discussion will proceed from the upper most HUC-11 (Upper North Fork) to the HUC-11 (Crow River) that outlets the Crow River. Lakes less than 4 ha (10 acres) will not be included in the discussion or tables provided.

Feedlot and permitted discharge sites were reviewed to assist with the determination of the land use characteristics within each of the HUC-11 watersheds (Figure 5). Additional information regarding the permitting of feedlots and discharge sites can be found at:
http://www.pca.state.mn.us/index.php/regulations/permits-and-rules/permits-and-the-permitting-process.html

Upper North Fork Crow River HUC-11 Watershed

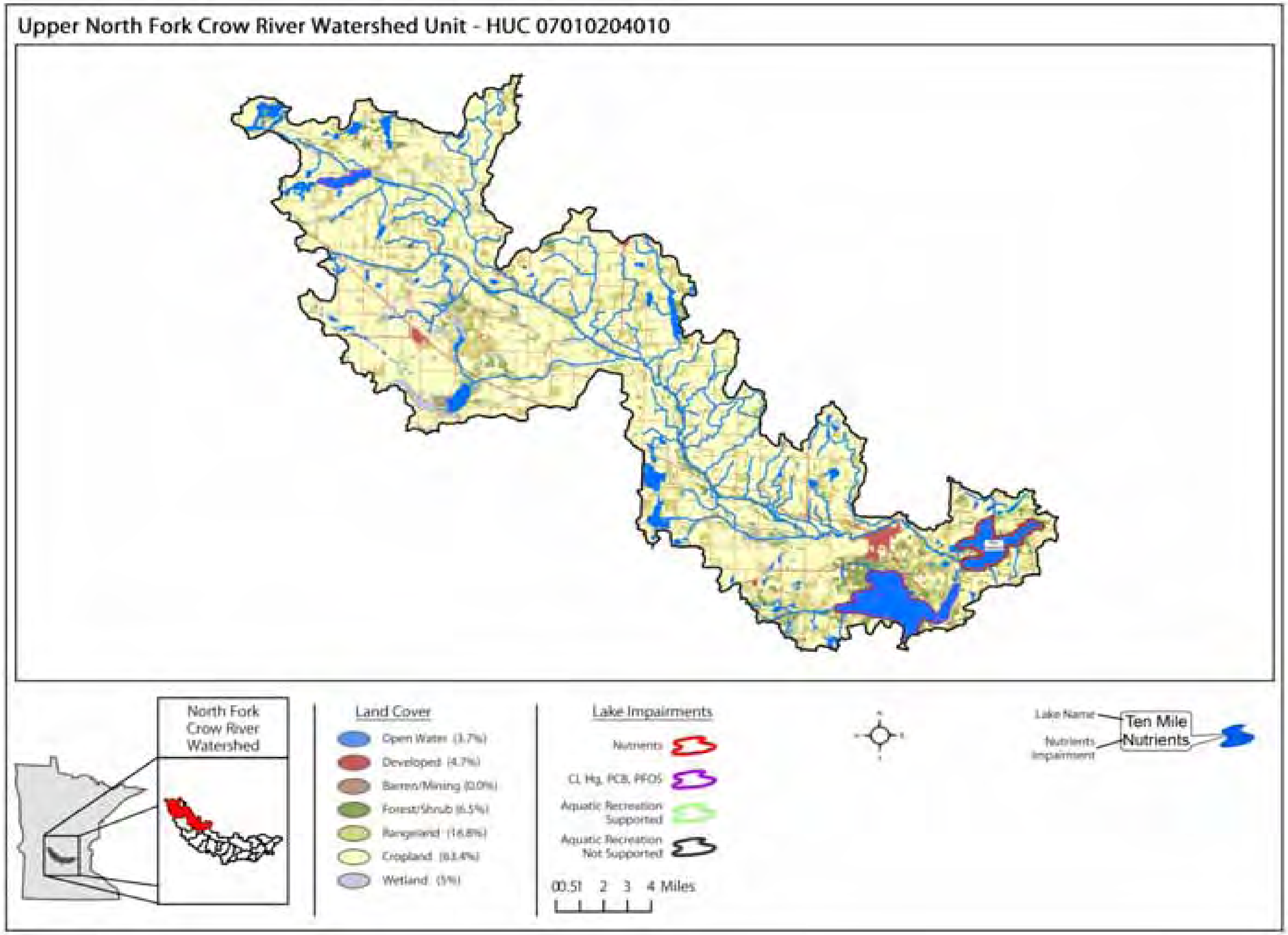
The Upper North Fork Crow River (07010204010) HUC-11 watershed is located in the northwest portion of the North Fork Crow Watershed, draining parts of Pope, Stearns, Kandiyohi, and Meeker Counties. The watershed is 74,130 ha (183,180 acres) and comprises 19% of the North Fork Crow River watershed. It drains from northeast to southwest starting in Lake Alice to its convergence with Lake Koronis near Paynesville, MN and is completely within the NCHF Ecoregion. Agriculture and pasture are the dominant land uses in the watershed (Figure 7). Five of the fifteen lakes in the watershed have been assessed against aquatic recreation use standards (ARUS; Table 5). Three hundred and nine feedlots are located throughout the watershed.

Table 5: Lakes within the Upper North Fork Crow River HUC -11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	[1]Recreation Assessment
KANDIYOHI	34016100	Unnamed	10		
KANDIYOHI	34051000	Unnamed	7		
POPE	61001700	Unnamed	9		
POPE	61001900	Mud	13		
POPE	61002000	Lincoln	11		
POPE	61002300	Grove	144	9.5	FS
POPE	61002400	McCloud	89	3	
POPE	61003200	Alice	47		
POPE	61031000	Unnamed	7		
STEARNS	73014400	Pirz	27		FS
STEARNS	73019600	Rice	613	12.5	NS
STEARNS	73020001	Mud	55	1.5	FS
STEARNS	73020002	Koronis (main lake)	1,190	39	IF
STEARNS	73025800	George	127		
STEARNS	73027800	Tamarack	113	1.2	

[1] FS is defined as supporting aquatic recreation use, IF is defined as insufficient data to determine support, and NS is defined as not supporting aquatic recreation use.

Figure 7: Upper North Fork Crow River watershed land use and lake assessment status



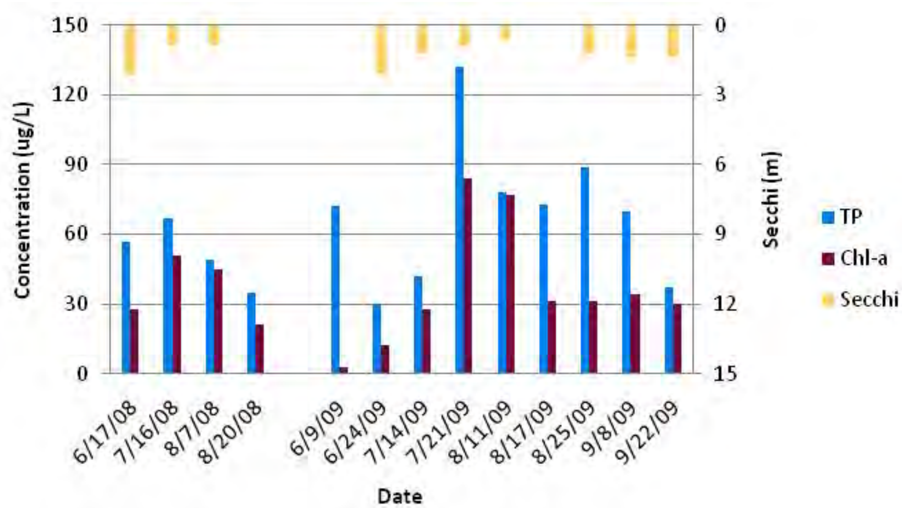
Rice Lake 73-0196-00

Rice Lake is a deep, 613 hectare (ha) lake with a maximum depth of 12.5 meters (m; 41 feet) located 3 miles east of Paynesville, MN. The lake has a 70,075 ha watershed (114:1 watershed to lake ratio) dominated by agricultural land uses (crop and pasture). The lake was listed for excess nutrients in 2008 and a total maximum daily load (TMDL) is s currently in development. Details on this study can be found at: http://www.pca.state.mn.us/water/tmdl/project-northforkcrow-nutrients.html. The lake is highly developed (288 homes or cabins) and receives moderate recreational use (DNR, 2010).

Profile data was available from 2009 (Appendix C). The lake does appear to have some thermal stratification; primarily in July at site 209 and weakly in midsummer at site 203. While the temperature gradient is not strong at either site, the dissolved oxygen concentration approached zero below a depth of 4 to 6 meters for most of the summer. At these concentrations (< 5 milligrams per liter - mg/L), the water at depth would not have been able to support game fish.

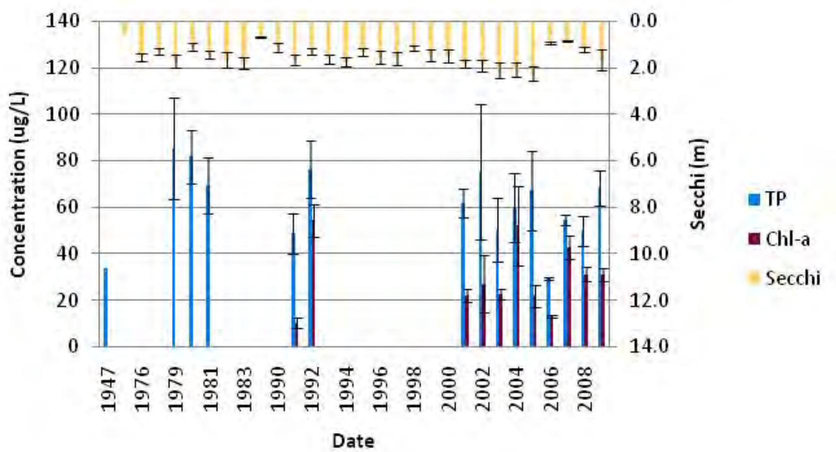
Water chemistry data was collected in 2008 and 2009 on Rice Lake at multiple locations. Data from the primary site (deepest location in the lake) is found in Figure 8. Seasonally, TP and chl-*a* concentrations increase until midsummer and then decline towards fall. The chl-*a* and Secchi response are not always a tight fit with the change in TP (see late summer 2009). It is possible that a change in weather (cool, cloudy days) could have limited the algal production.

Figure 8: Rice Lake water quality data (primary site 209)



Rice Lake has a long water quality record; Secchi has been collected nearly continuously since 1976 and chemistry data was available from the early 80s and 90s and annually since 2001 (Figure 9). Based on the 28 years of available data, the lake is not exhibiting a trend in Secchi transparency. The TP and chl-*a* concentrations exceeded the NCHF ecoregion lake eutrophication standards and is considered to not be supporting aquatic recreation use.

Figure 9: Rice Lake long-term water quality data



MINLEAP was run for Rice Lake as a basis for comparing the 2000 to 2009 data with that predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for the NCHF ecoregion. The observed TP and chl-*a* were lower, but not significantly different from the modeled results. Observed Secchi was better than the modeled predictions. The lake retains approximately 47% of the phosphorus that enters it and has a residence time on the order of three months. Complete modeling results can be found in Appendix B.

Lake Koronis 73-0200-00

Lake Koronis is the largest lake in this watershed and is comprised of two separate basins, Lake Koronis (Main Lake 73-0200-02), and Mud Lake (73-0200-01). It has been the subject of numerous studies over the years. The main lake is 1,190 ha with a maximum depth of 40 m (132 feet). The smaller basin, Mud Lake, as an area of 54 ha and a maximum depth of 1.5 m (5 feet). The North Fork Crow River flows through the Mud Lake portion and the southeast portion of the Main Lake. The lake is located 1 mile south of Paynesville and the 74,542 ha watershed (60:1 watershed to lake ratio) is dominated by agricultural land uses (crop and pasture). The lake is highly developed and receives moderate recreational pressure (DNR 2010).

Profile data was available from 2005 for temperature only (Appendix C). The main basin of the lake thermally stratifies between depths of 6 to 8 meters during the summer months. It does appear that full mixing does occur in the spring and fall. This may explain the increases in TP that are found in the spring and fall samples.

TP, chl-*a*, and Secchi were sampled in 2007 to 2009 for the main basin and in 2005 and 2009 for the smaller basin. Data on Lake Koronis was collected at site 206 (NW bay) and 211(deep hole in the center of the lake). There was a difference on several dates of 10 to 20 ug/L TP between the deep hole and the NW bay, however, similar changes in chl-*a* were not observed. These values were averaged for the graphs below (Figure 10). The smaller basin (Mud Lake), was inundated with rooted aquatic vegetation and had a short residence time on the order of 2 days; these are likely the reasons for the low chl-*a* levels observed in recent sampling (Figure 11).

Figure 10: Lake Koronis (Main Basin) water quality data

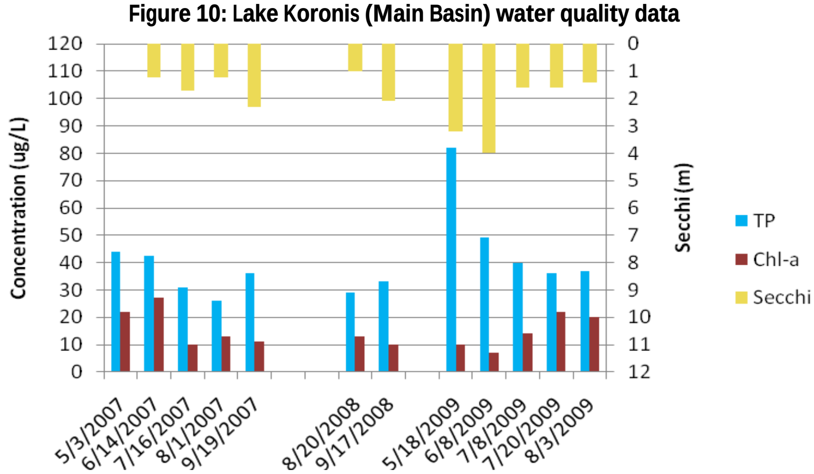
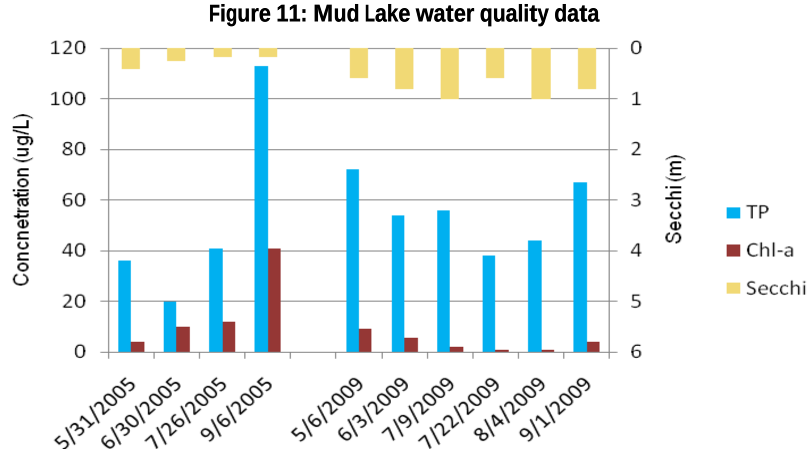


Figure 11: Mud Lake water quality data



The main basin of Lake Koronis has a long water quality data record. The Secchi record spans 28 years, starting in 1973. Water chemistry was collected in the early 90s and then annually since 2001. TP in the main basin varies between 30-40 µg/L in most summers and there is no distinct trend (Figure 12). Mud Lake has data from the mid 90s, 2005, and 2009 (Figure 13). The river heavily influences this smaller basin, and the water quality has large shifts between years that likely reflect variations in river TP and chl-*a*. Chl-*a* was not always collected in conjunction with TP data; the TP concentration was significantly higher in the 90s for Mud Lake. Secchi transparency was limited by the depth of the lake for most occasions in 2009; therefore observed Secchi is an underestimate and would account for discrepancy in TSI values for the lake.

Figure 12: Lake Koronis (Main Basin) long-term water quality data

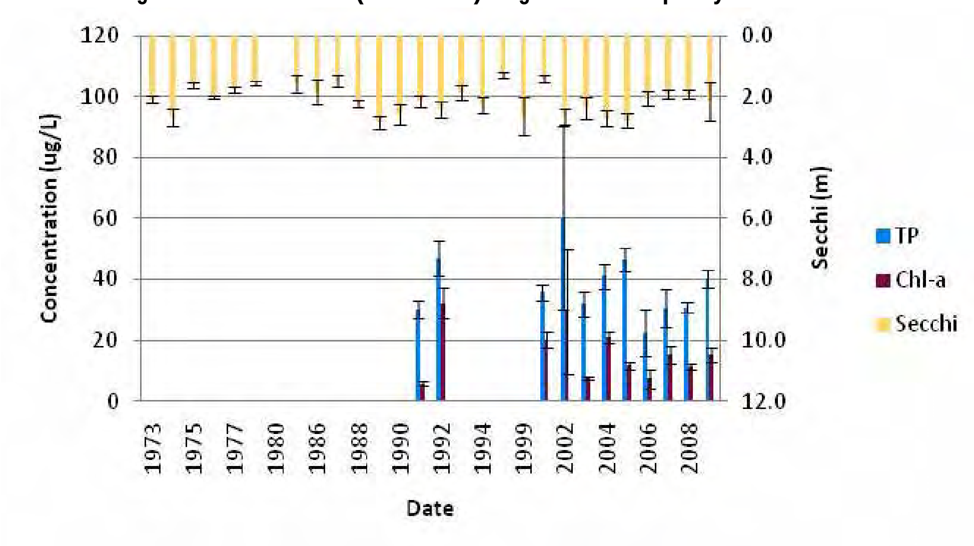
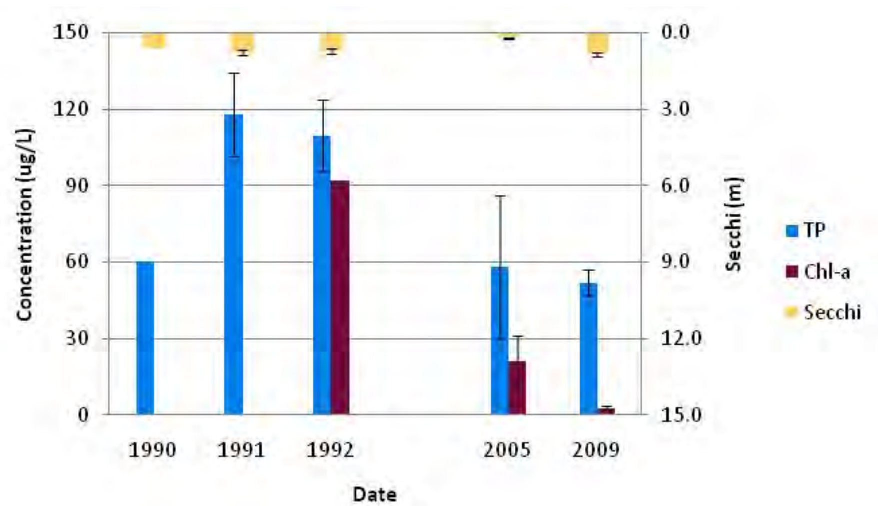


Figure 13: Mud Lake long-term water quality data



Based on the most recent Secchi transparency trend analysis, there is a possible improvement in transparency on the main lake with an estimated increase of 0.1 meter per decade. The main lake is at the standard for TP and above the standard for chl-*a*; it will likely be above the ARUS should phosphorus increase (Table 6). Mud Lake, with its shallow depth, is held to the shallow lake standards and meets those criteria and would be considered to be supporting of aquatic recreation (Table 6). However, the lake has a residence time of approximately 2 days and in the future may not be assessed as a lake.

MINLEAP was run for Lake Koronis as a basis for comparing the observed data with that predicted by the model based on lake depth and size, watershed size, and ecoregion location. Observed TP and chl-*a* were lower, but not significantly different than modeled predictions for Lake Koronis (Main Basin). The lake retains ~ 63% of the phosphorus that enters the lake and has a residence time on the order of 1 year. The predicted background TP for the main lake is 21 ug/L. Mud Lake was predicted to have much higher levels of phosphorus and chl-*a*, considering the upstream watershed size. However, Rice Lake likely retains phosphorus and the short retention time of the basin likely prevents algal communities from producing large blooms with the available phosphorus. Mud Lake is slightly above the predicted background TP of 50 ug/L. Complete modeling results can be found in Appendix B.

Upper North Fork Crow River HUC-11 Watershed Summary

Many of the lakes in the watershed are headwaters and quite small and are strongly influenced by runoff from their immediate watershed. The flow-through lakes: Rice and Koronis, which are located at the end of the watershed, are more strongly influenced by the watershed-wide transport of nutrients.

The watershed would benefit from restoration activities to reduce TP levels that are impacting downstream flow-through lakes (Rice and Koronis; Table 6).

Table 6: Summer-mean values compared to NCHF eutrophication standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
Rice Lake 2000-2009 average	60	29.8	1.6
Koronis (Main Lake) 2000-2009 average	40	18	2.2
NCHF – Aquatic Rec. Use (Class 2B) Shallow Lakes	< 60	< 20	> 1.0
Koronis (Mud Lake) 2000-2009 average	54	9.6	0.6

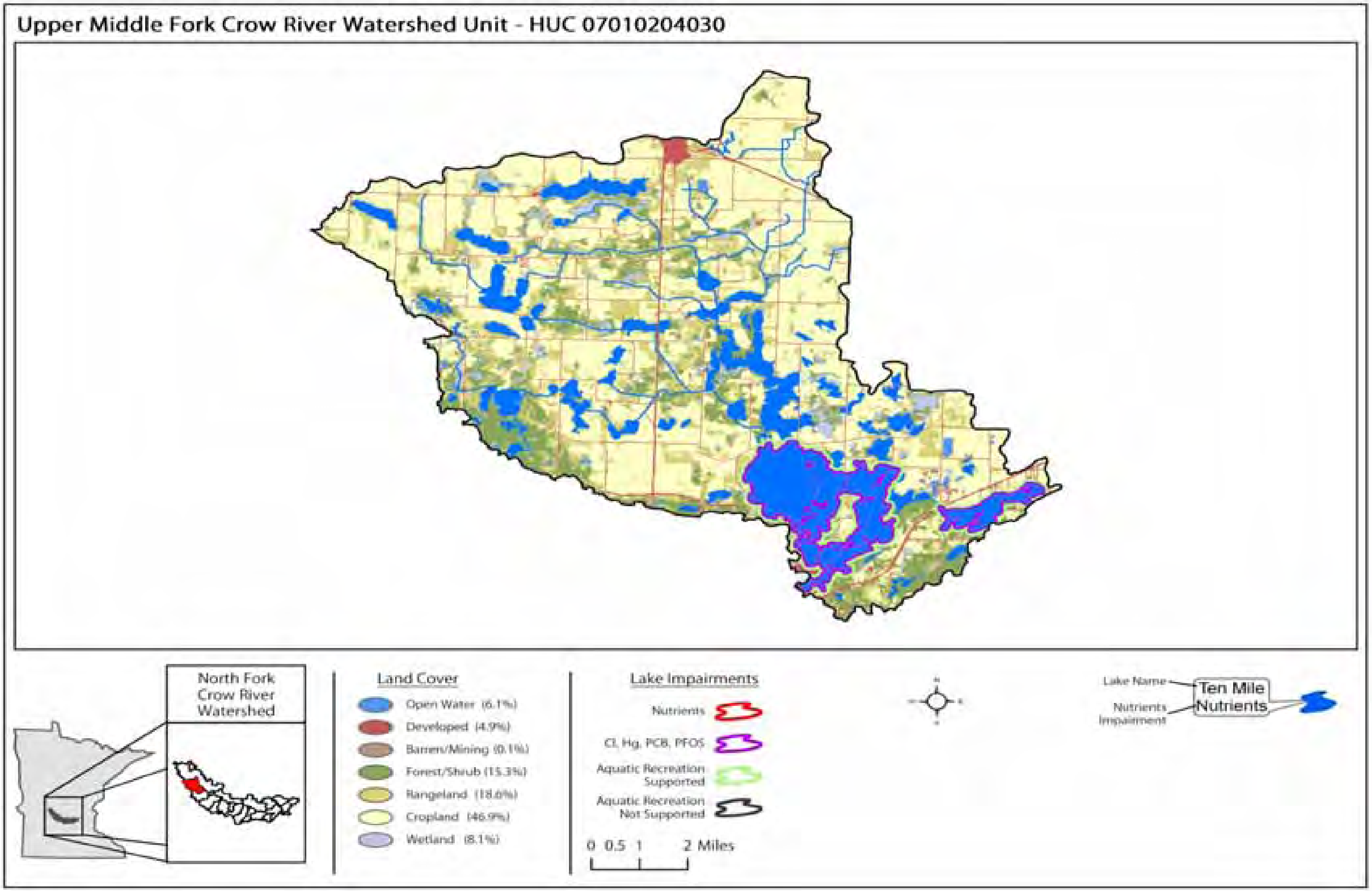
Upper Middle Fork Crow River HUC-11 Watershed

The Upper Middle Fork Crow River (07010204030) HUC-11 watershed is located in the northwestern portion of the North Fork Crow Watershed draining parts of Stearns and Kandiyohi counties, to the north and west of New London, MN. The watershed is 25,242 ha (62,376 acres), comprises 7% of the North Fork Crow River watershed, and is located entirely within the NCHF ecoregion. It drains from northwest to south starting near Belgrade to the New London Dam at the outlet of Crow River Mill Pond near New London. Agriculture (crop) is the dominant land use the in watershed, followed by pasture and forest (Figure 14). Five of the nine basins in the watershed have been assessed for aquatic recreation use support (Table 7). Ninety-three feedlots are located throughout the watershed.

Table 7: Lakes within the Upper Middle Fork Crow River HUC -11 Watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
KANDIYOHI	34006600	Long	127	13.7	FS
KANDIYOHI	34015100	Unnamed	5		
KANDIYOHI	34015801	Mud	360	1.2	FS
KANDIYOHI	34015802	Mud	329	1.8	FS
KANDIYOHI	34015803	Crow River Mill Pond(East	13	4.2	FS
KANDIYOHI	34015804	Crow River Mill Pond(Mid)	8	4.2	FS
KANDIYOHI	34024300	Skull	8		
STEARNS	73027900	Crow	90	0.9	
STEARNS	73028100	Fish	70	1.2	

Figure 14: Upper Middle Fork Crow River watershed land use and lake assessment status



Mud/Middle Fork Crow Reservoir 34-0158-00

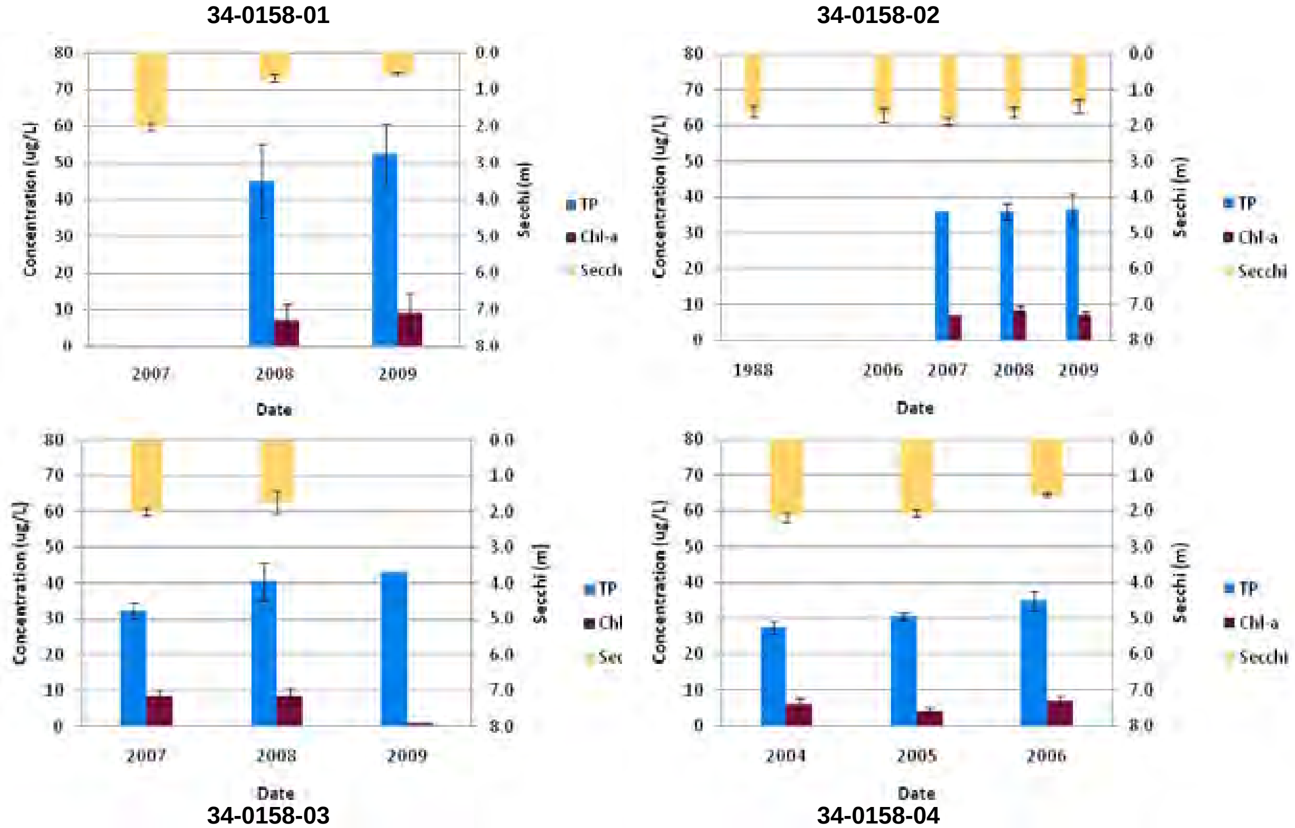
This reservoir is made up of five distinct shallow basins (Figure 15), Lake Monongalia (Main), Lake Monongalia (Middle Fork Crow Reservoir), Crow River Mill Pond (East), Crow River Mill Pond (Middle), and Crow River Mill Pond (West). Together these basins make up 713 ha. The maximum depth of 4.2 m is found in the Mill Ponds; Monongalia is less than 1.2 m deep and heavily vegetated. The Reservoir is approximately 1.8 m deep. The Middle Fork Crow River enters the chain in the main basin and exits the chain at the New London Dam at the end of the Crow River Mill Pond (West) basin. The lake is located to the north of New London and the 29,922 ha watershed (36:1 watershed to lake ratio) is dominated by agricultural land uses (crop and pasture) and forest. The basins have a history of partial winterkill and winter aeration does occur in portions of the lake. The primary development is on the western shore and in the city of New London, MN; approximately 135 homes/cabins are on the basins (DNR, 2010).

Figure 15: Middle Fork Crow Reservoir basin map

Surface temperature and dissolved oxygen data were collected at the surface for the -01 and -02 basins and profiles were collected on -03 during the 2008 and 2009 sampling seasons (Appendix C). No thermal stratification was detected in the -03 basin, however, at 2 to 2.5 meters, the dissolved oxygen did decline – this is a small basin that is not easily mixed by wind; it is possible that intermittently during the summer months the water may become anoxic at depth and phosphorus could be released from the sediments.

TP, chl-*a*, and Secchi were sampled in 2008 and 2009 by MPCA staff for the -01, -02, and -03 basins. Local monitoring efforts collected data on the -04 basin in 2004 through 2006 and on the -02 and -03 basins in 2007 and 2008. All of the basins have very low chl-*a* levels; rooted aquatic vegetation is prominent in the -01 and -02 basins (Figure 16). In the -01 basin, the Secchi is limited by depth; on all dates, the disk was still visible when resting on the bottom of the lake. As a result, the Secchi does not accurately reflect the clarity of the lake.

Figure 16: Water quality data



All of the basins of the lake would be held to the shallow lake standards for the NCHF ecoregion; based on available data, they are all well within those standards and would be considered fully supporting of aquatic recreation use (Table 8).

MINLEAP was run for Mud Lake as a basis for comparing the recent data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was calibrated to stream TP concentrations measured at the inlet to Mud Lake from 2007 to 2009, which averaged 47 ug/L and to the upstream basin average TP concentration for downstream basins. The model consistently over predicted the chl-*a* concentrations; these basins support extensive rooted aquatic vegetation, which take up the TP that would otherwise allow for a more abundant algal community. The over prediction may also have to do with the short residence time for the basins. TP was typically within the error of the model. The residence time for the entire lake is approximately 2 months and estimated background TP ranged from 47 ug/L in the upstream basin to 35 ug/L in the -04 basin. Complete modeling results can be found in Appendix B.

Upper Middle Fork Crow River HUC-11 Watershed Summary

The percentage of forested land use is somewhat higher in this HUC-11 than it is in the larger HUC-8 watershed. This should result in somewhat lower watershed TP loading to lakes that are off the main stem of the river. For those on the main stem upstream storage in larger lakes (e.g. Koronis) in the Upper North Fork Crow River HUC-11 watershed should serve to reduce downstream loads. Overall lake water quality in this watershed is of good condition (Table 8).

Table 8: Summer-mean values compared to NCHF eutrophication standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2B) Shallow Lakes	< 60	< 20	> 1.0
Main Basin 34-0158-01	52	8.2	0.6
Reservoir 34-0158-02	36	7.9	1.7
East Mill Pond 34-0158-03	36	7.8	1.8
Middle Mill Pond 34-0158-04	31	5.7	1.9

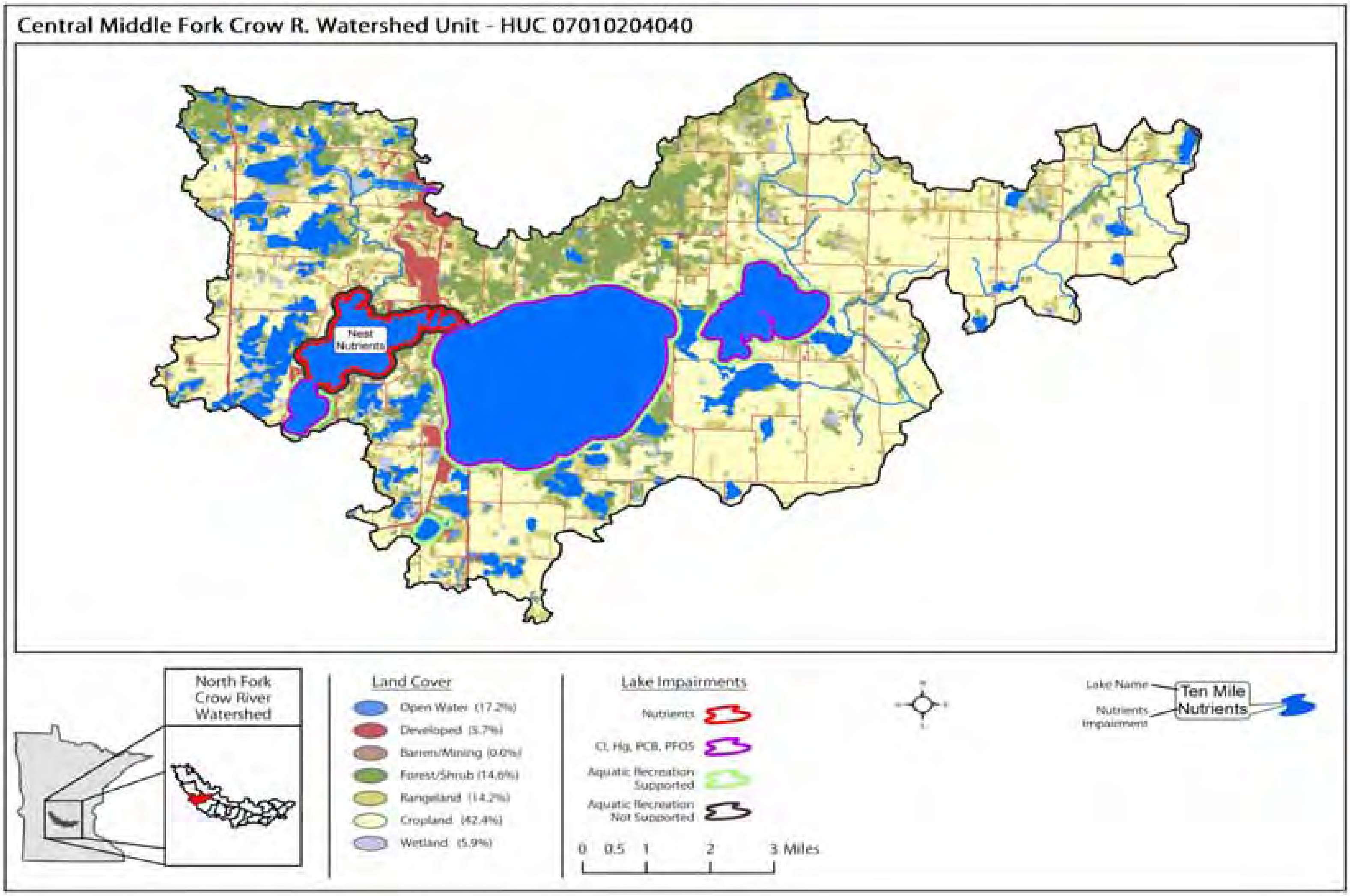
Central Middle Fork Crow River HUC-11 Watershed

The Central Middle Fork Crow River (07010204040) HUC-11 watershed is located in the southwestern portion of the North Fork Crow Watershed, to the north and east of Spicer, MN. The watershed is 21,628 ha (53,445 acres), 6% of the total watershed, and drains from north to the south starting at the New London Dam to its convergence with County Ditch 28 near the Kandiyohi/Meeker County line. The watershed is completely within the North Central Hardwood Forests ecoregion but would be considered to be in a transition zone to the Western Corn Belt Plains ecoregion. Agriculture is the dominant land use, followed closely by open water, forest, and pasture (Figure 17). Four of the nineteen lakes in the watershed have been assessed for aquatic recreation use support (Table 9).

Table 9: Lakes within the Central Middle Fork Crow River HUC -11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
KANDIYOHI	34012000	Alvig	29		
KANDIYOHI	34014800	Bear	56		
KANDIYOHI	34006200	Calhoun	250	4	FS
KANDIYOHI	34011400	Carlson	11		
KANDIYOHI	34014600	Eight	22		
KANDIYOHI	34011900	Elkhorn	28		FS
KANDIYOHI	34012600	Gina	20		
KANDIYOHI	34007900	Green	2,239	45	FS
KANDIYOHI	34011600	Henderson	28	17	IF
KANDIYOHI	34006000	Jesse	31		
KANDIYOHI	34015400	Nest	397	12	NS
KANDIYOHI	34011300	Unnamed	4.8		
KANDIYOHI	34014400	Unnamed	4.5		
KANDIYOHI	34015600	Unnamed	8		
KANDIYOHI	34015700	Unnamed	14.5		
KANDIYOHI	34039100	Unnamed	6		
KANDIYOHI	34061100	Unnamed	17		
KANDIYOHI	34011200	Woodcock	46		
KANDIYOHI	34014100	Woodcock	69	2.4	IF

Figure 17: Central Middle Fork Crow River watershed land use and lake assessment status



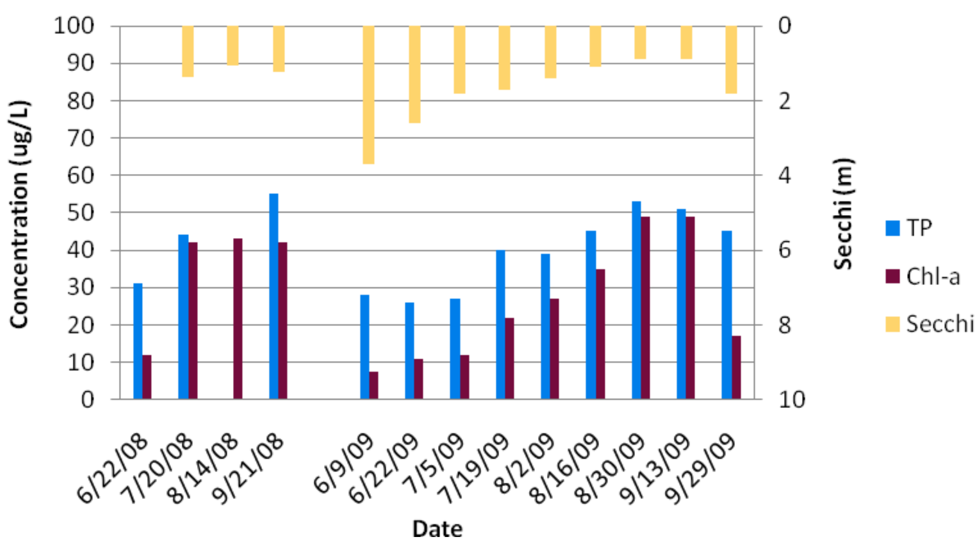
Nest Lake 34-0154-00

Next Lake is a 396 ha lake with a maximum depth of 12 m (40 feet); the lake is 55% littoral. The lake is located 1 mile northwest of Spicer and the watershed (31,842 ha; 80:1 watershed to lake ratio) is dominated by crop, pasture, and forested land uses. A Lake Assessment Report was completed on this lake in 2008; the report can be viewed at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/lake-water-quality-assessment-reports.html. The northwest side of the lake is undeveloped; however the remainder of the shoreline is heavily developed with over 190 homes/cabins (DNR 2010).

Profile data was collected intermittently over the entire data record. A comparison of mid-summer profiles indicated that the lake remained thermally mixed on most dates; however the dissolved oxygen would decline at depth with anoxic conditions present. This could result in the release of TP from the sediments (MPCA, 2008).

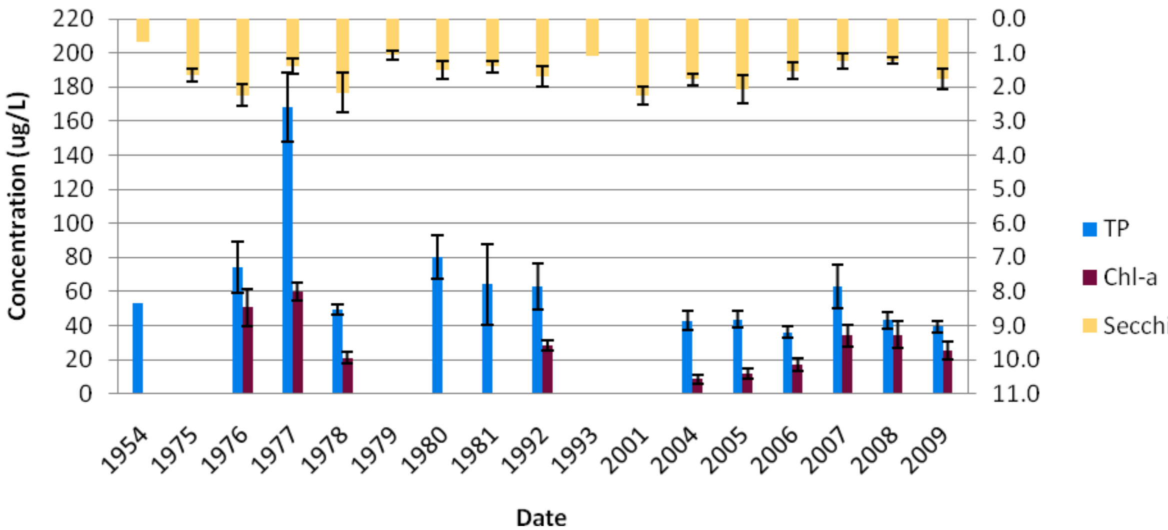
TP, chl-a, and Secchi were collected in 2008 and 2009 (Figure 18). TP and chl-*a* generally increase across the season and a corresponding decline in Secchi is evident. In this way the lake mimics patterns seen more often in shallow lakes; deep lakes tend to have high TP in May and September and a decline across the summer months in nutrients. The lake is a flow through lake with the Middle Fork of the Crow River inleting on the north side of the lake and outleting on the east end into Green Lake. The river likely drives the nutrient loading to the lake.

Figure 18: Nest Lake water quality results for 2008 and 2009



Nest Lake has a long water quality record; with samples first collected in 1954, and more recently from 2004 through 2009 (Figure 19). Chl-*a* was not always collected with TP samples. More recent water quality data is lower in TP than data collected in the early 80s and 90s; however, chl-*a* has not made a similar decline. The Secchi record spans 16 years. At this time no trend in Secchi transparency is evident. The lake exceeds the lake eutrophication standards and is considered to be not supporting aquatic recreation use; the total maximum daily load project is slated to begin in 2017 (Table 10).

Figure 19. Nest Lake long-term summer-mean water quality data



Both MINLEAP and BATHTUB modeling were completed on Nest Lake as part of a diagnostic study on the watershed and the follow up lake assessment report (MPCA, 2008). The estimated background TP concentrations were predicted to be 24 ug/L. The lake has a 4 to 6 month residence time and is was estimated that 80% of the TP in Nest Lake was coming from the Middle Fork Crow River and the lake retains 40 to 60% of the TP that it receives (Wilson, et al, 2005).

Green Lake 34-0079-00

Green Lake is a 2,239 ha lake with a maximum depth of 34 m (110 feet) and an average depth of 8.2 m (27 feet). The lake has a 37,716 ha watershed (17:1watershed to lake ratio) that is dominated by cultivated, pasture, and forested land uses. The lake has a large fetch and as a result is often windswept. The lake is fully developed with the exception of the outlet area on the east end of the lake; Eurasian watermilfoil was discovered in the lake in 2000 (DNR 2010).

The most recent dissolved oxygen and temperature profile data collected on Green Lake was from 1999 over the deepest site in the lake (Appendix C). That data does show that the lake does experience slight thermal stratification (drop of 5 to 10 degrees over the 30 meter depth). The dissolved oxygen declines below 5 mg/L below a depth of 7 to 12 meters during the summer months and anoxic conditions are present at the lake bed. This would allow for TP to be released from the sediment and contribute to internal loading in the fall when the lake mixes.

TP, chl-*a*, and Secchi were collected during 2008 and 2009 (Figure 20). TP concentrations reach their peak in the fall, which coincides with the lake mixing and surge of TP from the hypolimnetic waters. Chl-*a* and Secchi match well, with increases in chl-*a* concentrations typically resulting in a corresponding decline in Secchi transparency.

Green Lake has a long water quality data record (Figure 21). Chemistry data was first collected in 1956, then through the 70s and early 80s. Since 2004, data has been collected annually. TP has varied over the years, but generally, values since 2004 (typically 15-20 µg/L) are better than those from the 70s and 80s (typically 20-30 µg/L). Secchi records span 33 years. Recent trend analysis of available Secchi data indicated that the clarity in Green Lake is almost certainly improving, with an estimated increase of 0.4 m per decade. The estimated change could potentially range from an increase of 0.3 m per decade to an increase of 0.5 m per decade. The lake fully meets the ARUS for the NCHF ecoregion (Table 10).

Figure 20: Green Lake summer water quality data 2008-2009

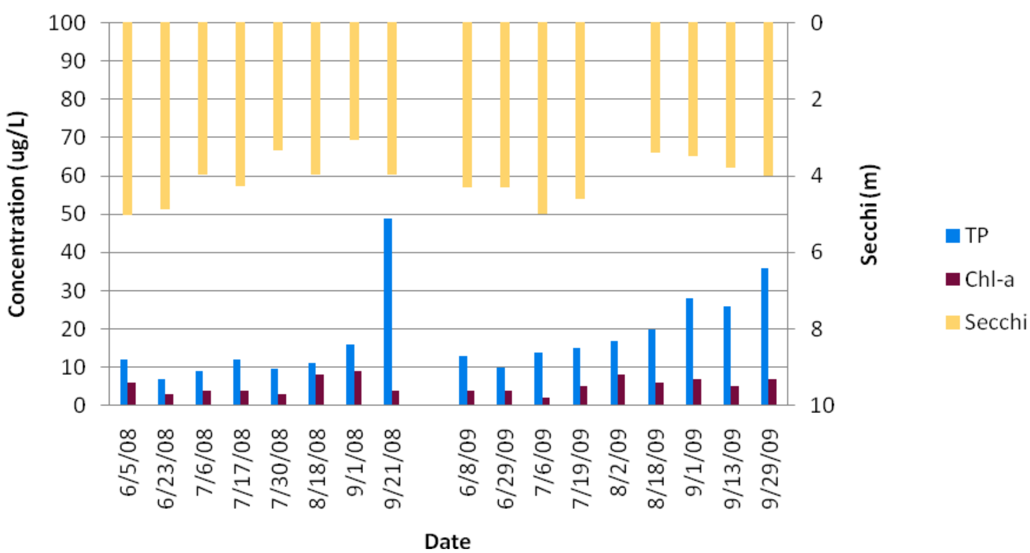
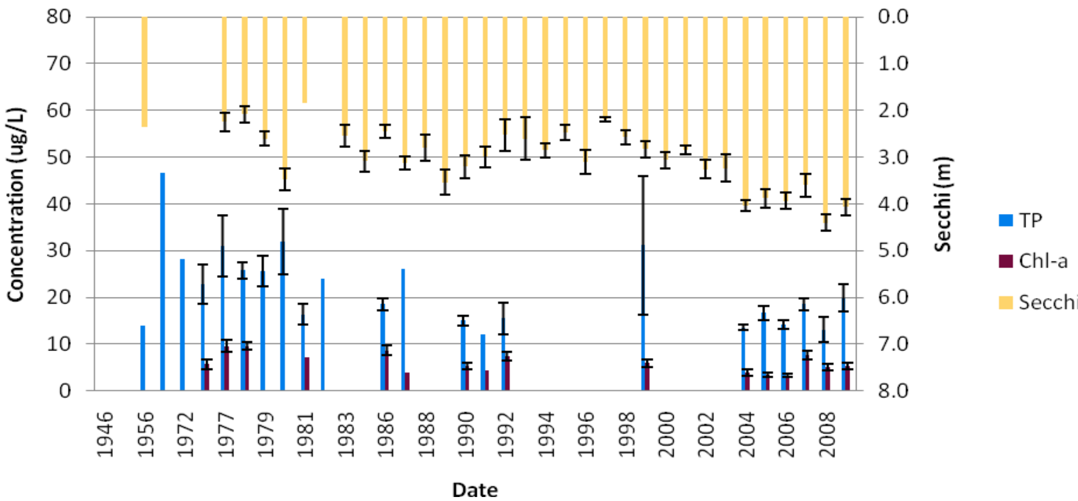


Figure 21: Green Lake long-term water quality data



MINLEAP was run for Green Lake as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was calibrated to match the in-lake concentration of Nest Lake, the upstream contributor to Green Lake. The modeled and observed values matched well, all within the standard error of the model. The model predicted that the lake retains approximately 67% of the TP that it receives and the residence time of the lake is on the order of three to four years. Based on model predictions, the lake is at or below the estimated background TP concentration of 21 ug/L based on the seasonal averages in recent years. Complete modeling results can be found in Appendix B.

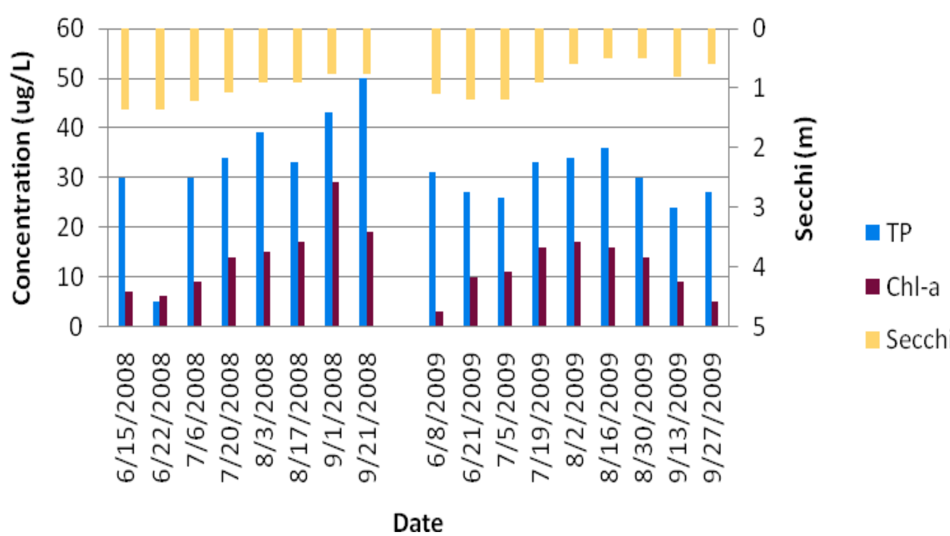
Lake Calhoun 34-0062-00

Lake Calhoun is a shallow, 250 ha lake with a maximum depth of 4 m (12.6 feet). The lake has a 3,066 ha watershed (12:1 watershed to lake ratio) dominated by cultivated, pasture, and forested land uses. The lake has residential development on the north and east sides, with 51 homes/cabins (DNR 2010).

Limited profile data was available on Lake Calhoun (Appendix C). DO and temperature were recorded to maximum depth in mid-summer 2004; the lake was completely mixed and likely never stratifies.

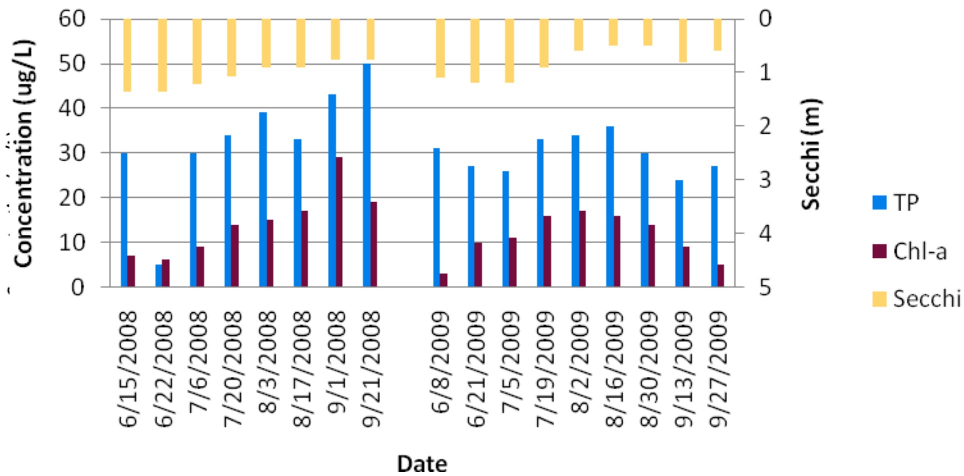
TP, chl-*a*, and Secchi were collected in 2008 and 2009. The 2008 data followed the expected pattern for shallow lakes, with TP and chl-*a* increasing across the season with a corresponding decline in Secchi. Secchi corresponds well to changes in nutrient and algal populations on Lake Calhoun (Figure 22).

Figure 22: Lake Calhoun water quality data 2008-2009



Lake Calhoun has been sampled for water quality since 2004 and for Secchi transparency since 1999 (Figure 23). With the exception of 2009, water chemistry has been increasing in concentration since 2004; however on most years, it is within the standard error and is not indicative of a significant trend. Based on the existing Secchi record, it appears that water clarity in Lake Calhoun is very likely declining, with an estimated decrease of 0.3 m per decade. The estimated change could range from a decrease of 0.6 m per decade to no change. The lake is well within the lake eutrophication standards for shallow lakes in the NCHF ecoregion and is considered to be supporting aquatic recreation use (Table 10).

Figure 23: Lake Calhoun long-term water quality data



MINLEAP was run for Lake Calhoun as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model predicted residence time on the order of 8 months and 59% retainage of phosphorus that enters the lake. The model predicted worse water quality than was observed. Stream TP was checked against model calibrations, and the default in the model was determined to be appropriate for this lake. Considering the declining trend in transparency and the model predictions, it is likely this lake will continue to decline in water quality unless efforts are taken to reduce phosphorus inputs to the lake. Complete modeling results are available in Appendix B.

Central Middle Fork Crow River HUC-11 Watershed Summary

This watershed benefits from a considerable portion of the land use being in forested cover. Nest Lake provides the TP sink that prevents the downstream lakes from more rapid eutrophication. The watershed is of relatively good water quality, based on available data (Table 10).

The watershed would benefit from restoration activities to reduce TP levels influencing water quality in Nest Lake and in the more agriculturally developed areas draining to Lake Calhoun.

Table 10: Summer-mean values compared to NCHF and WCBP eutrophication standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
Nest Lake 2000-2009 average	43	19.8	1.8
Green Lake 2000-2009 average	16	4.8	3.7
Lake Calhoun 2000-2009 average	32	10.9	1.3

Lower Middle Fork Crow River HUC-11 Watershed

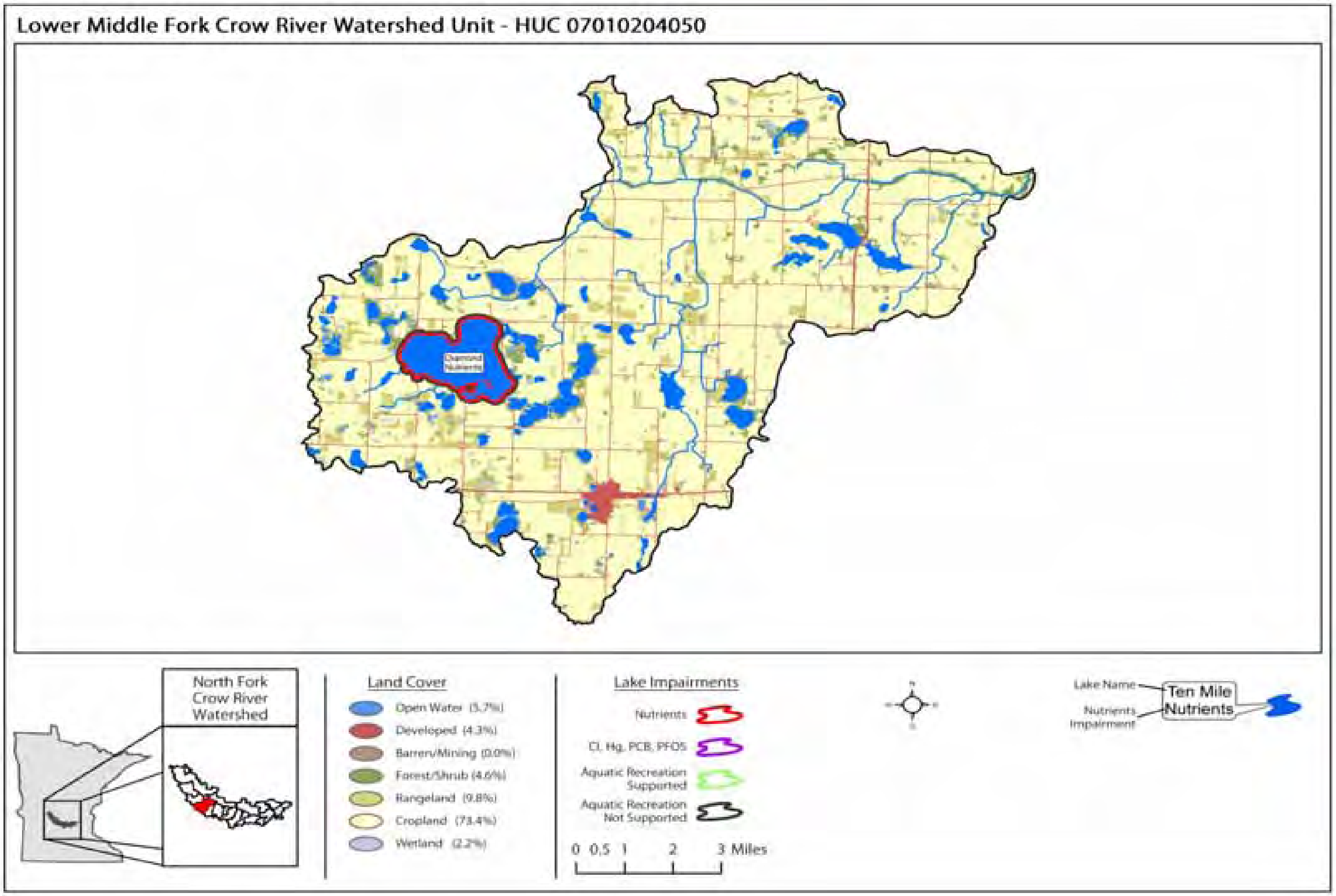
The Lower Middle Fork Crow River (07010204050) HUC-11 watershed is located in the southwestern portion of the North Fork Crow Watershed, draining parts of Kandiyohi and Meeker counties, to the north and east of Atwater, MN. The watershed is 24,827 ha (61,350 acres) and comprises 6% of the total watershed. The watershed drains tributaries from southwest to northeast starting in Diamond Lake; the outlet tributary converges with the Middle Fork Crow River and the watershed ends at the convergence with the North Fork Crow River near Manannah, MN. Agriculture and pasture are the dominant land uses in the watershed and two ecoregions are spanned, NCHF and WCBP (Figure 24). One of the fifteen lakes in the watershed has been assessed for aquatic recreation use support (Table 11).

This watershed is dominated by agricultural land uses. The lakes are not as buffered as in upstream watersheds. Data is being collected as part of the TMDL for Diamond Lake; the water quality data available would indicate that this watershed has degraded lake water quality.

Table 11: Lakes within the Lower Middle Fork Crow River HUC -11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
KANDIYOHI	34002300	Pay	12.5		
KANDIYOHI	34002700	Summit	55	1.8	
KANDIYOHI	34002800	Unnamed	8.5		
KANDIYOHI	34004000	Sperry	53		
KANDIYOHI	34004400	Diamond	628	8.2	NS
KANDIYOHI	34004600	Taits	5		
KANDIYOHI	34004900	Schultz	63		
KANDIYOHI	34005100	Wheeler	104		
KANDIYOHI	34005600	Unnamed	9		
KANDIYOHI	34007800	Bass	20		
MEEKER	47019300	Wilcox	24		
MEEKER	47019400	Miller	32		
MEEKER	47019800	Peterson	54		
MEEKER	47019900	Helga	47		
MEEKER	47020500	Whitney	22		

Figure 24: Lower Middle Fork Crow River watershed land use and lake assessment status



Diamond Lake 34-0044-00

Diamond Lake is a 628 ha lake with a maximum depth of 8.2 m (27 feet) and a mean depth of 4.8 m (15.6 feet). The lake is located approximately 4 miles northwest of Atwater, MN. The lake has a 7,280 ha watershed (12:1 watershed to lake ratio) with cultivated and pasture as the dominant land uses. The lakeshore is highly developed, with over 350 homes/cabins; curly-leaf pondweed is present on the northern portions of the lake (DNR 2010).

The lake was sampled in 2005 as part of the Citizen Lake Monitoring Plus Program. The report can be found at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/citizen-lake-monitoring-program/clmp-reports-fact-sheets-and-newsletters.html. The lake also had a sediment core taken as a part of a statewide study to assess temporal trends in TP and other variables and that report may be found at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/lake-water-quality.html

The TMDL on Diamond Lake started in February 2008; more information regarding that effort may be found at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesota-s-impaired-waters-and-tmdls/tmdl-projects/upper-mississippi-river-basin-tmdl-projects/underway-tmdl-diamond-lake-excess-nutrients.html?menuid=&missing=0&redirect=1.

Due to the more advanced analysis that is currently being completed as part of the TMDL, no further discussion will be provided on Diamond Lake.

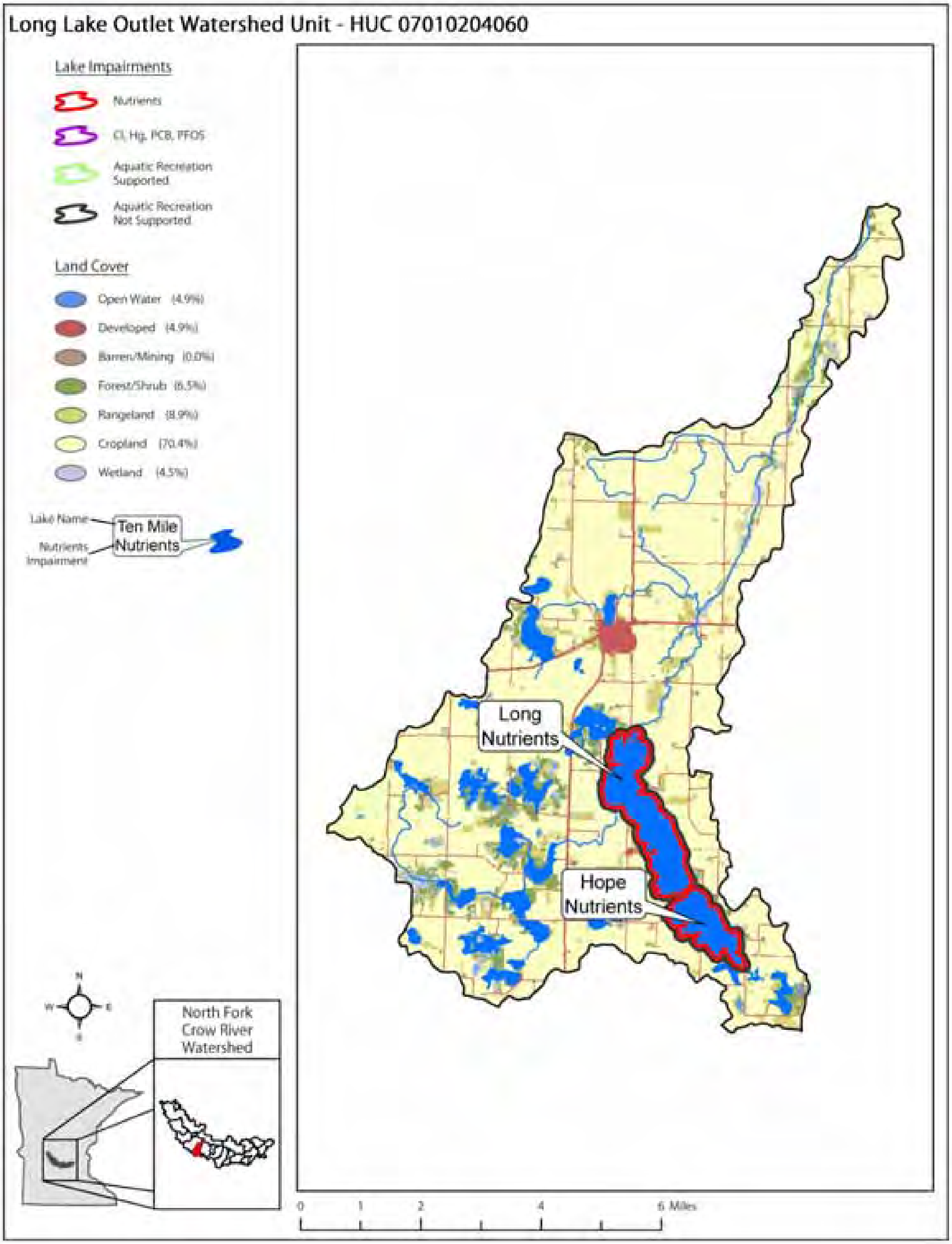
Long Lake Outlet HUC-11 Watershed

The Long Lake Outlet (07010204060) HUC-11 watershed is located in the south central portion of the North Fork Crow Watershed, to the south and north of Grove City, MN. The watershed is 12,578 ha (31,082 acres), comprises 3% of the North Fork Crow River Watershed and drains from south to north with Grove Creek flowing through Long Lake and converging with the North Fork Crow River near Manannah. The watershed spans two ecoregions (Western Corn Belt Plains and North Central Hardwood Forests), Kandiyohi and Meeker counties, and is dominated by cultivated and pasture land uses (Figure 25). Two of the nine lakes in the watershed have been assessed for aquatic recreation use support (Table 12).

Table 12: Lakes within the Long Lake Outlet HUC-11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
MEEKER	47013000	Unnamed	12		
MEEKER	47017300	Popple	18		
MEEKER	47017700	Long	281	3.4	NS
MEEKER	47017800	Sather	27		
MEEKER	47017900	Moe	16		
MEEKER	47018300	Hope	89		NS
MEEKER	47018900	Unnamed	12		
MEEKER	47019100	Unnamed (Grove)	12.5		
MEEKER	47019200	Lund	45		

Figure 25: Long Lake Outlet watershed land use and lake assessment status



Long Lake 47-0177-00

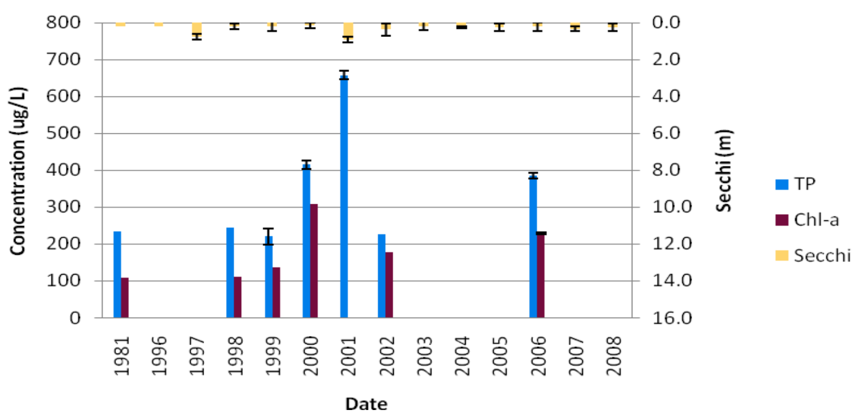
Long Lake is a shallow, 281 ha lake with a maximum depth of 3.4 m (11 feet) and a mean depth of 1.8 m (5.7 feet). The lake is located 2 miles south of Grove City, MN and has a 7,353 ha watershed dominated by cultivated land use. The lake has a narrow band of undeveloped woodland along the shore, a history of winterkill, and dense curly-leaf mats (DNR 2010). The lake was sampled in 2006 and a Lake Assessment Report was completed; excerpts from this report follow and the full report can be found at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/lake-water-quality-assessment-reports.html.

Temperature and dissolved oxygen profiles were collected on Long Lake in 2006. Data indicate that the lake is polymictic, or continually mixing (MPCA, 2007). The lake had sufficient oxygen on all dates to support game fish (minimum of 5 mg/L).

Total phosphorus, chl-*a*, and Secchi were most recently sampled in 2006 (Figure 26). The lake does exhibit a seasonal increase in TP and chl-*a* across the summer months, as noted in many shallow lakes (MPCA, 2007). The lake exceeds ecoregion ranges and eutrophication criteria for all parameters, as far back as 1981. Based on the most recent Secchi transparency trend analysis, it was determined that Long Lake is not exhibiting a clear trend. The lake exceeds the lake eutrophication standards and is considered to be not supporting aquatic recreation use (Table 13). The total maximum daily load project is slated to begin in 2017.

MINLEAP and BATHTUB were both run on Long Lake as part of the Lake Assessment Report completed in 2007. The lake is degraded considerably more than predicted by the models; internal loading is likely a large contributor to the TP load. The lake has an estimated residence time of 6 months and retains ~49% of the TP that it receives (MPCA, 2007). Complete modeling results can be found in Appendix B.

Figure 26: Long Lake long-term water quality data



Hope Lake 47-0183-00

Hope Lake is a shallow, 118 ha lake with a maximum depth of 3 m (10 feet) and a mean depth of 1.6 m (5.3 feet). The lake is located 4 miles south of Grove City, MN and has a 1,856 ha watershed (16:1 watershed to lake ratio) dominated by cultivated land use. Hope Lake has an undeveloped shoreline; the lake has a history of winterkills (DNR 2010). The lake was sampled in 2006 and a Lake Assessment Report was completed; excerpts from this report follow and the full report can be found at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/lake-water-quality-assessment-reports.html.

Temperature and dissolved oxygen profiles were collected on Hope Lake in 2006. Data indicate that the lake is polymictic, or continually mixing (MPCA, 2007). The lake had sufficient oxygen on all dates to support game fish (minimum of 5 mg/L).

Total phosphorus, chl-*a*, and Secchi were sampled in 2006. The lake does exhibit a seasonal increase in TP and chl-*a* across the summer months, as noted in many shallow lakes (MPCA, 2007). The lake exceeds ecoregion ranges and eutrophication criteria for all parameters.

Only one year of data exists for Hope Lake, as such, no trend analysis could be completed. The lake exceeds the lake eutrophication standards and is considered to be not supporting aquatic recreation use (Table 13). The total maximum daily load project is slated to begin in 2017.

MINLEAP and BATHTUB were both run on Hope Lake as part of the Lake Assessment Report completed in 2007. The lake is degraded considerably more than predicted by the models; internal loading is likely a large contributor to the TP load. The lake has a modeled residence time of 6.5 months and retains 54% of the TP that it receives (MPCA, 2007). Complete modeling results can be found in Appendix B.

Long Lake Outlet HUC-11 watershed summary

The lakes in this watershed are shallow, nutrient rich basins. Internal loading plays a significant role in the continued elevated TP levels.

This watershed is intensively managed for agricultural purposes. The large lakes have very little buffer around them; little to no data is available on the smaller basins. Based on existing water quality data, it would be recommended that this watershed be considered for restoration activities to improve lake water quality conditions.

Table 13: Summer-mean values compared to WCBP eutrophication standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
WCBP – Aquatic Rec. Use (Class 2B) Shallow Lakes	< 90	< 30	> 0.9
Long Lake 2000-2009 average	418	244	0.3
Hope Lake 2000-2009 average	263	237	0.2

Jewett Creek HUC-11 Watershed

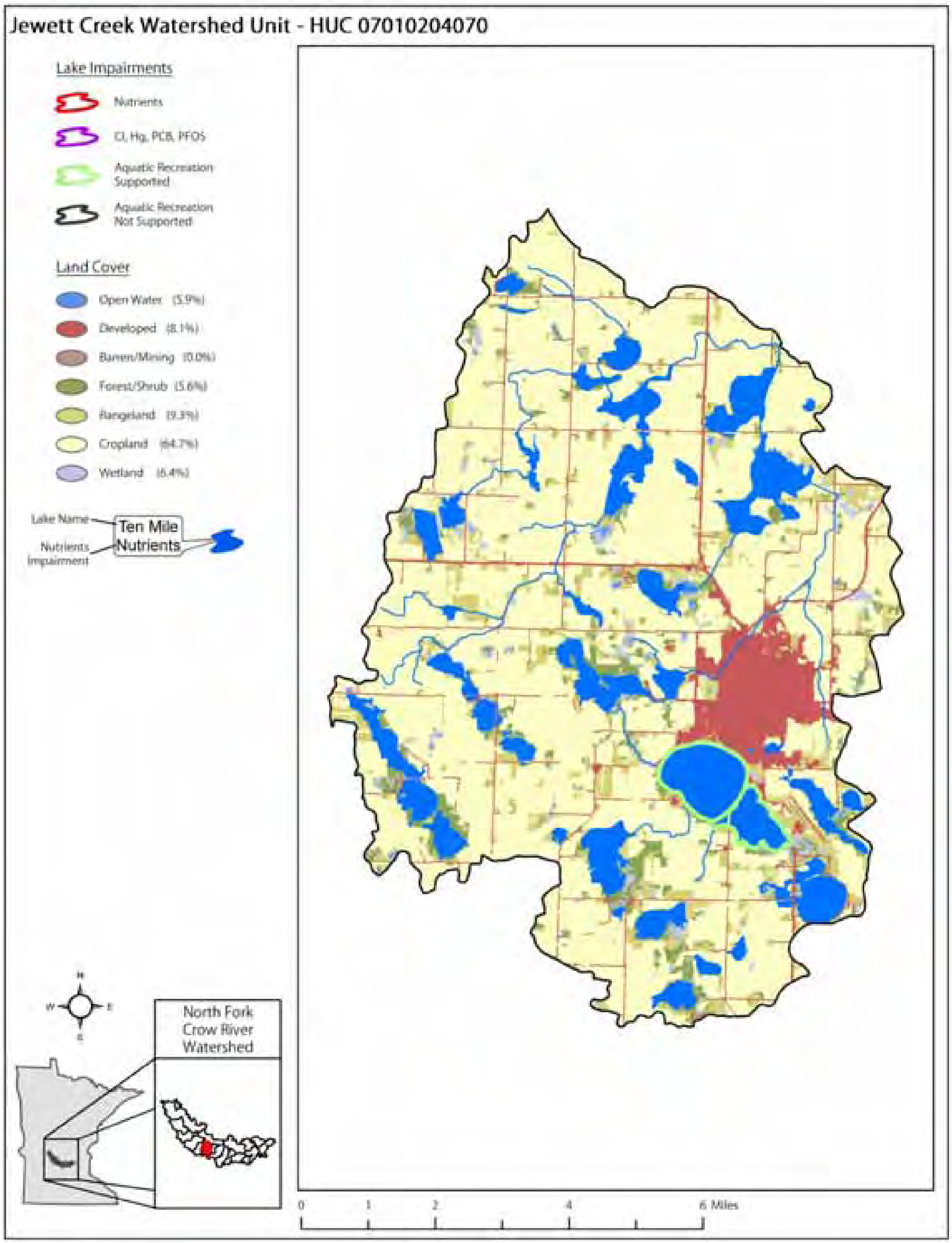
The Jewett Creek (07010204070) HUC-11 watershed is located in the south central portion of the North Fork Crow Watershed, to the north and south of Litchfield, MN. The watershed is 17,629 ha (43,563 acres), comprises 5% of the North Fork Crow River Watershed and drains from south to north, ending with the confluence of Jewett Creek 4 miles N of Litchfield, MN and spans two ecoregions (Western Corn Belt Plains and North Central Hardwood Forests). The watershed is entirely within Meeker County. Agriculture and pasture are the dominant land uses in the watershed (Figure 27). One of the eighteen lakes in the watershed has been assessed for aquatic recreation use support (Table 14).

This watershed is intensively altered, with high percentages of agricultural and urban land uses. Little data is available on the many lakes in the watershed. While Ripley is in good condition, it is anticipated that the smaller basins may be more impacted by nutrients.

Table 14: Lakes within the Jewett Creek HUC -11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
MEEKER	47007300	East Andrew Nelson	16		
MEEKER	47010100	Andrew Nelson	36		
MEEKER	47010200	Round	106	2.4	
MEEKER	47011600	Hoosier	42		
MEEKER	47013200	Unnamed	9.7		
MEEKER	47013300	Chicken	41		
MEEKER	47013401	Ripley (east portion)	54		
MEEKER	47013402	Ripley (west portion)	240	5.5	FS
MEEKER	47013600	West Hanson	21		
MEEKER	47013700	Harold	49		
MEEKER	47013800	Youngstrom	67		
MEEKER	47014000	Minnesota	47		
MEEKER	47014200	Towers	21		
MEEKER	47014300	Mary	36		
MEEKER	47014400	Half Moon	7		
MEEKER	47014700	Schultz	18		
MEEKER	47014800	Unnamed	23.8		
MEEKER	47015400	Thoen	85		

Figure 27: Jewett Creek watershed land use and lake assessment status



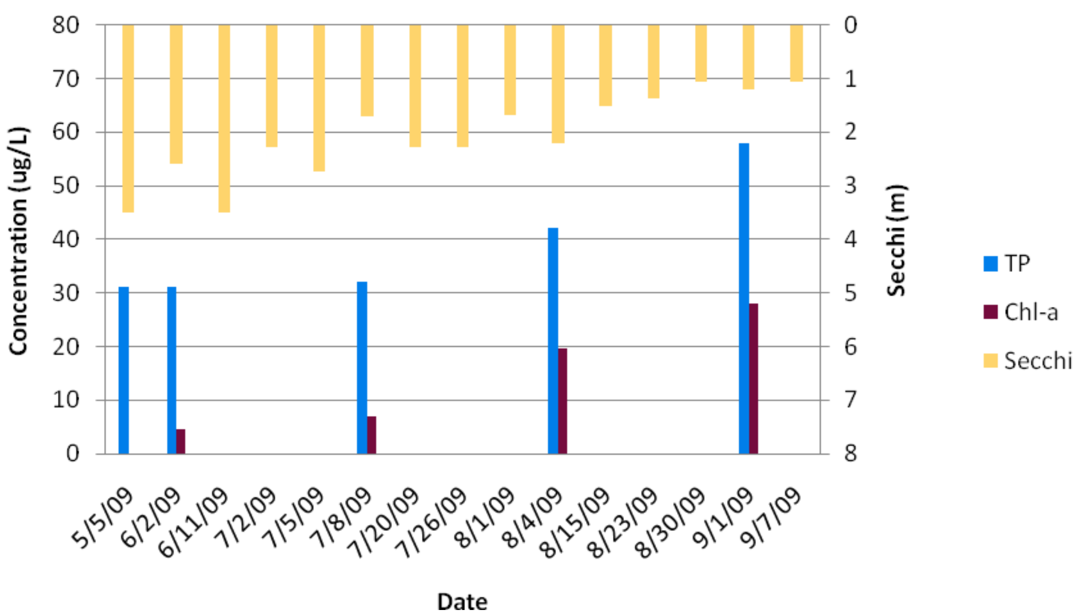
Lake Ripley 47-0134-00

Lake Ripley is a shallow 295 ha lake with a maximum depth of 5.5 m (18 feet) located in Litchfield, MN. The lake consists of a 240 ha main basin (47-0134-02) and a shallower 54 ha eastern basin (47-0134-01). Data is only available for the main basin. The lake has a 3,343 ha watershed (11:1 watershed to lake ratio) that is dominated by cultivated land use. The lake is located at the border between the NCHF and WCBP ecoregions. Much of the lake shoreline is developed as city parkland; in 2002 Eurasian watermilfoil was first documented in the lake (DNR 2010). The lake was sampled by MPCA in 1985 and a Lake Assessment Report exists detailing the results of that study at: http://www.pca.state.mn.us/water/lakereport.html

Profile data was available from 2009 (Appendix C). The lake does not thermally stratify. In mid-summer, anoxic conditions were present at the deepest point in the lake; high temperatures and pH can cause this anoxic condition in the absence of thermal stratification. The lake would be considered to be polymictic.

TP, chl-*a*, and Secchi were sampled in 2009 by MPCA (Figure 28). Lake Ripley exhibits a pattern found in many shallow lakes, where the TP and chl-*a* increase across the season and Secchi declines. Elevated temperatures and pH can allow for the release of TP from bottom sediments throughout the season and continual mixing of the lake brings the TP to the surface where is is readily available for uptake by algae.

Figure 28: Lake Ripley summer water quality data 2009



Water quality data has been collected sporadically since 1979 (Figure 29). Secchi was collected annually from 1987 to 1991 and then not again until 2004. Water chemistry has a similar history, with phosphorus being sampled in the early and late 80s and then not again until 2004. Chl-*a* was not always collected with the TP data. TP and chl-*a* levels are significantly lower in 2004 and 2009 than were observed in the 80s and 90s. This is likely the result of the Litchfield WWTP effluent limit of 1 mg/L TP that was being met since fall 2004. Based on the most recent Secchi transparency trend analysis, water clarity in this lake is very likely improving, with an estimated increase of 0.5 m (1.7 feet) per decade. The lake is well within (better than) both the deep and shallow lake eutrophication standards and is considered to be supporting aquatic recreation use (Table 15).

Figure 29: Lake Ripley long-term water quality data

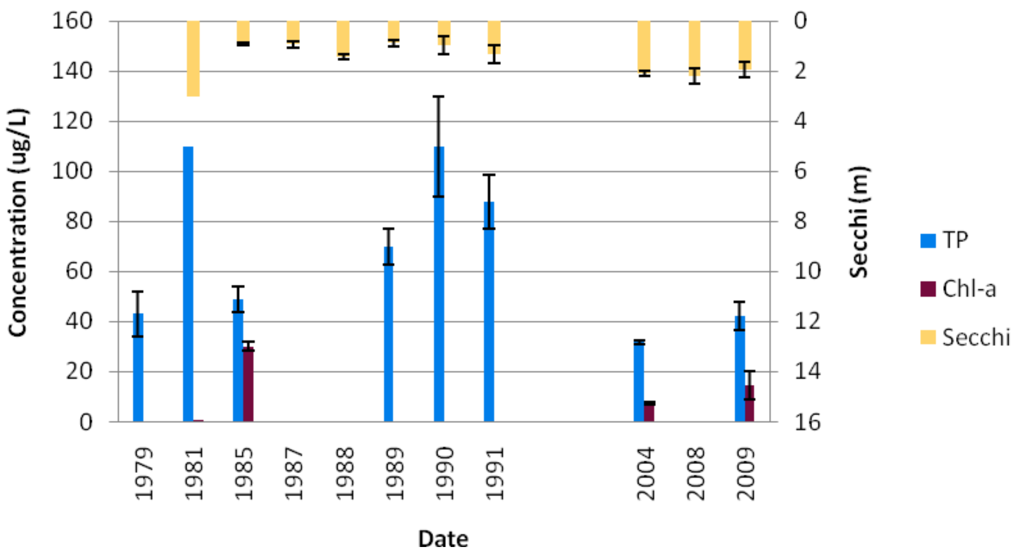


Table 15: Lake Ripley summer-mean values compared to NCHF and WCBP eutrophication standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2B) Shallow Lakes	< 60	< 20	> 1.0
WCBP – Aquatic Rec. Use (Class 2B) Shallow Lakes	< 90	< 30	> 0.7
Lake Ripley 2000-2009 average	34	9.2	2.1

MINLEAP was run for Lake Ripley as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for both NCHF and WCBP ecoregions, as Lake Ripley is in the transition zone between the ecoregions. Based on an evaluation of the land use for the lake's watershed, it would appear that the NCHF ecoregion would be most appropriate for comparison. TP and chl-*a* was lower, but not significantly different than predicted levels; Secchi observed levels were better than the model predictions. Predicted background TP of 28 ug/L would be a desirable goal to achieve. The lake retains approximately 70% of the phosphorus that enters it and has a 1.5 to 2 year residence time. Complete modeling results can be found in Appendix B.

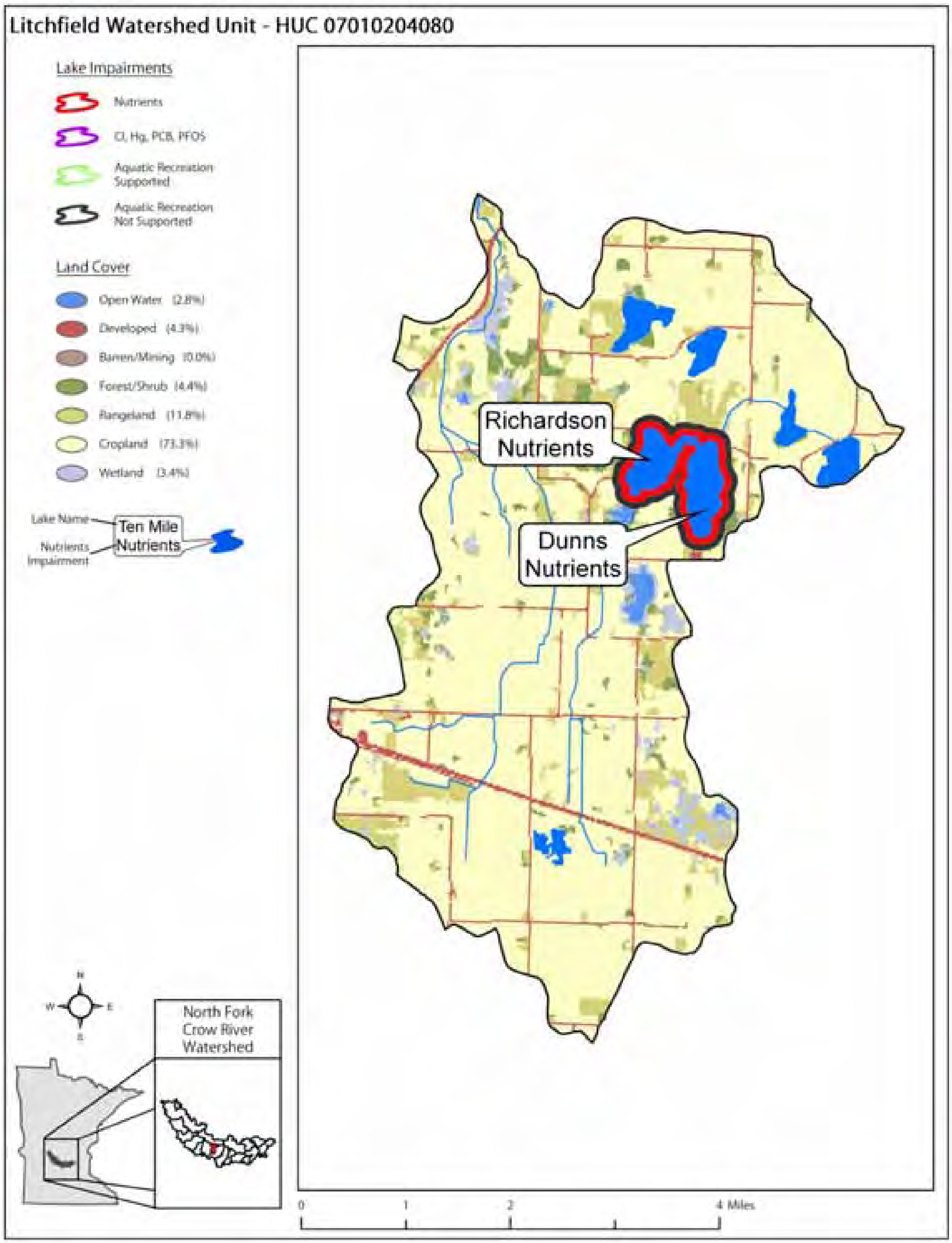
Litchfield HUC-11 Watershed

The Litchfield (07010204080) HUC-11 watershed is located in the central portion of the North Fork Crow Watershed, to the east of Litchfield, MN. The watershed is 5,978 ha (14,774 acres), and comprises 2% of the total North Fork Crow River watershed and drains from south to north and east; one outlet into County Ditch 36 and the other with the North Fork Crow River. The watershed is just northeast of the NCHF and WCBP boundary. Agriculture and pasture are the dominant land uses in the watershed (Figure 30). Two of the three lakes in the watershed have been assessed for aquatic recreation use support (Table 16).

Table 16: Lakes within the Litchfield Creek HUC-11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
MEEKER	47008200	Dunns	63	6	NS
MEEKER	47008700	Rice	28		
MEEKER	47008800	Richardson	48	14	NS

Figure 30: Litchfield watershed land use and lake assessment status



Richardson Lake 47-0088-00

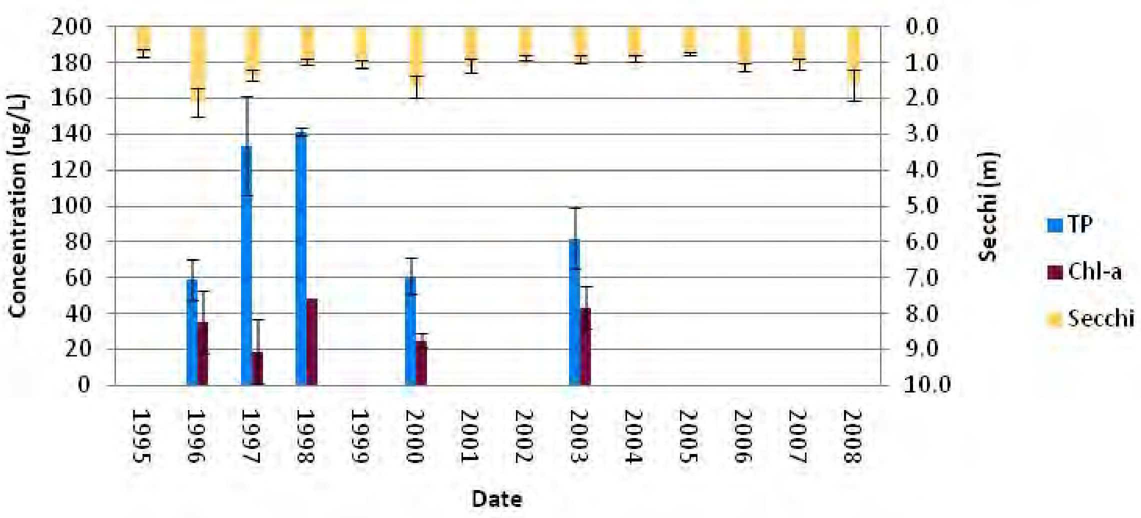
Richardson Lake is a 48.5 ha lake with a maximum depth of 14.3 m (40 feet) located 4 miles north of Darwin, MN. The lake has a large watershed (2,057 ha, 42:1 watershed to lake ratio) that is dominated by cultivated and pasture land uses. The lake is located in the NCHF ecoregion, near the border with the WCBP ecoregion. The lake was sampled by MPCA in 1996 and a Lake Assessment Report exists detailing the results of that study at: http://www.pca.state.mn.us/water/lakereport.html Richardson Lake was also a part of the diatom reconstruction study detailed at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/lake-water-quality.html. TMDL development is slated to begin in the second half of 2010.

Based on profiles collected during the 1996 sampling season, Richardson Lake stratifies throughout the summer (MPCA, 1997a). A thermocline developed between 3 and 6 meters June to September. The hypolimnetic water was less than 5 mg/L dissolved oxygen and would not have been able to support game fish.

TP, chl-*a*, and Secchi were sampled in 1996 by MPCA and more recently water chemistry was collected through other efforts in 1997, 1998, 2000, and 2003 (Figure 31). The Secchi record spans 14 years with sampling occurring from 1995 to 2008. No trend is Secchi transparency was evident from this dataset.

TP and chl-*a* levels are have been high throughout the data record. Of the seasonal averages available, none of the TP or chl-*a* average values were within the lake eutrophication standards. The lake exceeds (worse than) both the NCHF and WCBP lake eutrophication standards for TP and chl-*a* and is considered to be not supporting aquatic recreation use (Table 17).

Figure 31: Richardson Lake long-term water quality data



MINLEAP was run for Richardson Lake as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for both NCHF and WCBP ecoregions, as the lake is in the transition zone between the ecoregions. Based on diatom reconstruction, the NCHF ecoregion is the appropriate for comparison. Observed TP, chl-*a*, and Secchi were higher, but not significantly higher, than predicted values. The model estimated background TP of 21 ug/L, significantly lower than present day conditions. The lake retains approximately 63% of the phosphorus that enters it and has an estimated residence time of one year. Complete modeling results can be found in Appendix B.

Dunns Lake 47-0082-00

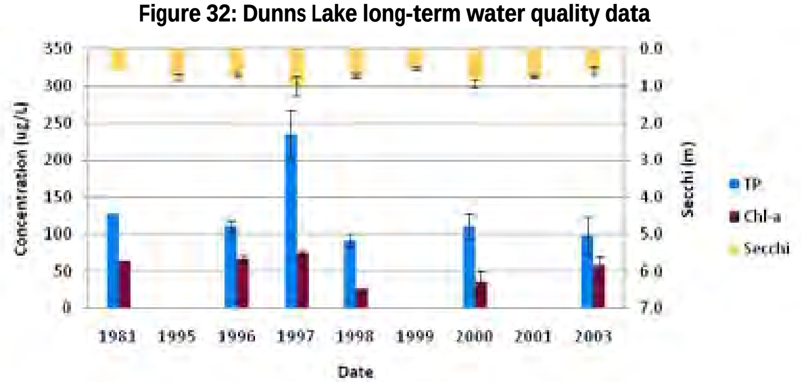
Dunns Lake is a 63 ha lake with a maximum depth of 6.1 m (20 feet) located 4 miles north of Darwin, MN. The lake has a 2,260 ha watershed (35:1 watershed to lake ratio) that is dominated by cultivated and pasture land uses, and is immediately downstream of Richardson Lake. The lake is located in the NCHF ecoregion, near the border with the WCBP ecoregion. Dunns Lake has a history of partial winterkills; the lake also has sparse vegetation with little diversity. Half of the shoreline is undeveloped, predominantly forested (DNR 2010). The lake was sampled by MPCA in 1996 and a Lake Assessment Report exists detailing the results of that study at: http://www.pca.state.mn.us/water/lakereport.html Dunns Lake was also a part of the diatom reconstruction study detailed at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/lake-water-quality.html. TMDL development is slated to begin in the second half of 2010.

Based on profiles collected during the 1996 sampling season, Dunns Lake remains well mixed throughout the summer (MPCA, 1997a). Near the sediment at the deepest point of the lake, the dissolved oxygen levels did drop below the 5 mg/L necessary to support game fish.

TP, chl-*a*, and Secchi were sampled in 1996 by MPCA and more recently water chemistry was collected through other efforts in 1997, 1998, 2000, and 2003 (Figure 32). The Secchi record spans 9 years with sampling occurring in 1981, 1995 – 2001, and 2003. No trend is Secchi transparency was evident from this dataset.

TP and chl-*a* levels are have been high throughout the data record. Of the seasonal averages available, none of the TP or chl-*a* average values were within the lake eutrophication standards. Based on the diatom reconstruction, limited littoral area (56%), and the maximum depth of 6 m, the lake is considered to be a deep lake for the purposes of comparison to standards. The lake exceeds (worse than) both the NCHF and WCBP lake eutrophication standards for TP and chl-*a* and is considered to be not supporting aquatic recreation use (Table 17).

Figure 32: Dunns Lake long-term water quality data



MINLEAP was run for Dunns Lake as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for both NCHF and WCBP ecoregions, as Dunns Lake is in the transition zone between the ecoregions. Based on diatom reconstruction, the NCHF ecoregion is the appropriate for comparison (Heiskary and Swain, 2002). TP was significantly higher than predicted levels; chl-*a* and Secchi observed levels were worse than, but not significantly different than the model predictions. The model predicted a background TP of 23 ug/L and the diatom reconstruction provided a 20 ug/L background concentration of TP. The lake is clearly exhibiting highly eutrophic conditions. The lake retains approximately 58% of the phosphorus that enters it and has a residence time on the order of 6 months to a year. Complete modeling results can be found in Appendix B.

Litchfield HUC-11 Watershed Summary

Agriculture is the primary land use in this watershed. The lakes are highly eutrophic; watershed loading, and in the case of Dunns Lake, internal loading is also driving increased eutrophication. The lakes are of poor water quality; watershed improvements would be recommended to improve the lake condition.

Table 17: Summer-mean values compared to NCHF eutrophication standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
Richardson Lake 2000-2009 average	68	32	1.1
Dunns Lake 2000-2009 average	106	42.7	0.8

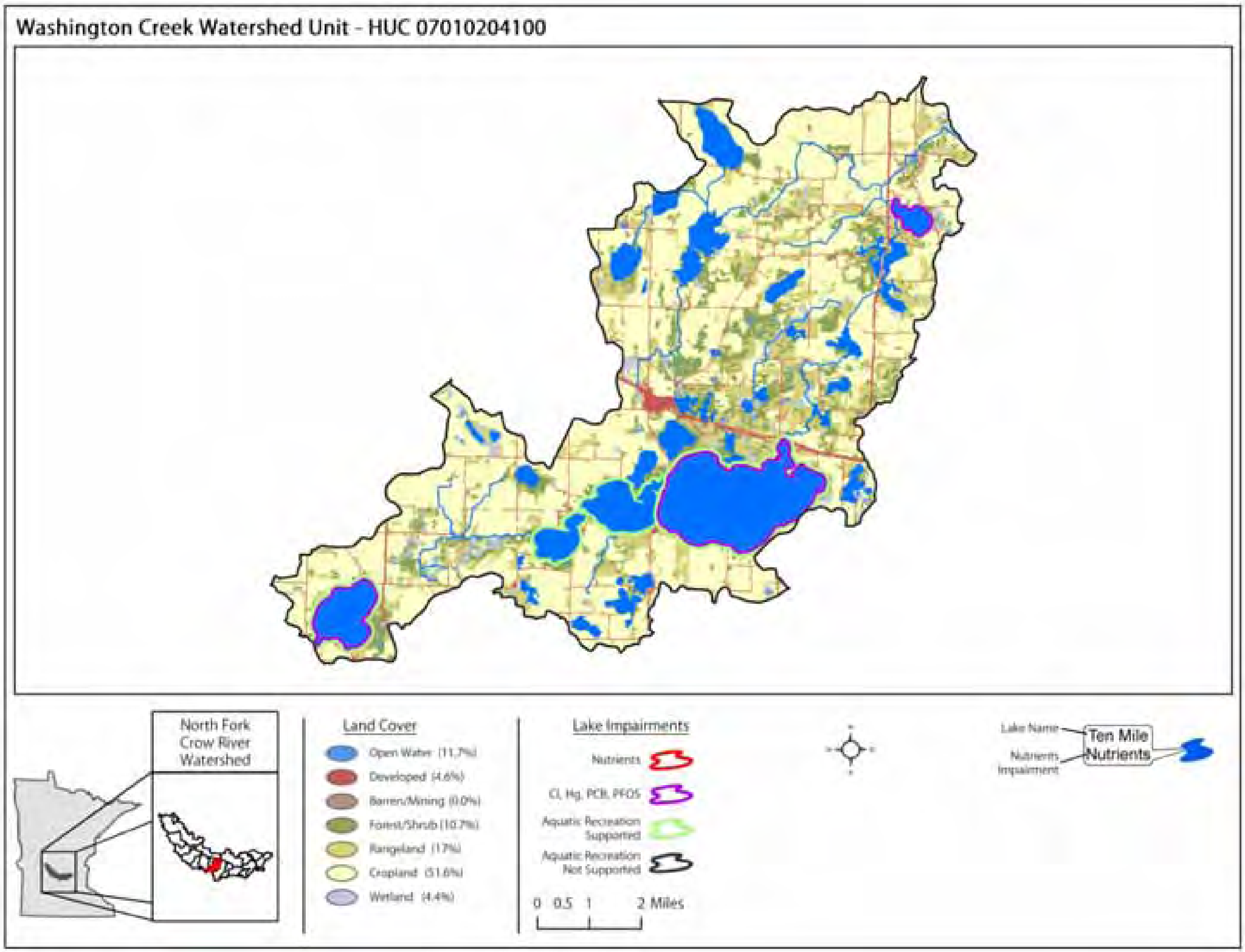
Washington Creek HUC-11 Watershed

The Washington Creek (07010204100) HUC-11 watershed is located in the south central portion of the North Fork Crow Watershed, to the south and east of Litchfield, MN. The watershed is 17,914 ha (44,268 acres), and comprises 5% of the total North Fork Crow River watershed. It drains from south to north starting in Lake Minnie-Belle to its convergence with the North Fork Crow River near Kingston, MN and spans two ecoregions (Western Corn Belt Plains and North Central Hardwood Forests). Agriculture and pasture are the dominant land uses in the watershed (Figure 33). Four of the sixteen lakes in the watershed have been assessed for aquatic recreation use support (Table 18). Two wastewater treatment plants discharge in the watershed and 30 feedlots are located throughout the watershed.

Table 18: Lakes within the Washington Creek HUC -11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
MEEKER	47002300	Arvilla	53		
MEEKER	47002900	Hart	22		
MEEKER	47003500	Sellards	40		
MEEKER	47004600	Washington	979	5.2	FS
MEEKER	47004700	Unnamed	15.8		
MEEKER	47004800	Powers	101		
MEEKER	47005000	Manuella	117	15.5	FS
MEEKER	47005500	Birch	20		
MEEKER	47006800	Stella	240	23	FS
MEEKER	47006900	North Buckley	4.4		
MEEKER	47007000	South Buckley	25		
MEEKER	47007400	Turtle	19		
MEEKER	47007600	Darwin	63		
MEEKER	47007700	Stevens	10.5		
MEEKER	47008000	Casey	34		
MEEKER	47011900	Minnie-Belle	239	15	FS

Figure 33: Washington Creek watershed land use and lake assessment status



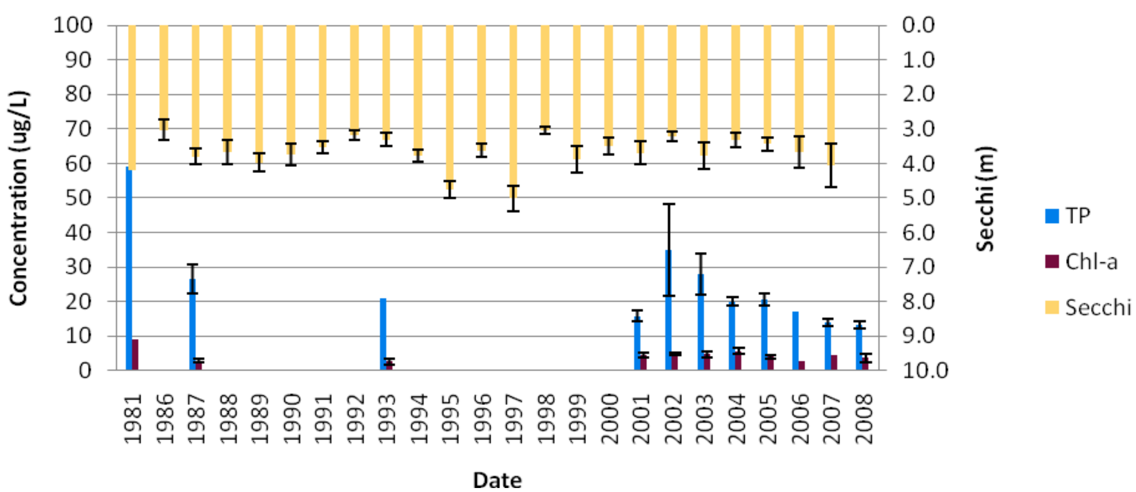
Lake Minnie-Belle 47-0119-00

Lake Minnie-Belle is a 239 ha lake, with a maximum depth of 14.9 m (49 feet) located 4 miles south of Litchfield. The lake has a small 783 ha watershed (3:1 watershed to lake ratio) that is dominated by cultivated land use. Three feedlots are in the watershed. The lake was sampled by MPCA in 1987 and a Lake Assessment Report exists detailing the results of that study at: http://www.pca.state.mn.us/water/lakereport.html

Profile data was available from 2004 (Appendix C). The lake does appear to thermally stratify near a depth of 8 meters on most dates, with complete mixing of the water column present in May and September. Dissolved oxygen profiles indicate that below a depth of 8 meters, there will likely not be sufficient oxygen to support game fish (5 mg/L).

Lake Minne-Belle has a long water quality data record (Figure 34). Secchi has been collected annually 1981 to 2007 and chemistry was collected intermittently between 1981 and 1993, and annually from 2001 to 2008. Within seasons, TP tends to be high in the spring, decline across the summer, and increase again in late fall. This is likely due to the stratification of the lake and the mixing of the phosphorus- laden hypolimnetic water in the fall.

Figure 34: Lake Minnie-Belle long-term water quality data



Phosphorus appears to be declining in recent years (since 2002). The lake is very likely improving in Secchi transparency with an estimated increase in water clarity of 0.2 meters over a decade. The lake is well above (better than) the lake nutrient standards and is considered to be fully supporting aquatic recreation use (Table 19).

MINLEAP was run for Lake Minnie-Belle as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for both NCHF and WCBP ecoregions, as Minnie-Belle is in the transition zone between the ecoregions. Based on an evaluation of the land use for the lake's watershed, it would appear that the NCHF ecoregion would be most appropriate for comparison. TP was higher, but not significantly different than predicted levels; chl-*a* and Secchi observed levels were better than the model predictions. The lake retains approximately 90% of the phosphorus that enters it and has an estimated 17 year residence time. Complete modeling results can be found in Appendix B.

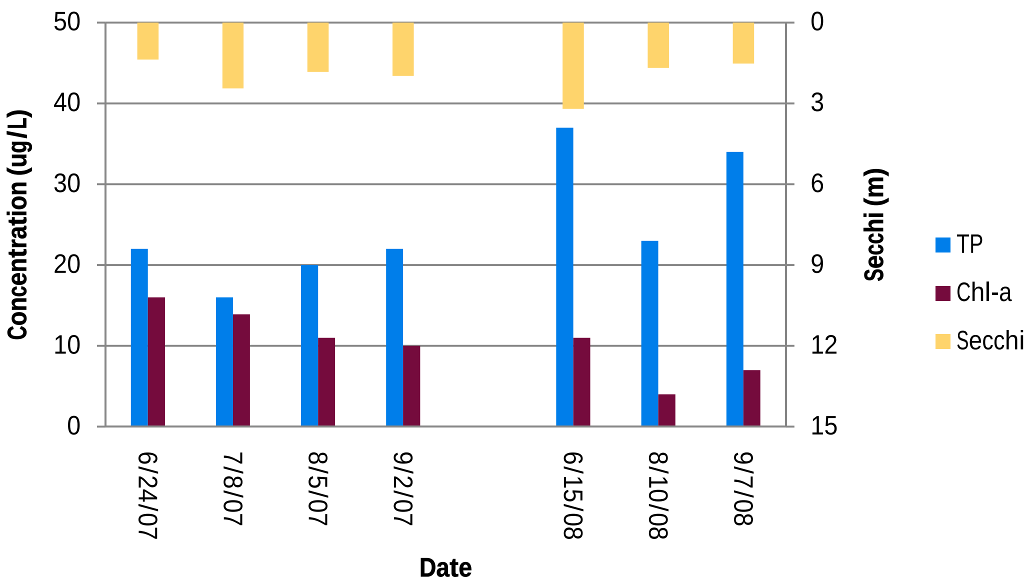
Lake Stella 47-0068-00

Lake Stella is a 240 ha lake, with a maximum depth of 22.9 m (75 feet) located 2 miles south of Darwin. The lake has a 3,069 ha watershed that is dominated by cultivated land use. Eleven feedlots are in the watershed. Eurasian watermilfoil has been present in the lake since 1999 (DNR 2010). The lake was sampled by MPCA in 1998 and a Lake Assessment Report exists detailing the results of that study at: http://www.pca.state.mn.us/water/lakereport.html.

The most recent temperature or dissolved oxygen profile data collected on Lake Stella is from 2005 (Appendix C). That data indicates that the lake does stratify and that the hypolimnion is anoxic during the summer months below a depth of approximately 8-10 meters.

TP, chl-*a*, and Secchi were sampled the summers of 2007 and 2008 (Figure 35). TP concentrations were notably lower in 2007 with higher chl-*a* values. Below average rainfall may help to explain these conditions – long stretches of warm, sunny days will allow the increased production in algae. In 2008, when rainfall returned to normal amounts, the phosphorus increased, as would be expected with additional runoff. Typically, in deep, stratified lakes, the phosphorus will be highest in the spring, decline across the summer and peak again after fall turnover. Without profile data, it is not possible to determine if the peak in TP in September 2008 was the result of turnover or if the lake was still stratified.

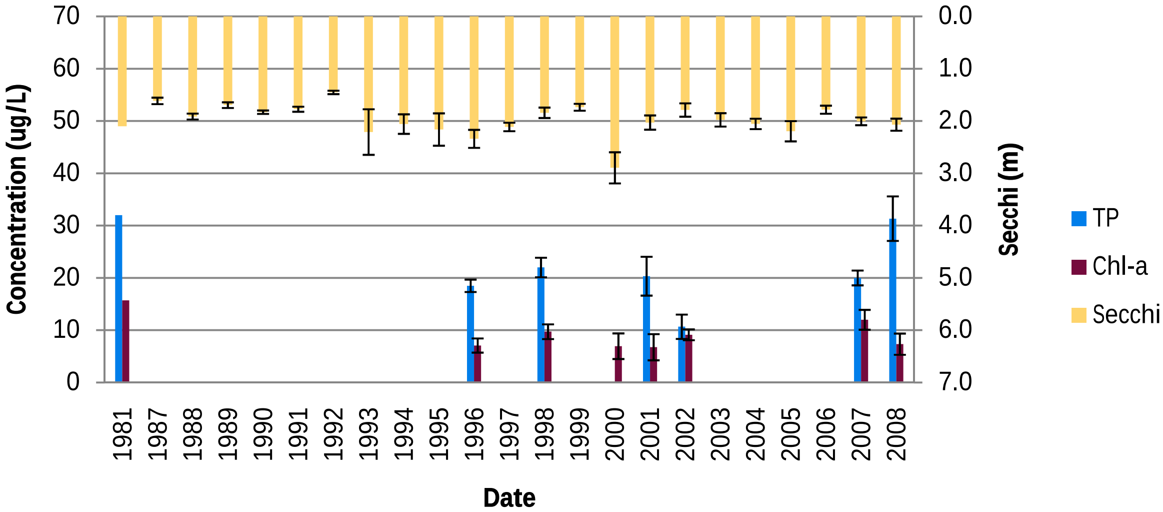
Figure 35: Lake Stella summer water quality data 2007-2008



Lake Stella has a long water quality data record. Secchi has been collected annually since 1987 and chemistry was collected intermittently between since 1991; two consecutive years of data are available for 2007 and 2008 (Figure 36).

Phosphorus has varied across the years. On several years in the dataset, TP and chl-*a* were not collected consistently; often the midsummer samples were missing from the dataset. The lake is very likely improving in Secchi transparency with an estimated increase in water clarity of 0.2 meters over a decade. The lake is well within (better than) the lake eutrophication standards and is considered to be fully supporting aquatic recreation use (Table 19).

Figure 36: Lake Stella long-term water quality data



MINLEAP was run for Lake Stella as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for the NCHF ecoregion. TP was significantly lower than predicted levels; chl-*a* and Secchi observed levels were better than the model predictions. The lake retains approximately 76% of the phosphorus that enters it and has an estimated 3 year residence time. The lake is at or below estimated background TP concentrations. Complete modeling results can be found in Appendix B.

Lake Washington 47-0046-00

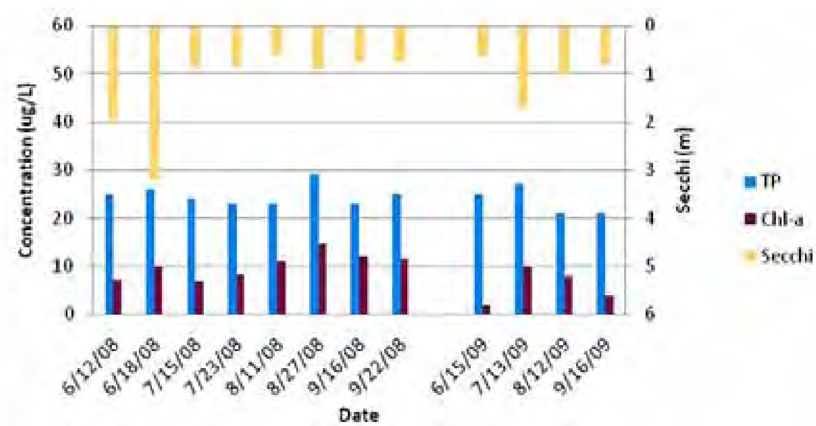
Figure 37: Lake Washington bathymetry and sites

Lake Washington is a 979 ha shallow lake, with a maximum depth of 5.2 m (17 feet) located just south of Darwin and Dassel, MN. The lake has a 9,136 ha watershed (9:1 watershed to lake ratio) that is dominated by cultivated land use. Twelve feedlots are in the watershed. Eurasian watermilfoil has been present in the lake since 1999 (DNR 2010). The lake was sampled by MPCA in 1992 (MPCA 1993) and 2008 (MPCA 2009) and a Lake Assessment Report exists detailing the results of the earlier study at: http://www.pca.state.mn.us/water/lakereport.html. The Lake Washington Improvement Association has been actively monitoring the lake for 3 years.

The most recent temperature or dissolved oxygen profile data collected on Lake Washington is from 2008. That data indicates that the lake does not stratify (i.e. is continually mixing) and has sufficient oxygen at all depths to support game fish (Appendix C).

MPCA and Association monitoring occurred at site 101 in 2008; those data are in good agreement and are shown in Figure 38. TP, chl-*a*, and Secchi were monitored at 5 separate locations on Lake Washington in 2008 and 2009 by local efforts (Figure 37). Sites 205 (outlet bay) and 209 (inlet from Lake Stella) are less than 5 feet deep.

Figure 38: Lake Washington summer water quality data 2008-2009



There does not appear to be a consistent pattern across the different sites; depending on the date, each site had the highest concentration at some point over 2008 and 2009 (Figure 39). On dates where there were large differences (June and September 2008), the high sites were the inlet and outlet, respectively. As these sites are the shallowest, it would be easy to inadvertantly mix bottom sediments into the integrated sample which may account for the higher phosphorus values. Rain records indicate a 1.5 inch event 6 days prior to the June sample and 1 inch event a day prior to the September sample. On most dates, the values are in close proximity to each other; it is likely that sampling could be reduced to a single location on the lake for chemistry and continued at all locations for Secchi transparency.

Lake Washington has a long Secchi data record. Secchi was first measured in 1981, the annually from 1985 to 2001 and 2006 to present. Water chemistry was collected in 1981 and 1992 and 2006 to present (Figure 40). Within seasons, TP tends to vary; more often in shallow lakes an increase in nutrients across the summer is noted. Total suspended solids was relatively high on this lake, 2008 sampling found an average of 10 mg/L; even with the organic portion removed, suspended inorganic solids averaged 3.8 mg/L. This may have contributed to the varied transparency across the season.

Figure 39: Lake Washington site specific summer water chemistry results for 2008 and 2009

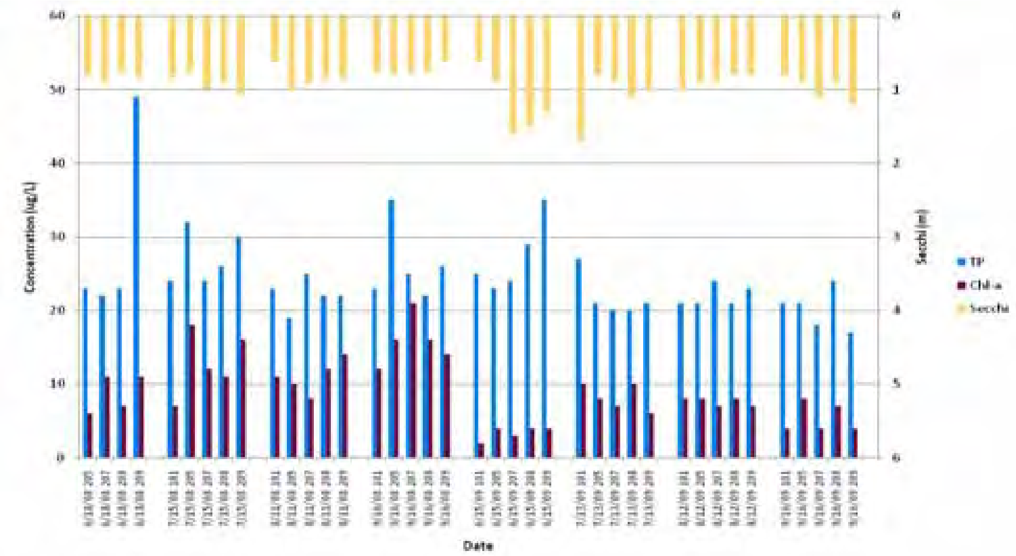
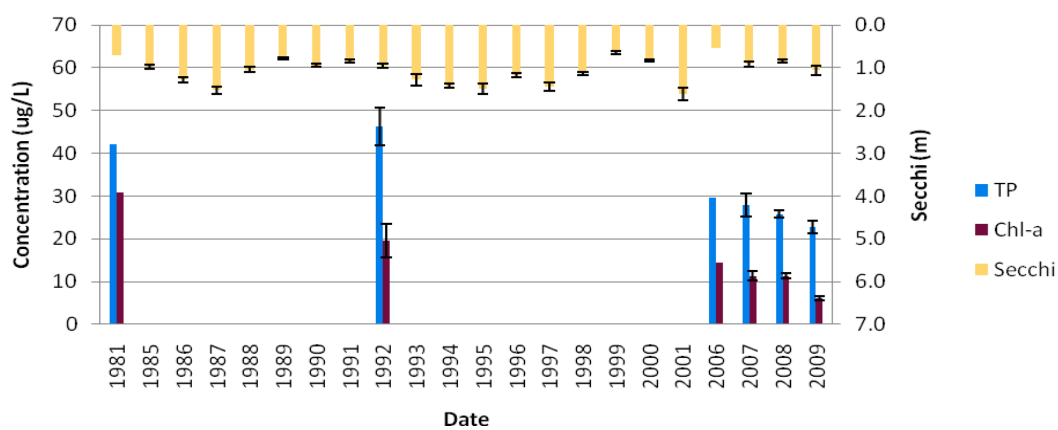


Figure 40: Lake Washington long-term summer-mean data



TP and chl-*a* concentrations have declined (improved) since monitoring began in 1981. No trend in Secchi transparency is evident. The lake is very windswept and it is often difficult to obtain a good Secchi reading from the 101 location. On several years in the dataset, TP and chl-*a* were not collected consistently; often the midsummer samples were missing from the dataset. The lake is supporting aquatic recreation use (Table 19).

MINLEAP was run for Lake Washington as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for the NCHF ecoregion. TP was significantly lower than predicted levels; chl-*a* and Secchi were lower, but not significantly different than the model predictions. The lake retains approximately 76% of the phosphorus that enters it and an estimated residence time of 3 years. The lake is at or below the predicted background TP concentration. Complete modeling results can be found in Appendix B.

Washington Creek HUC-11 Watershed Summary

This watershed has considerably more forested cover that most upstream watersheds in the HUC-8. Many of the lakes are in a chain, which benefits each downstream lake, as TP is trapped in the basin immediately upstream. Little data is available on the smaller lakes. Based on the existing data, the lakes in the Washington Creek HUC-11 are of good water quality and the watershed would benefit from protection strategies to maintain current conditions.

Washington Lake is in the upper portion of the watershed and has tributaries from lakes of good water quality (Stella, Minnie-Belle). Since upstream lakes retain much of the phosphorus that flow into them, Lake Washington benefits from this storage of phosphorus in upstream, deep lakes. Lakes Minnie-Belle, Stella, and Washington are well within (better than) the lake nutrient standards and is considered to be fully supporting aquatic recreation use (Table 19).

Table 19: Summer-mean values compared to NCHF eutrophication standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
Lake Minnie-Belle 2000-2009 average	27	4.6	3.5
Lake Stella 2000-2009 average	21	10	2.1
NCHF – Aquatic Rec. Use (Class 2B) Shallow Lakes	< 60	< 20	> 1.0
Washington Lake 2000-2009 average	26	10.3	1.1

Collinwood Creek HUC-11 Watershed

The Collinwood Creek (07010204110) HUC-11 watershed is located in the south central portion of the North Fork Crow Watershed, to the northeast and southwest of Dassel, MN. The watershed is 20,812 ha (51,428 acres), comprises 5% of the total North Fork Crow River Watershed, and drains parts of McLeod, Meeker, and Wright counties. It drains from south and west to north starting in Hook Lake to the Collinwood Creek convergence with the North Fork Crow River near Kingston, MN and spans two ecoregions (WCBP and NCHF). Agriculture and pasture are the dominant land uses in the watershed (Figure 41). Seven of the thirty-five lakes in the watershed have been assessed for aquatic recreation use support (Table 20).

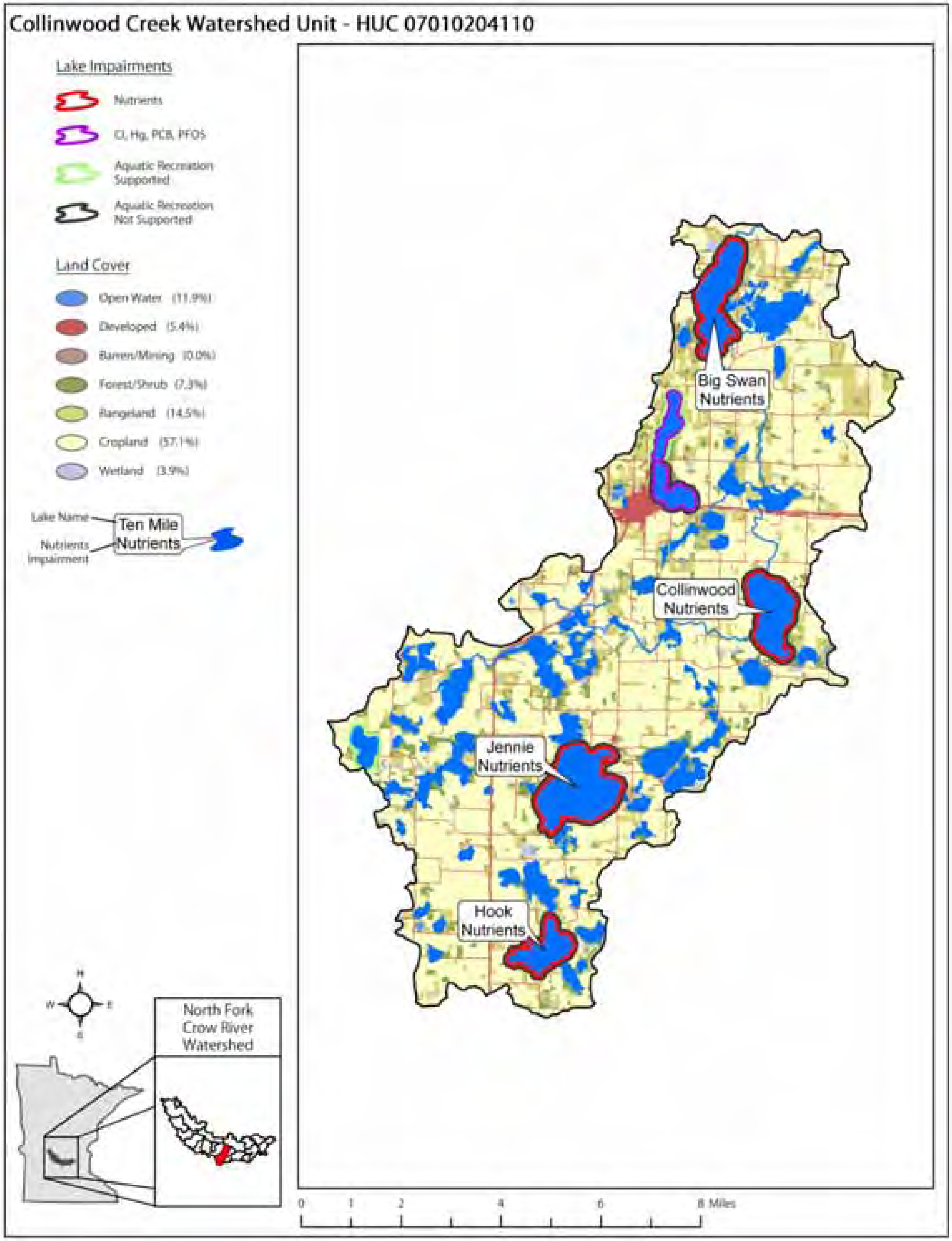
Table 20: Lakes within the Collinwood Creek HUC -11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
MCLEOD	43007000	Longanans	25.8		
MCLEOD	43007100	Todd	86.6	1.8	
MCLEOD	43007300	Hook	131	5.4	NS
MCLEOD	43007400	Emily	31		
MCLEOD	43008100	Echo	33.6		
MCLEOD	43010200	Dettmans	6		
MCLEOD	43010800	Campbells	11		
MEEKER	47000100	Maple	54.6		
MEEKER	47000500	Butternut	31		
MEEKER	47000700	Unnamed	8		
MEEKER	47000800	Pigeon	101		
MEEKER	47000900	Unnamed	32		
MEEKER	47001400	Spencer	57		
MEEKER	47001500	Jennie	427	4.2	NS
MEEKER	47001600	Wolf	106	4	
MEEKER	47001700	Collins Lake	23		
MEEKER	47001900	Little Wolf	25		
MEEKER	47002500	Little Swan	20		
MEEKER	47002600	Long	65.5	8.5	FS
MEEKER	47003100	Mud	38		
MEEKER	47003200	Spring	80	9	NS
MEEKER	47003300	Unnamed	4.4		
MEEKER	47003600	Little Spring	28		
MEEKER	47003700	Boo	14.6		
MEEKER	47003800	Big Swan	261	9.7	NS
MEEKER	47004300	Heenan	11		
MEEKER	47004400	Jewitt	102	1.5	
MEEKER	47004500	Fallon	89	1.5	
MEEKER	47005700	Porter	41		

Table 20: Lakes within the Collinwood Creek HUC -11 Watershed, continued

COUNTY	DNR Lake ID	Lake Name	Lake Area (acres)	Maximum Depth (meters)	Recreation Assessment
MEEKER	47006400	Erie	75	10.4	FS
MEEKER	47033800	Unnamed	26		
WRIGHT	86029300	Collinwood	252	8.5	NS
WRIGHT	86029500	Swan	25	0.6	
WRIGHT	86029600	Beaver Dam	8		

Figure 41: Collinwood Creek watershed land use and lake assessment status



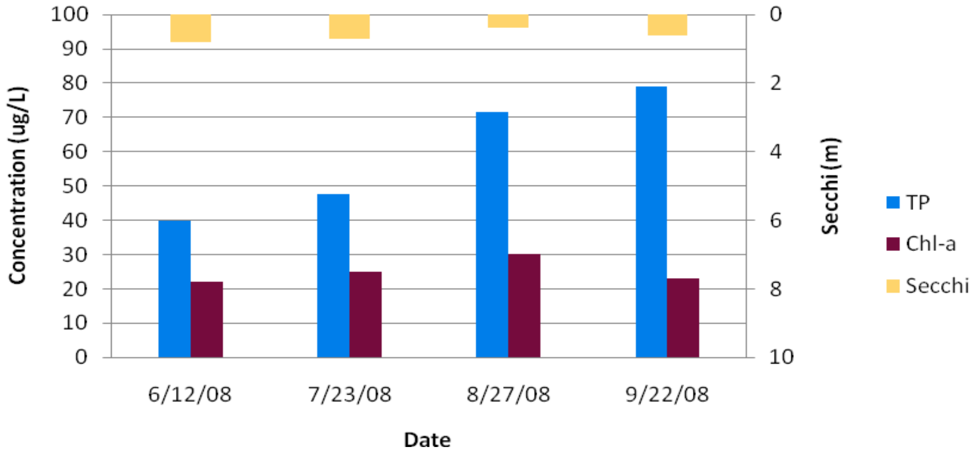
Lake Jennie 47-0015-00

Lake Jennie is a shallow 428 ha lake with a maximum depth of 3.5 m located 5 miles south of Dassel, MN. The lake has a 5,001 ha watershed (11:1 watershed to lake ratio) that is dominated by cultivated, water, and pasture land uses. The shoreline is 50% developed into residential properties; curly-leaf pondweed is abundant in the lake (DNR 2010). The lake was sampled by MPCA in 1996 (MPCA, 1997b) and a Lake Assessment Report exists detailing the results of that study at: http://www.pca.state.mn.us/water/lakereport.html. The lake will be included in the upcoming North Fork Crow River Watershed TMDL development beginning in late 2010.

Profile data was available from 2008 (Appendix C). The lake is well mixed throughout the summer season. The lake is quite shallow and is susceptible to wind mixing. On all dates in 2008, the lake had sufficient oxygen to support game fish (greater than 5 mg/L).

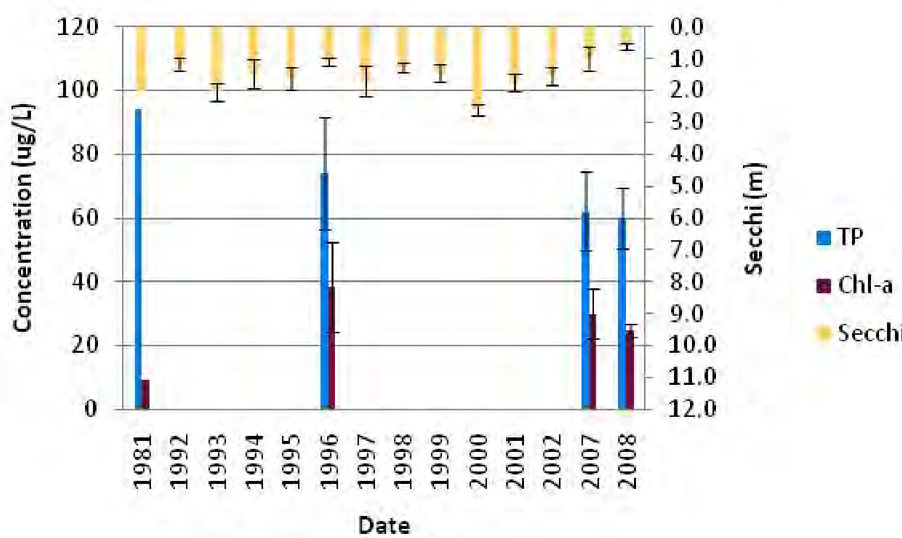
TP, chl-*a*, and Secchi were sampled in 2008 (Figure 42). TP follows a pattern exhibited in most shallow lakes, with nutrients increasing across the summer months. As temperatures increase, the TP can release from the lake sediments and increase the concentration through internal loading. Chl-*a* increased through August and then declined in September and Secchi followed a similar pattern, with the worst clarity occurring in August.

Figure 42: Lake Jennie summer water quality data (2008)



Lake Jennie has been sampled for nutrients in 1981, 1996, 2007, and 2008. The Secchi record is longer, with the first reading recorded in 1981, and then annual measurements from 1992 through 2002 and then again in 2007 and 2008 (Figure 43). The TP has been high throughout the data record. With the exception of the single sample in 1981, average chl-*a* observations have exceeded the standards as well. Secchi has been quite low in recent years. The lake is likely declining in transparency, with an estimated decrease of 0.4 m per decade. This estimated change could potentially range from no change to a decrease of 0.5 m per decade. TP and chl-*a* exceed (are worse than) the lake eutrophication standards and the lake is considered to be not supporting aquatic recreation use (Table 21).

Figure 43: Lake Jennie Long-Term Water Quality Data



MINLEAP was run for Lake Jennie as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for the NCHF ecoregion. Observed TP and chl-*a* were higher but not significantly different than predicted model outputs. The lake retains approximately 68% of the phosphorus that enters it and has an estimated 1.6 year residence time. Observed TP is significantly higher than the predicted background TP of 29 ug/L. Complete modeling results can be found in Appendix B.

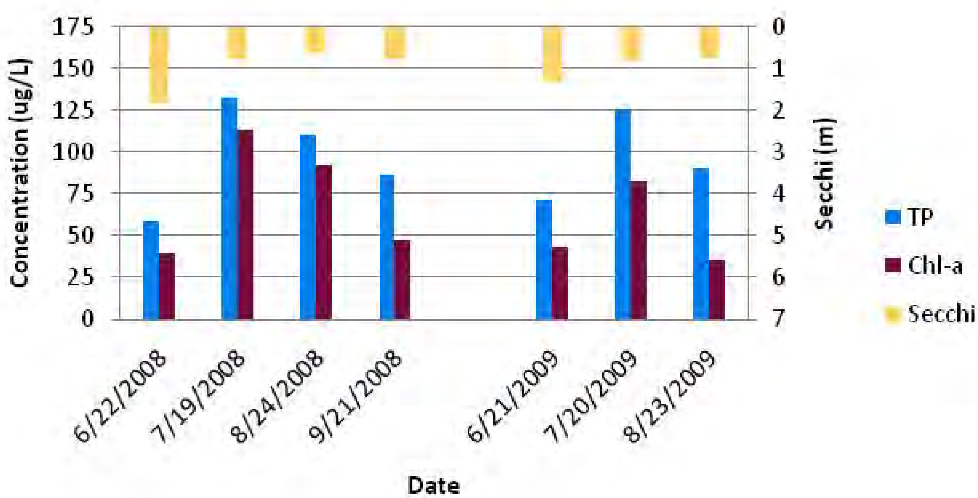
Collinwood Lake 86-0293-00

Collinwood Lake is a 253 ha lake with a maximum depth of 7.6 m located 3 miles southeast of Dassel, MN. The lake has a large 13,185 ha watershed (52:1 watershed to lake ratio) that is dominated by cultivated, water, and pasture land uses. The lake was sampled by MPCA in 1996 and a status report exists at: http://www.pca.state.mn.us/water/lakereport.html. The lake will be included in the upcoming North Fork Crow River Watershed TMDL development beginning in late 2010.

Profile data was collected in 1996 as part of the MPCA monitoring effort. The lake was well mixed in spring and fall and weakly stratified during the summer months. Temperature declined 3 to 6 ^{0}C from surface to depth. Dissolved oxygen fell below the 5 mg/L necessary to support game fish at depths greater than 6 meters. While depth TP samples were not collected, it is likely that during the low oxygenated conditions that TP was released from the sediment and made available to the water column.

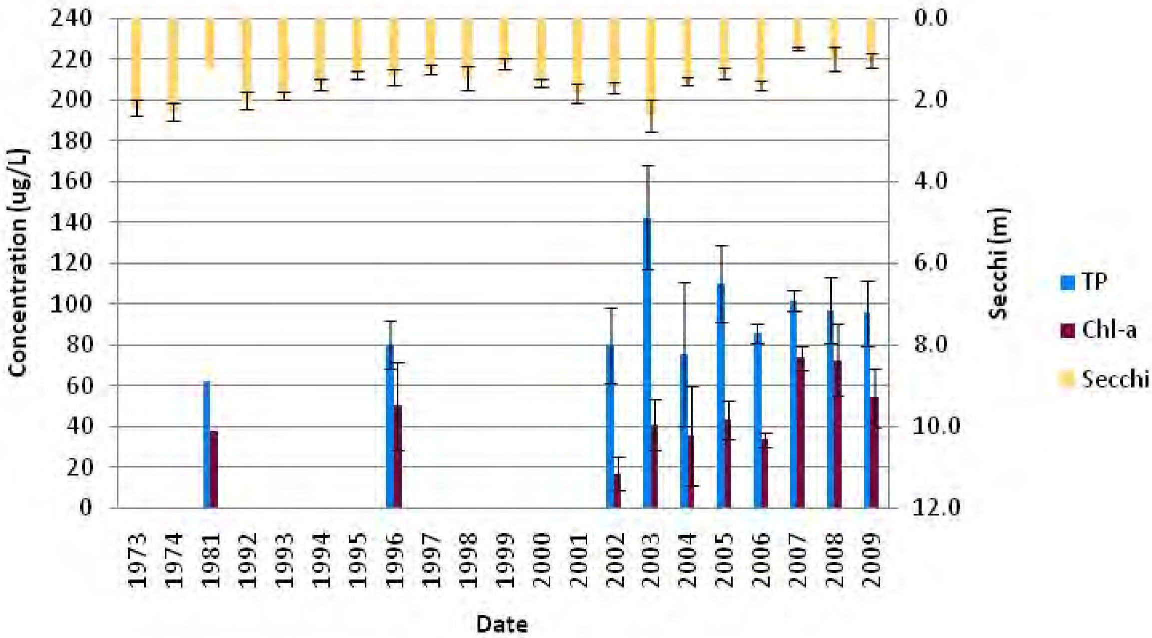
TP, chl-*a* and Secchi were collected during the summer of 2008 and 2009 (Figure 44). Observations and patterns were similar between the years, with TP reaching its peak in July and then declining across the rest of the summer.

Figure 44: Collinwood Lake summer water quality data (2008-2009)



Collinwood Lake has a long water quality data record. TP and chl-*a* were collected in 1981, 1996, and 2002 to present. Secchi was first measured in 1973, annual measurements are available from 1992 to present. Average TP and chl-*a* values have exceeded (been worse than) the eutrophication standards for all years on record (Figure 45). Based on the 21 year Secchi record, it appears that the water clarity in Collinwood Lake is likely declining, with an estimated decrease of 0.2 m per decade. This estimated change could potentially range from no change to a decrease of 0.3 m per decade. The lake exceeds the lake eutrophication standards for all parameters and is considered to be not supporting aquatic recreation use (Table 21).

Figure 45: Collinwood Lake long-term water quality data



MINLEAP was run for Collinwood Lake as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for the NCHF ecoregion. Observed TP and chl-*a* were higher but not significantly different than the modeled predictions. The lake retains approximately 53% of the TP that enters it and has an estimated residence time of 6 months. The lake is significantly higher in TP than the predicted background TP of 26 ug/L. Complete modeling results can be found in Appendix B.

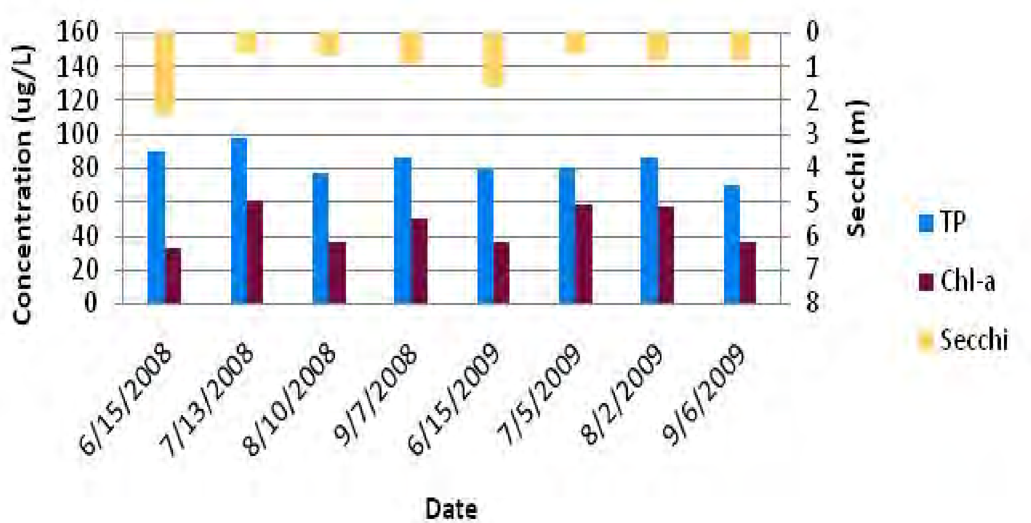
Big Swan Lake 47-0038-00

Big Swan Lake is a 261 ha lake with a maximum depth of 9.8 m located 3 miles northeast of Dassel, MN. The lake has a very large 20,363 ha watershed (78:1 watershed to lake ratio) that is dominated by cultivated, water, and pasture land uses. The lakeshore is 40% developed. Curly-leaf pondweed is present in the lake; however, Big Swan Lake has been experiencing large fluctuations in water level (8 foot bounce) which appears to be limiting the spread of this invasive (DNR 2010). The lake will be included in the upcoming North Fork Crow River Watershed TMDL development beginning in late 2010.

The most recent profile data was collected in 2007. The lake does not thermally stratify. In 2007, very high temperatures occurred during the July and August sampling dates. The corresponding dissolved oxygen profiles dipped below the 5 mg/L necessary to support game fish. Under these conditions, it is likely that phosphorus was released from the sediments and could have contributed to internal loading.

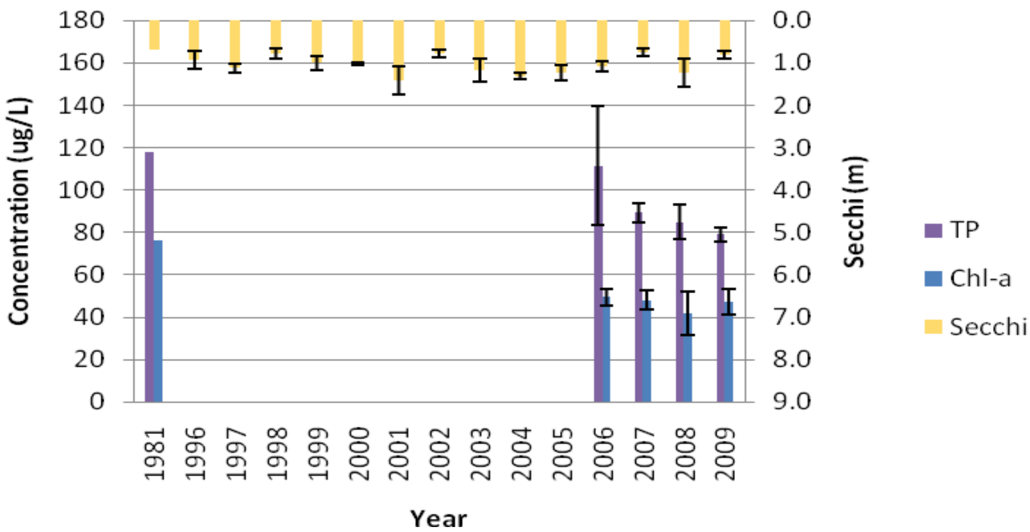
TP, chl-*a*, and Secchi were collected most recently in 2008 and 2009. Data was collected from two sites on the lake; the follow graphs depict an average for the lake. No pattern is evident in TP or chl-*a* between the two seasons. Secchi is consistently highest in early spring and then declines and slowly recovers across the season.

Figure 46: Big Swan summer water quality data 2008-2009



Big Swan Lake has a relatively recent water quality record, with TP and chl-*a* collected one time in 1981 and then not again until 2006 (Figure 47). Since then the water monitoring has been annual. Secchi has consistently been sampled annually since 1996. TP and chl-*a* have declined slightly from 2006 to 2008, but the decrease is not statistically significant. No trend is detected in Secchi transparency. All parameters exceed the lake eutrophication standards and the lake is considered to be not supporting aquatic recreation use (Table 21).

Figure 47: Big Swan Lake long-term water quality data



MINLEAP was run for Big Swan Lake as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for the NCHF ecoregion. TP and chl-*a* observed values were higher but not significantly different than modeled predictions. The lake retains approximately 51% of the TP that enters the basin and has an estimated residence time of 6 months. The lake is significantly higher in TP than the predicted background concentration of 24 ug/L. Complete modeling results can be found in Appendix B.

Collinwood Creek HUC-11 watershed summary

Collinwood Creek HUC-11 is a very lake rich watershed. Many of the lakes have very large watershed to lake ratios; the lake is receiving runoff from a large land area. The lakes in this watershed also tend to be shallow. While there are some lakes in the watershed in good condition, it would be recommended that work be done in the watershed to reduce TP loading, as the majority of the lakes with existing data are impaired (Table 21).

Table 21: Summer-mean values compared to NCHF eutrophication standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2B) Shallow Lakes	< 60	< 20	> 1.0
Lake Jennie 2000-2009 average	61	27.7	1.6
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
Collinwood Lake 2000-2009 average	99	46.5	1.6
Big Swan Lake 2000-2009 average	91	46.7	1.1

Sucker Creek HUC-11 Watershed

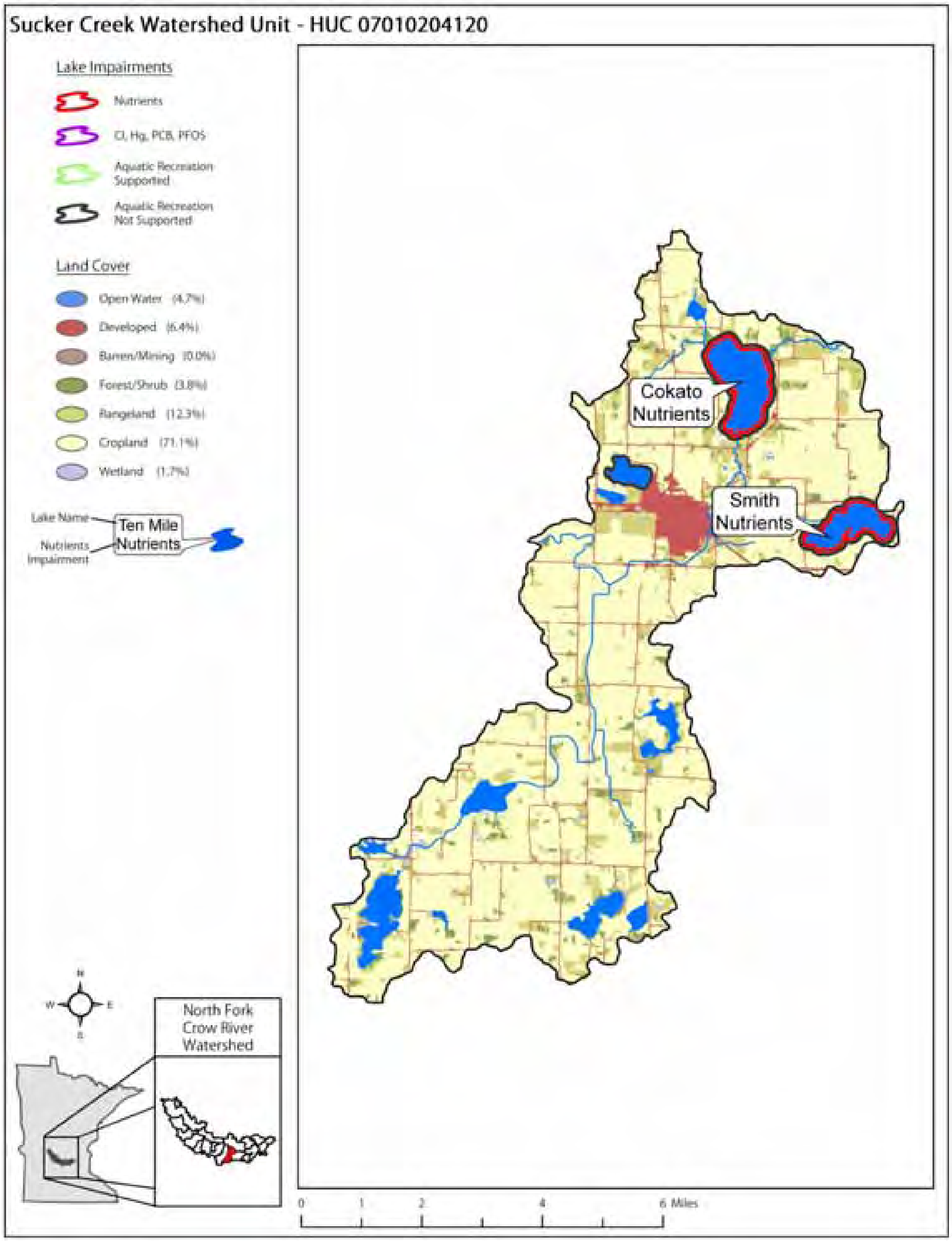
The Sucker Creek (07010204120) HUC-11 watershed is located in the south central portion of the North Fork Crow Watershed, to the north and south of Cokato, MN. The watershed is 12,043 ha (29,758 acres), comprises 3% of the total watershed area, and drains parts of McLeod, Meeker, and Wright counties. It drains from south to north starting in Shakopee and Byron Lakes through Cokato Lake and ends with the convergence of Sucker Creek with the North Fork Crow River near Cokato, MN. The entire watershed is within the NCHF ecoregion with agriculture, pasture, and urban are the dominant land uses in the watershed (Figure 48) Three of the five lakes in the watershed have been assessed for aquatic recreation use support (Table 22).

The Sucker Creek HUC-11watershed is intensively row cropped and has a high proportion of urban development compared to upstream watersheds. The lakes with existing data in this watershed are impaired; the watershed would benefit from restoration activities to improve the water quality.

Table 22: Lakes within the Sucker Creek HUC -11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
MEEKER	47000400	Byron	137		
WRIGHT	86025000	Smith	74	1.5	NS
WRIGHT	86025500	Shakopee	46	0.6	
WRIGHT	86026300	Cokato	220	1.6	NS
WRIGHT	86026400	Brooks	39	6.4	NS

Figure 48: Sucker Creek HUC -11 watershed land use and lake assessment status



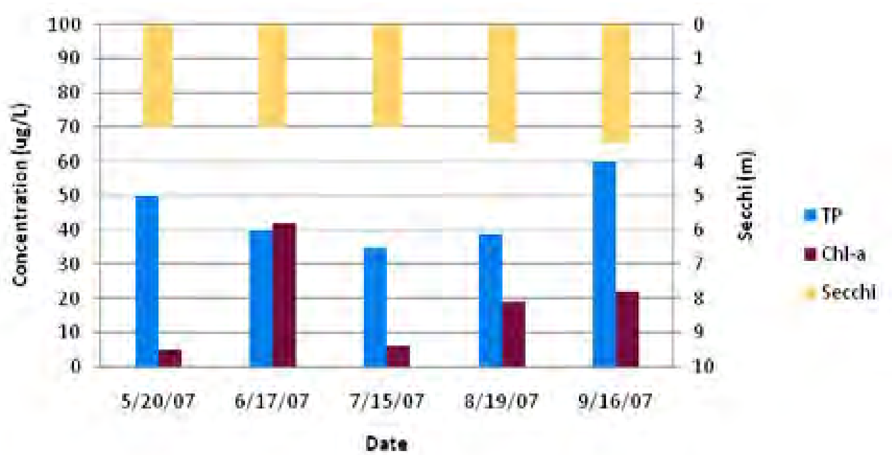
Cokato Lake 86-0263-00

Cokato Lake is a 221 ha lake with a maximum depth of 15.8 m (52 feet) located 2 miles northeast of Cokato, MN. The lake has a large 11,855 ha watershed (53:1 watershed to lake ratio) that is dominated by cultivated, pasture, and urban land uses. Cokato Lake has a low abundance of aquatic plants. Residential development of the shoreline has undergone a rapid expansion on recent years (DNR 2010). The lake will be included in the upcoming North Fork Crow River Watershed TMDL development beginning in late 2010.

The most recent profile data was collected in 2007 (Appendix C). The available profile was from August; the thermocline developed between 8 and 10 meters on that date. Dissolved oxygen dropped to zero below a depth of 8 meters. These anoxic conditions would have allowed for TP to be released from the sediments and contribute to internal loading once the lake mixed in the fall.

TP, chl-*a*, and Secchi were collected most recently in 2007 (Figure 49). TP follows a pattern expected for deep lakes, declining across the season and then peaking in fall when phosphorus laden hypolimnetic water mixes with the surface water during turnover. The pattern is less evident with chl-*a* and Secchi.

Figure 49: Cokato Lake summer water quality data (2007)



Cokato Lake has a long water quality record, with TP and chl-*a* collected in the 60s and 70s and more recently from 2003 to 2007 (Figure 50). Secchi was first sampled in 1951, and then sporadically until 2003 when annual sampling occurred through 2007. TP and chl-*a* have declined since the late 60s and 70s. The lake had a point source discharge until around 1980; the city of Cokato was directly discharging the waste water treatment plant effluent into the lake. Since the diversion of the point source, the TP and chl-*a* have varied, but no recent trend in water quality is evident. Based on the most recent Secchi transparency trend analysis, water clarity in Cokato Lake is likely improving, with an estimated increase of 0.2 m per decade. This estimated change could potentially range from an increase of 0 m per decade to an increase of 0.5 m per decade. TP and chl-*a* exceed the lake eutrophication standards and the lake is considered to be not supporting ARUS (Table 23).

Figure 50: Cokato Lake long-term water quality data

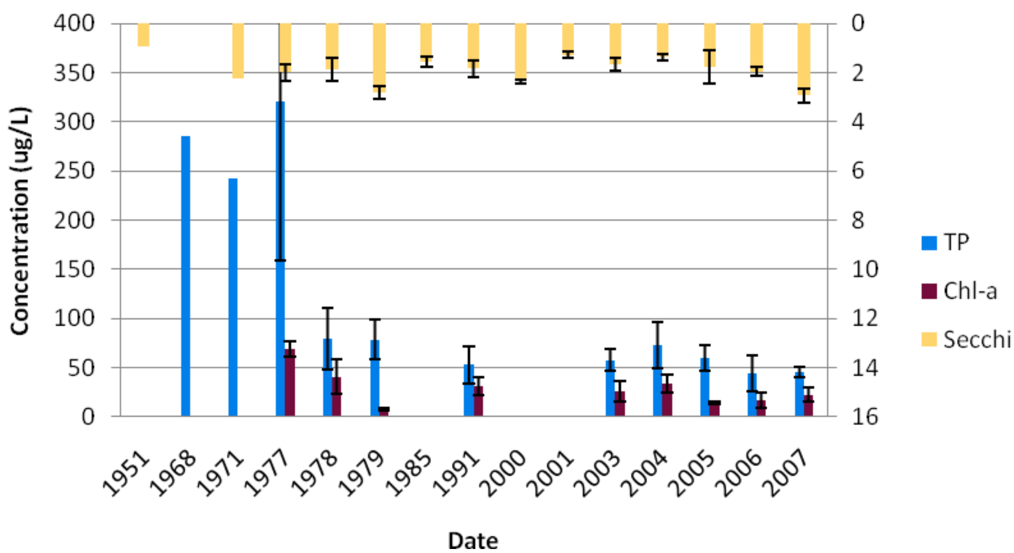


Table 23: Cokato Lake summer-mean values compared to NCHF eutrophication standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
Cokato Lake 2000-2009 average	54	22	1.9

MINLEAP was run for Lake Cokato as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for the NCHF ecoregion. TP and chl-*a* observed values were slightly lower but not significantly different than modeled predictions. The lake retains approximately 61% of the TP that enters the basin and has an estimated residence time of 11 months. The lake is significantly higher in TP concentration than predicted background concentration of 22 ug/L. Complete modeling results can be found in Appendix B.

Twelve Mile Creek HUC-11 Watershed

The Twelve Mile Creek (07010204130) HUC-11 watershed is located in the southeastern portion of the North Fork Crow Watershed, to the southwest of Waverly, MN. The watershed is 15,190 ha (37,535 acres), comprises 4% of the total watershed area, and is entirely within Wright County and the NCHF ecoregion. It drains from southwest to northeast draining Ann, Emma, Howard and Dutch Lakes before flowing through Little Waverly and Waverly to the confluence with the North Fork Crow River north of Waverly, MN. Agriculture and pasture are the dominant land uses in the watershed (Figure 51). Six of the twelve lakes in the watershed have been assessed for aquatic recreation use support (Table 24).

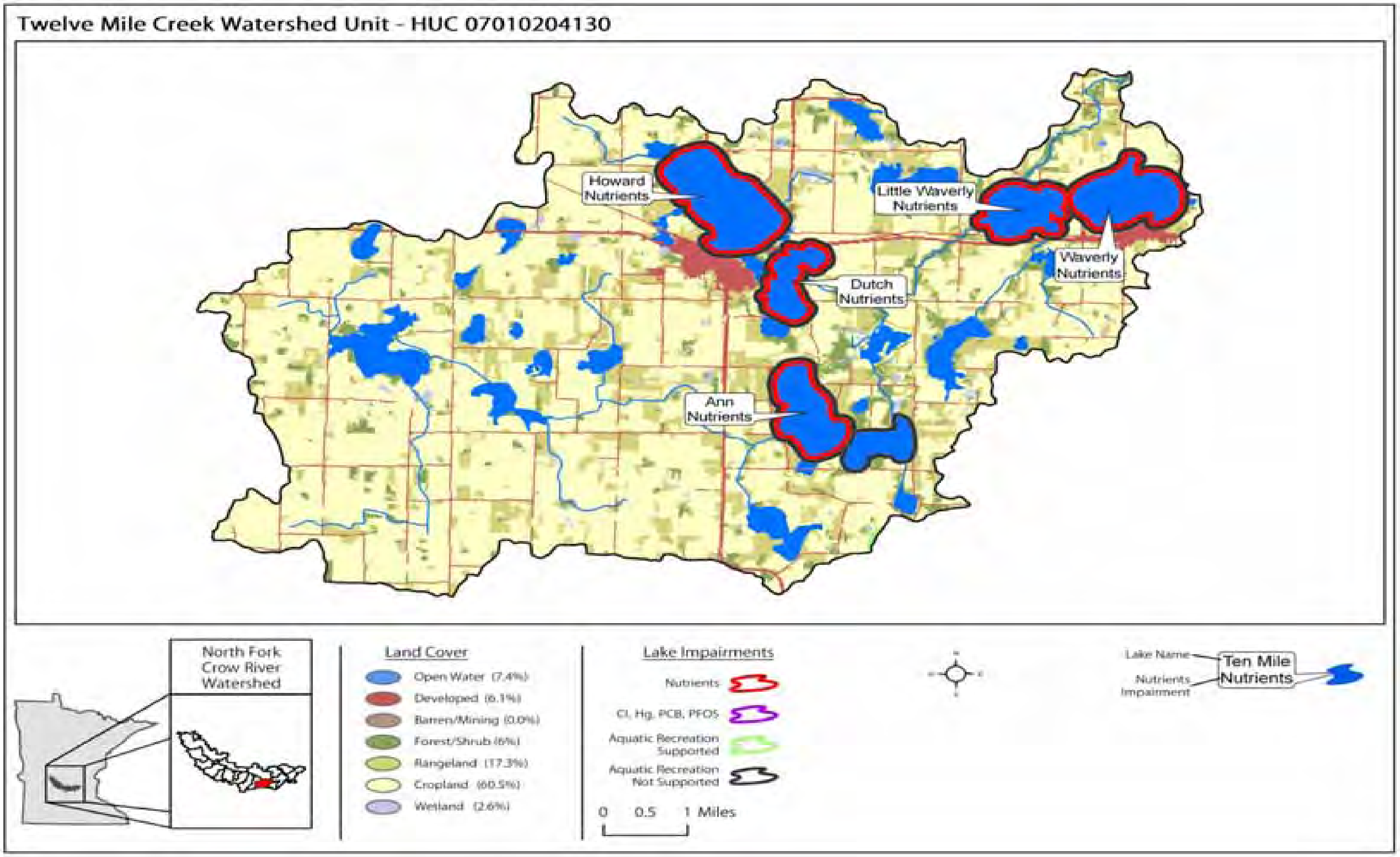
Of the 6 assessed lakes, 5 have completed Lake Assessment Reports completed. These reports can be found at: http://ww.pca.state.mn.us/water/lakereport.html. TMDL development has begun on Ann and Emma Lakes, updates can be found at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesota-s-impaired-waters-and-tmdls/tmdl-projects/upper-mississippi-river-basin-tmdl-projects/underway-tmdl-wright-county-lakes-excess-nutrients.html. The remaining lakes will be a part of the North Fork Crow River Watershed TMDL that will begin work in late 2010.

This watershed has undergone significantly development; row crop, pasture, and urban land uses make up the majority of the watershed. Watershed runoff combined with limited buffers has led to degraded conditions in the area lakes. Historical point sources have also contributed to degraded conditions in some of the lakes. It is recommended that this watershed have restoration practices put into place to reduce the TP loading to the lakes and improve the water quality.

Table 24: Lakes within the Twelve Mile Creek HUC-11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
WRIGHT	86010600	Little Waverly	136	3	NS
WRIGHT	86011400	Waverly	197	20	NS
WRIGHT	86017700	Yaeger	39		
WRIGHT	86018000	School Section	14	0.6	
WRIGHT	86018400	Dutch	64	9	NS
WRIGHT	86018800	Emma	73	4	NS
WRIGHT	86019000	Ann	151	5.8	NS
WRIGHT	86019200	Round	17	8.2	
WRIGHT	86019400	Long	20	0.9	
WRIGHT	86019900	Howard	295	11	NS
WRIGHT	86020000	Spring	22		
WRIGHT	86020600	Doefler	36		

Table 51: Twelve Mile Creek HUC-11 watershed land use and lake assessment status



Howard Lake 86-0199-00

Howard Lake is a 295 ha lake with a maximum depth of 11 m located in Howard Lake, MN. The lake has a small 1,726 ha watershed (6:1 watershed to lake ratio) that is dominated by cultivated, water and pasture land uses. Eurasian watermilfoil was discovered in the lake in 2003 (DNR 2010). The lake was sampled by MPCA in 2005, a Lake Assessment Report detailing the results of this study are available at: http://www.pca.state.mn.us/water/lakereport.html. The lake will be included in the upcoming North Fork Crow River Watershed TMDL development beginning in late 2010.

The most recent profile data was collected in 2005. The lake was well mixed in May and September, a weak thermocline developed during the summer months. The lake periodically stratifies (MPCA, 2006). Dissolved oxygen dropped to near zero below a depth of 8 meters. These anoxic conditions would have allowed for TP to be released from the sediments and contribute to internal loading when the lake mixed.

TP, chl-*a*, and Secchi were collected most recently in 2008 and 2009 (Figure 52). TP follows a pattern expected for shallow lakes, where the TP continually increases across the season as a result of internal loading. While Howard Lake is considered to be a deep lake, the lake only periodically remains stratified. Chl-*a* and Secchi respond to the increase in TP with increased algal production and reduced clarity as the season progresses.

Howard Lake was first sampled in 1981 and then again from 2002 to present for water chemistry (Figure 53). The Secchi record is similar on Howard Lake, with the addition of readings in 1990 and 2000. TP and chl-*a* have varied over the last decade, however, no trend is evident. Secchi transparency trend analysis was also unable to detect a trend in Howard Lake. All parameter exceed the lake eutrophication standards and the lake is considered to be not supporting aquatic recreation use (Table 25).

Figure 52: Howard Lake summer water quality data (2008 and 2009)

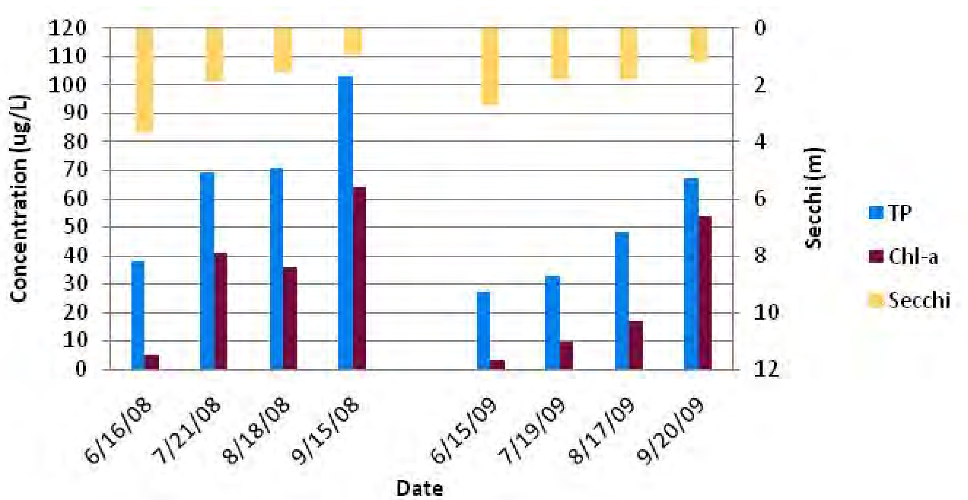


Figure 53: Howard Lake long-term water quality data

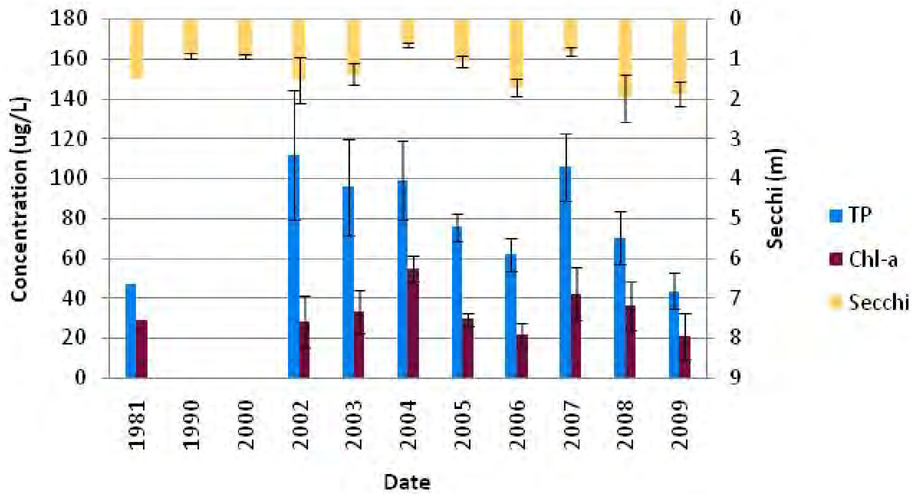


Table 25: Howard Lake summer-mean values compared to NCHF eutrophication standards

Ecoregion	TP	Chl-a	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
Howard Lake 2000-2009 average	82	33.2	1.3

MINLEAP was run for Howard Lake as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for the NCHF ecoregion. TP and chl-*a* observed values were significantly higher than predicted model outputs; this is likely due to the model's inability to account for internal loading. The lake retains approximately 82% of the TP that enters the basin and has an estimated residence time of 6 years. The lake is currently significantly higher than the predicted background TP concentration of 23 ug/L. Complete modeling results can be found in Appendix B. BATHTUB modeling was completed for Howard Lake in 2005. Results can be found in the Lake Assessment Report at: http://www.pca.state.mn.us/water/lakereport.html.

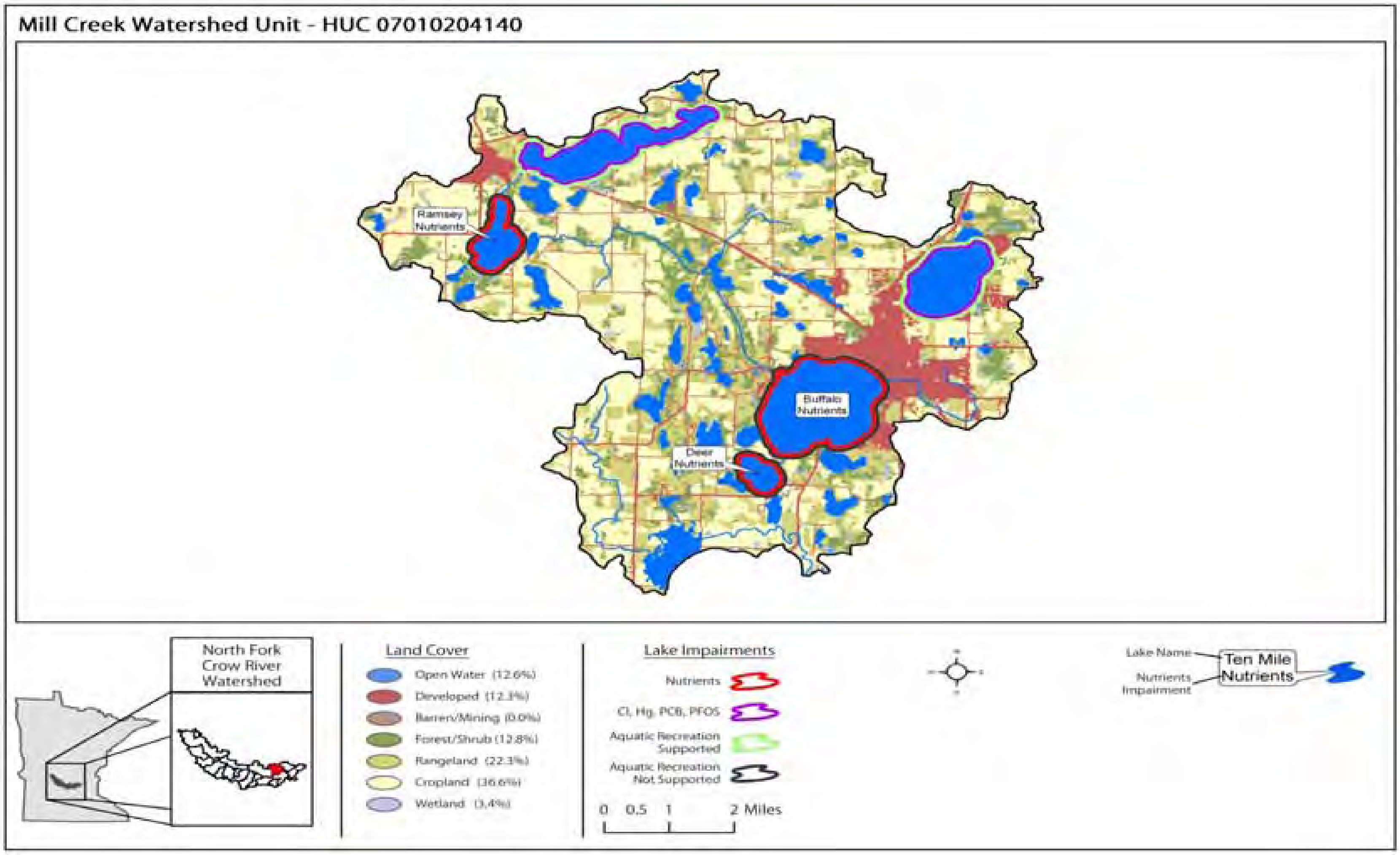
Mill Creek HUC-11 Watershed

The Mill Creek (07010204140) HUC-11 watershed is located in the northeastern portion of the North Fork Crow Watershed, between Maple Lake and Buffalo, MN. The watershed is 15,144 ha (37,421 acres), comprises 4% of the total watershed area, and is entirely within Wright County and the NCHF ecoregion. It drains from north to south draining Maple, Pulaski, and Buffalo Lakes before Mill Creek confluences with the North Fork Crow River south of Buffalo, MN. Agriculture and pasture are the dominant land uses in the watershed (Figure 54). Five of the seventeen lakes in the watershed have been assessed for aquatic recreation use support (Table 26).

Table 26: Lakes within the Mill Creek HUC-11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
WRIGHT	86005301	Little Pulaski	17	3.7	
WRIGHT	86005302	Pulaski (main bay)	291	26.5	FS
WRIGHT	86008900	Tamarack	23	8	
WRIGHT	86009000	Buffalo	620	10	NS
WRIGHT	86010700	Deer	68	8.2	NS
WRIGHT	86010800	Goose	20	4.2	
WRIGHT	86010900	Fadden	7	15	
WRIGHT	86011600	Birch	41	8	
WRIGHT	86012000	Ramsey	124	24	NS
WRIGHT	86012200	Light Foot	25	6.7	
WRIGHT	86012300	North Twin	18		
WRIGHT	86012400	Unnamed (Pauman)	8		
WRIGHT	86012600	South Twin	14.5		
WRIGHT	86013200	Abbie	45		
WRIGHT	86013401	Upper Maple	248	21	FS
WRIGHT	86013402	Mud	46	3	
WRIGHT	86013403	Maple (NE Bay)	45	9	

Figure 54: Mill Creek HUC-11 watershed land use



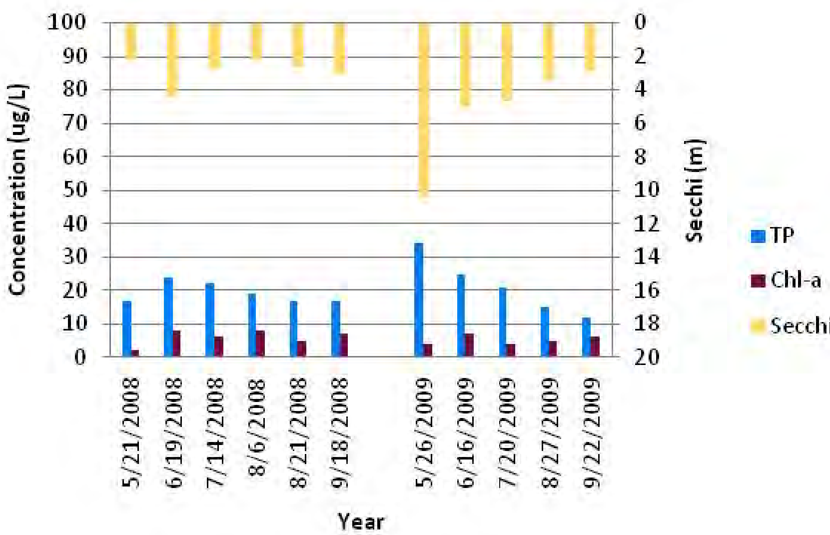
Lake Pulaski (Main Lake) 86-0053-02

Lake Pulaski (Main Lake) is a 291 ha lake with a maximum depth of 26.5 m located in Buffalo, MN. The lake has a relatively small 1,349 ha watershed (5:1 watershed to lake ratio) that is distributed evenly between water/wetland, cultivated, urban, and pasture land uses, with a smaller portion of the watershed in forested cover. The lakeshore is highly developed and the lake receives high recreation use. Eurasian watermilfoil has been present in the lake since 1991 (DNR 2010).

The most recent profile data was collected in 1996 (Appendix C). A thermocline develops between a depth of 5 and 10 meters during the summer months. Dissolved oxygen declined on all dates below a depth of 10 meters. During the late summer, the oxygen dropped below the 5 mg/L necessary to support game fish between 10 and 15 meters.

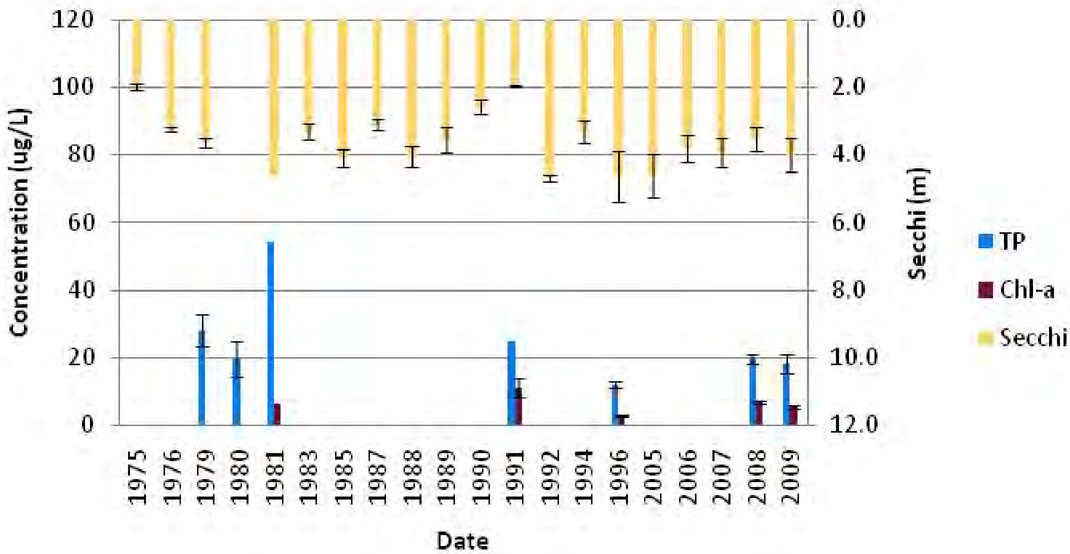
TP, chl-*a*, and Secchi were most recently sampled in 2008 and 2009. TP followed a pattern typical to deep lakes, with nutrient levels decreasing over the season (Figure 55). Once the lake mixes in the fall, a surge of TP from the hypolimnetic water would be expected, however, sampling dates in both years did not capture the fall turnover. Chl-*a* and Secchi do not follow the pattern observed with the nutrients; however, chl-*a* levels are very low throughout the summer and clarity never dropped below 2 meters in either year (Figure 55).

Figure 55. Lake Pulaski (Main Lake) summer water quality data (2008 and 2009)



Lake Pulaski (Main Lake) was first sampled for water chemistry in the late 1970s. Sampling was sporadic across the record, with two years of sampling in the 80s and 90s, and then the most recent sampling in 2008 and 2009 (Figure 56). The Secchi record is quite extensive on Lake Pulaski (Main Lake), with the first measurements taken in 1975. TP and chl-*a* have varied over the data record, but no significant trend is evident. Secchi transparency trend analysis was also unable to detect a trend in on Lake Pulaski (Main Lake). All parameters are well with (better than) the lake eutrophication standards and the lake is considered to be supporting aquatic recreation use (Table 27).

Figure 56: Lake Pulaski (Main Lake) long-term water quality data



MINLEAP was run for Lake Pulaski (Main Lake) as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for the NCHF ecoregion. TP and chl-*a* matched model predictions; observed Secchi was better than model predictions, but within the error of the model. The lake retains approximately 89% of the TP that enters the basin and has an estimated residence time of 17 years. The lake is slightly above the predicted background TP of 16 ug/L. Complete modeling results can be found in Appendix B.

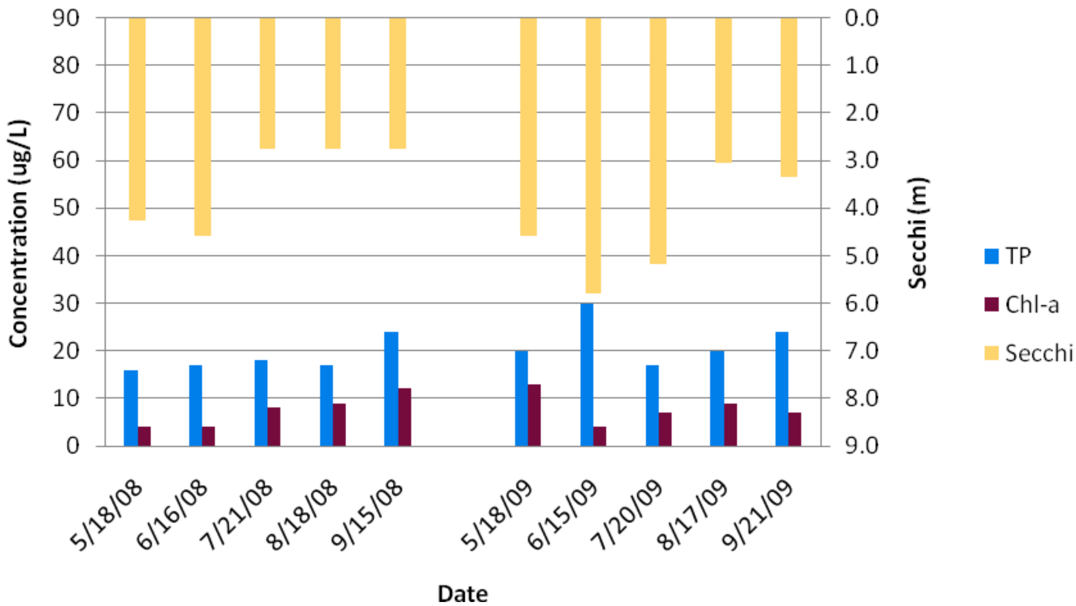
Upper Maple Lake 86-0134-01

Upper Maple Lake is the main basin of Maple Lake; two additional basins exist, Maple Lake NE and Mud Lake to the southwest. This discussion will be specific to Upper Maple Lake. Upper Maple Lake is a 251 ha lake with a maximum depth of 23 m located in Buffalo, MN. The lake has a relatively small 1,192 ha watershed (5:1 watershed to lake ratio) that is dominated by cultivated and water land uses. Upper Maple Lake is a popular recreation lake; Eurasian watermilfoil has been present in the lake since 2007 (DNR 2010). The lake was sampled in 1997 by MPCA; the Lake Assessment Report detailing the results of this study can be found at: http://www.pca.state.mn.us/water/lakereport.html.

The most recent profile data was collected in 1997. A thermocline develops between a depth of 5 and 8 meters during the summer months. Dissolved oxygen dropped below the 5 mg/L necessary to support game fish at a depth of 8 meters and anoxic conditions were present during the summer months. This would allow for TP to be released from the bottom sediments and reach the surface during the fall overturn.

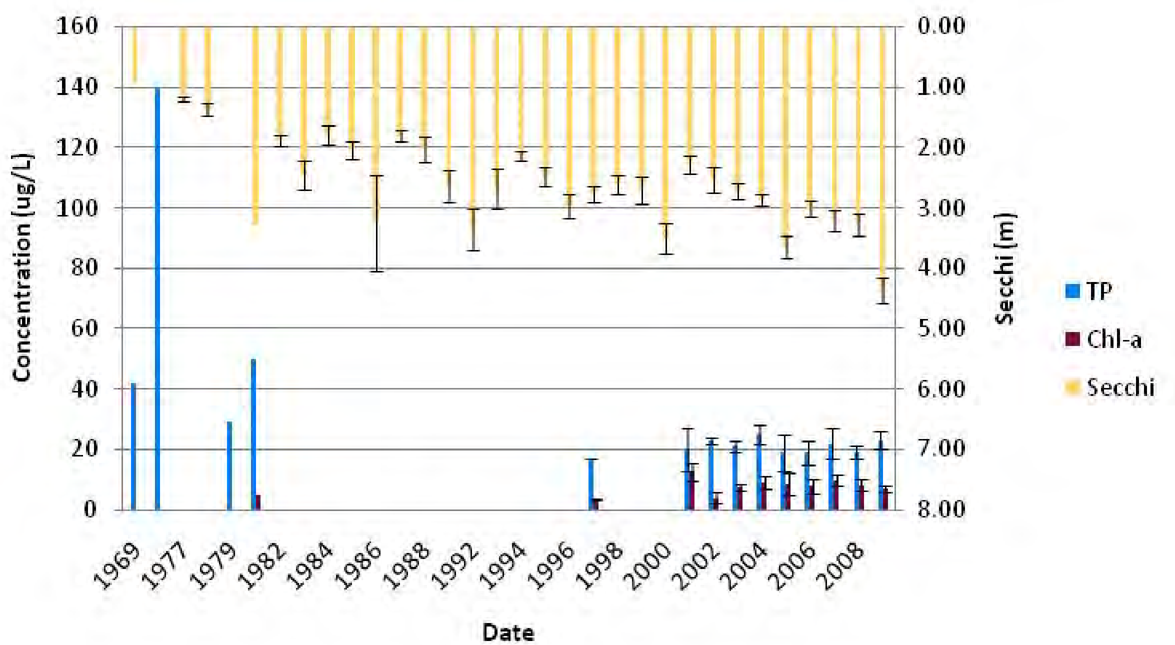
TP, chl-*a*, and Secchi were most recently sampled in 2008 and 2009. TP varied little over the season, with a slight increase from spring to fall (Figure 57). Once the lake mixes in the fall, a surge of TP from the hypolimnetic water would be expected. Chl-*a* levels are very low throughout the summer and Secchi responded to the chl-*a* concentration changes as expected (Figure 57).

Figure 57: Upper Maple Lake summer water quality data (2008 and 2009)



Upper Maple Lake was first sampled for water chemistry in 1969. Sampling occurred in the late 70s and into the early 80s. Since then the lake was sampled in 1997 and from 2001 to present (Figure 58). The Secchi record is quite extensive on Upper Maple Lake, with the first measurements taken in 1969 and annual readings since the early 80s. TP has declined since the measurements from the 70s and 80s; more recent data does not exhibit a trend and has been relatively stable. Based on the most recent Secchi trend analysis, water clarity in Upper Maple Lake is almost certainly improving, with an estimated increase of 0.5 m per decade. This estimated change could potentially range from an increase of 0.4 m per decade to an increase of 0.7 m per decade. All parameters are well within (better than) the lake eutrophication standards and the lake is considered to be supporting aquatic recreation use (Table 27).

Figure 58: Upper Maple Lake long-term water quality data



MINLEAP was run for Upper Maple Lake as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for the NCHF ecoregion. TP and chl-*a* were better than but within the error of the modeled predictions; observed Secchi was significantly better than model predictions. The lake retains approximately 84% of the TP that enters the basin and has an estimated residence time of 7 years. The lake is slightly below the predicted background TP concentration of 23 ug/L. Complete modeling results can be found in Appendix B.

Buffalo Lake 86-0090-00

Buffalo Lake is a 620 ha lake with a maximum depth of 10.7 m located in Buffalo, MN. The lake has a large 12,473 ha watershed (20:1 watershed to lake ratio) with cultivated, pasture, and water as the dominant land uses. The lake was sampled in 2005 as part of the Lake Assessment Program. The report can be found at: http://www.pca.state.mn.us/water/lakereport.html. The TMDL on Buffalo Lake starts in late 2010.

Because no new data is available since the 2005 report and the TMDL start date of 2010 which will include more advanced modeling of the lake, no further discussion will be provided on Buffalo Lake.

Mill Creek HUC-11 Watershed summary

The Mill Creek Watershed has a high percentage of forested land cover compared to upstream watersheds. The large, deeper lakes in the headwaters of the watershed are considered to be supporting aquatic recreation. However, the more downstream waterbodies are impaired. The watershed would benefit from restorative practices being in place to maintain or reduce TP loading in the watershed.

Table 27: Summer-mean values compared to NCHF eutrophication standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
Lake Pulaski (Main Lake) 2000-2009 average	19	6.2	3.9
Upper Maple Lake 2000-2009 average	21	8.3	3.0
Buffalo Lake 2000-2009 average	80	58	0.8

Louzers Lake Outlet HUC-11 Watershed

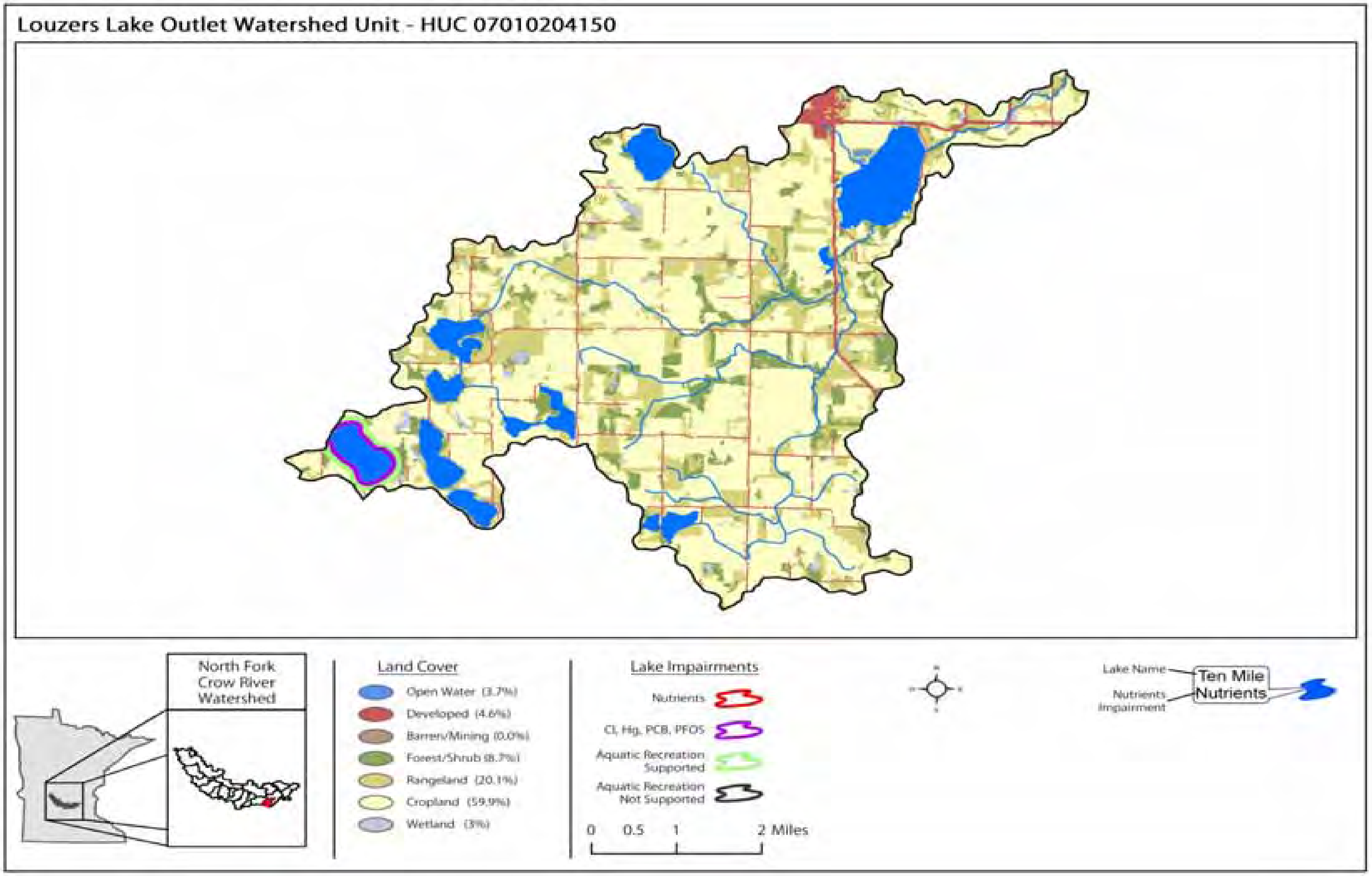
The Louzers Lake Outlet (07010204150) HUC-11 watershed is located in the southeastern portion of the North Fork Crow Watershed, southwest of Montrose, MN. The watershed is 8,054 ha (19,902 acres), comprises 2% of the total watershed area, and is entirely within the NCHF ecoregion. It drains from the southwest in Carver County to northeast in Wright County draining to the North Fork Crow River east of Montrose, MN. Agriculture and pasture are the dominant land uses in the watershed (Figure 59). One of the five lakes in the watershed has been assessed for aquatic recreation use support (Table 28).

Lakes in the Louzers Lake Outlet HUC-11 tend to be small and deep. The watershed is less intensively row cropped than upstream watersheds, and the lakes appear to have a forested buffer in most cases. It would be recommended that the watershed be protected to maintain current TP levels and prevent further increases.

Table 28: Lakes within the Louzers Lake Outlet HUC-11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
WRIGHT	86009700	Carrigan	53		
WRIGHT	86010000	Lauzers	29		
WRIGHT	86010300	Ida	33	9	
WRIGHT	86017800	Dog	41	7.6	
WRIGHT	86019300	Mary	74	14	FS

Figure 59: Louzers Lake Outlet HUC-11 watershed land use and lake assessment status



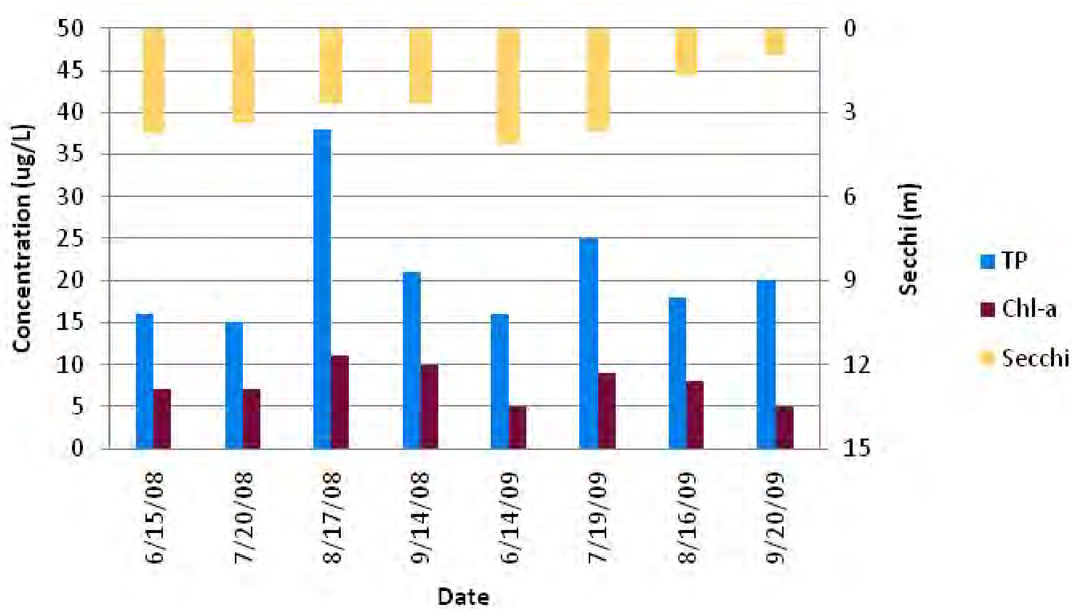
Lake Mary 86-0193-00

Lake Mary is a 74 ha lake with a maximum depth of 14.6 m located 2 miles northeast of Winsted, MN. The lake as a small 195 ha watershed (3:1 watershed to lake ratio) that is comprised mostly of open water, cultivated, and pasture land uses. The lake was sampled by MPCA in 1996.

The most recent temperature or dissolved oxygen profiled data collected on Lake Mary is from 1996. A thermocline develops between a depth of 5 and 8 meters during the summer months. Anoxic conditions were present below a depth of 7 meters and below a depth of 5 meters DO dropped below the 5 mg/L necessary to support game fish. The lake would be considered to be dimictic.

TP, chl-*a*, and Secchi were sampled most recently the summers of 2008 and 2009 (Figure 60). No strong pattern for TP or chl-*a* is evident for 2008 and 2009. Secchi declines across the season. Considering the anoxic conditions present in Lake Mary, it would be expected to observe a spike in TP at the point of fall overturn; it appears that sampling in 2008 and 2009 ceased prior to the mixing of the lake.

Figure 60: Lake Mary water quality data (2008 and 2009)



Lake Mary has a robust data record over the past 15 years. TP and chl-*a* were sampled in 1981, 1996, and then from 2001 to present (Figure 61). Secchi has been sampled annually since 1995. TP and chl-*a* have declined from the data point in 1981, but the variation on most years is within annual variability. Lake Mary water clarity is possibly improving, with an estimated increase of 0.2 m per decade. The estimated change could potentially range from no change to an increase of 0.6 m per decade. The lake is well within (better than) the lake eutrophication standards and is considered to be supporting of aquatic recreation use (Table 29).

Figure 61: Lake Mary long-term water quality data

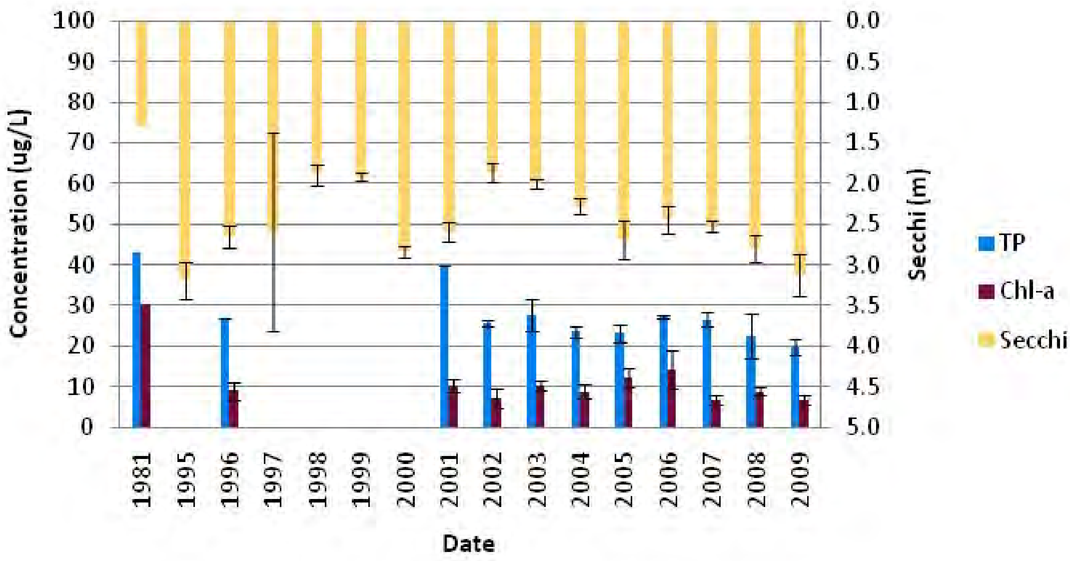


Table 29: Lake Mary summer-mean values compared to NCHF eutrophication standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
Lake Mary 2000-2009 average	26	9.5	2.4

MINLEAP was run for Lake Mary as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. The model was run for the NCHF ecoregion. All observed parameters matched well with the modeled values. The lake retains approximately 89% of the TP that enters the basin and has an estimated residence time of 14 years. The lake is slightly above the predicted background TP concentration of 22 ug/L. Complete modeling results can be found in Appendix B.

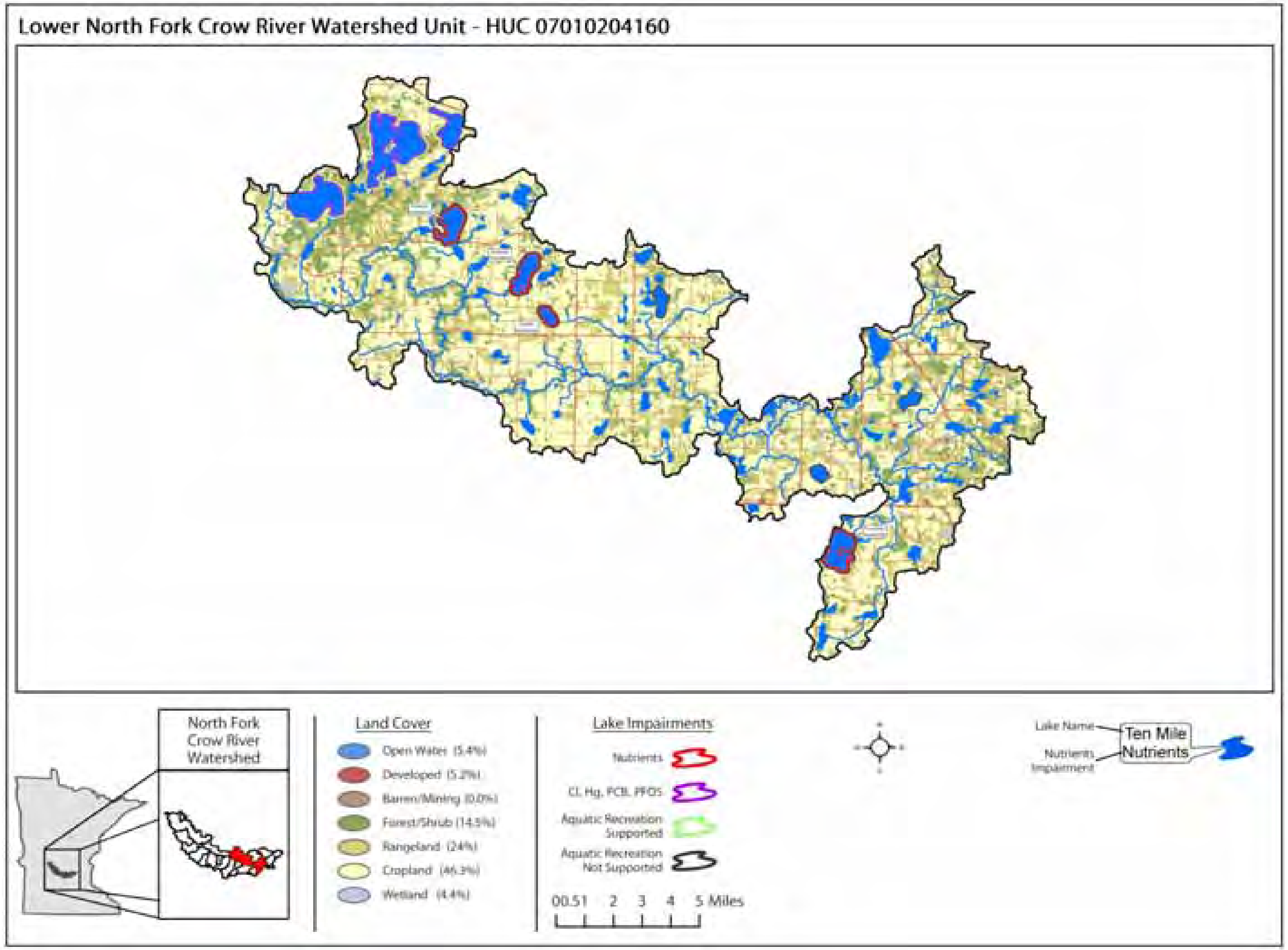
Lower North Fork Crow River HUC-11 Watershed

The Lower North Fork Crow River (07010204160) HUC-11 watershed is located in the eastern portion of the North Fork Crow Watershed, between Kingston and Rockford, MN. The watershed is 49,967 ha (123,471 acres), comprises 13% of the total watershed area, and drains parts of Meeker and Wright counties. It drains from northwest to east to the confluence of the North and South Forks of the Crow River near Rockford, MN. Agriculture and pasture are the dominant land uses in the watershed which is entirely within the NCHF ecoregion (Figure 62). Twelve of the thirty-two lakes in the watershed have been assessed for aquatic recreation use support (Table 30).

Table 30: Lakes within the Lower North Fork Crow River HUC-11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
MEEKER	47000200	Francis	425	5.8	FS
MEEKER	47004000	Mud	27		
WRIGHT	86003300	Unnamed	4		
WRIGHT	86003900	Unnamed	4		
WRIGHT	86004100	Dean	70	7	NS
WRIGHT	86004300	Unnamed (Rooney)	24		
WRIGHT	86004400	Mud	11		
WRIGHT	86004600	Crawford	43	5.8	FS
WRIGHT	86004900	Mary	136	1.8	
WRIGHT	86008600	Fountain	171	4.6	NS
WRIGHT	86010200	Pooles	30	1.8	
WRIGHT	86011200	Malardi	39		NS
WRIGHT	86017900	Mains	5		
WRIGHT	86018100	Little Rock	17		
WRIGHT	86018200	Rock	73	11	NS
WRIGHT	86020300	Unnamed	45		
WRIGHT	86020400	Taylor	19		
WRIGHT	86021400	White	47		
WRIGHT	86021700	Granite	143	10.4	NS
WRIGHT	86021800	Maxim	19		
WRIGHT	86022100	Camp	48	15.8	NS
WRIGHT	86027100	Moose	32	13	
WRIGHT	86027300	French	137	16.5	NS
WRIGHT	86027400	Dans	30	8.2	
WRIGHT	86027800	Goose	36	1.8	
WRIGHT	86027900	West Lake Sylvia	361	27	FS
WRIGHT	86028800	John	160	8.5	FS
WRIGHT	86028900	East Lake Sylvia	270	23.8	FS

Figure 62: Lower North Fork Crow River HUC-11 watershed land use and lake assessment status

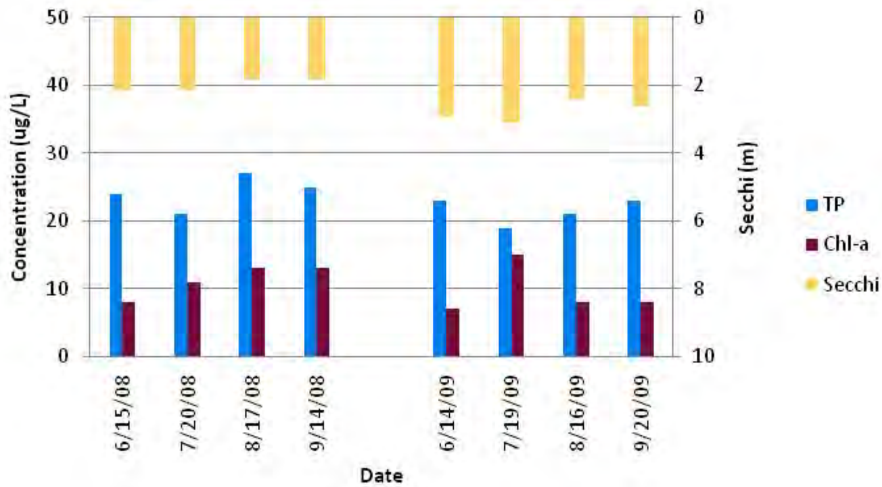


Lake John 86-0288-00

Lake John is a 160 ha lake with a maximum depth of 9.1 m located 2 miles west of Annandale, MN. The lake as a 1,452 ha watershed (9:1 watershed to lake ratio) that is dominated by cultivated, pasture, and open water land uses.

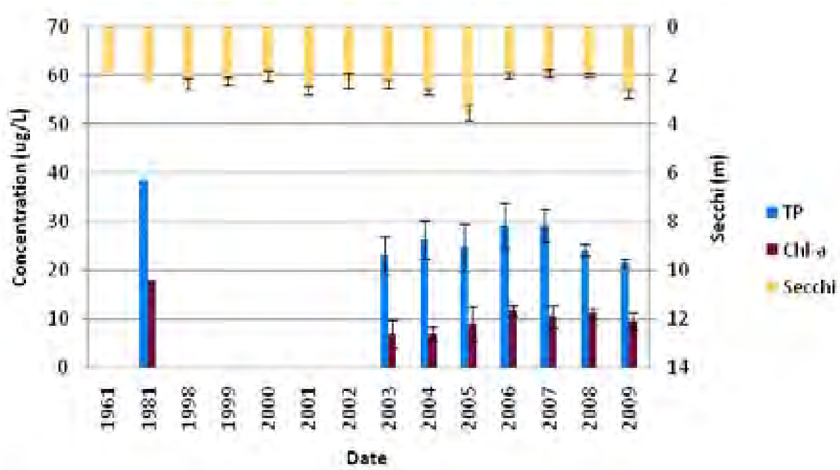
The lake was most recently sampled for TP, chl-*a*, and Secchi during the 2008 and 2009 summer seasons (Figure 63). TP and chl-*a* levels were low and did not exhibit a consistent pattern between the two seasons. Secchi responds to changes in chl-*a* as expected, with the exception of the 7/19/09 sampling date, when chl-*a* increased and the Secchi actually improved from the previous month.

Figure 63: Lake John Summer water quality data 2008-2009



Lake John has a relatively recent water quality record; samples were collected in 1981 and then not again until 2003 when annual sampling began (Figure 64). Single Secchi values were measured in 1961 and 1981 and then annually since 1998. No trend in TP or chl-*a* concentration is evident. During the most recent Secchi transparency trend analysis, Lake John did not exhibit a trend. The lake is well within (better than) the lake eutrophication standards and is considered to be supporting aquatic recreation use (Table 31).

Figure 64: Lake John long-term water quality data



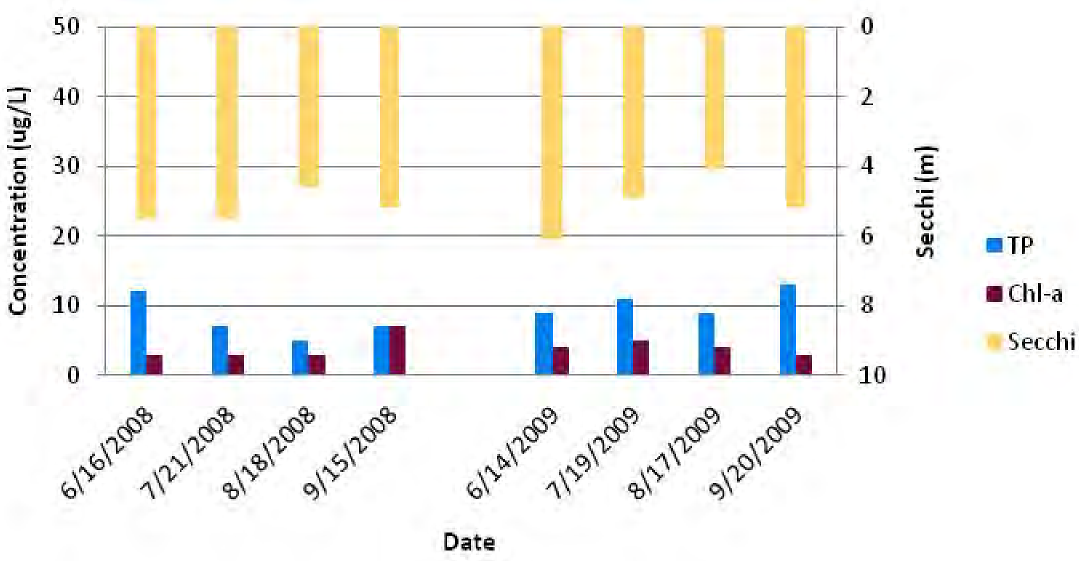
MINLEAP was run for Lake John as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. Observed TP and Secchi were significantly better than modeled predictions. Chl-*a* was better than, but not significantly different from the modeled prediction. The lake retains approximately 75% of the TP that enters the basin and has an estimated 2.8 year residence time. Complete modeling results can be found in Appendix B.

East Lake Sylvia 86-0289-00

East Lake Sylvia a 270 ha lake with a maximum depth of 21.6 m located 3 miles west of Annandale, MN. The lake as a relatively small 2,051 ha watershed (8:1 watershed to lake ratio) that is dominated by cultivated, open water pasture, and forested land uses. The lake has high recreational use. A diverse plant community was surveyed by DNR; Eurasian watermilfoil was found in 2008 (DNR 2010).

The lake was most recently sampled for TP, chl-*a*, and Secchi during the 2008 and 2009 summer seasons (Figure 65). TP and chl-*a* levels were very low and did not exhibit a consistent pattern between the two seasons. No algal blooms were evident on the dates sampled. In both seasons, Secchi reached the minimum during the August sampling event and was of high clarity for all dates sampled.

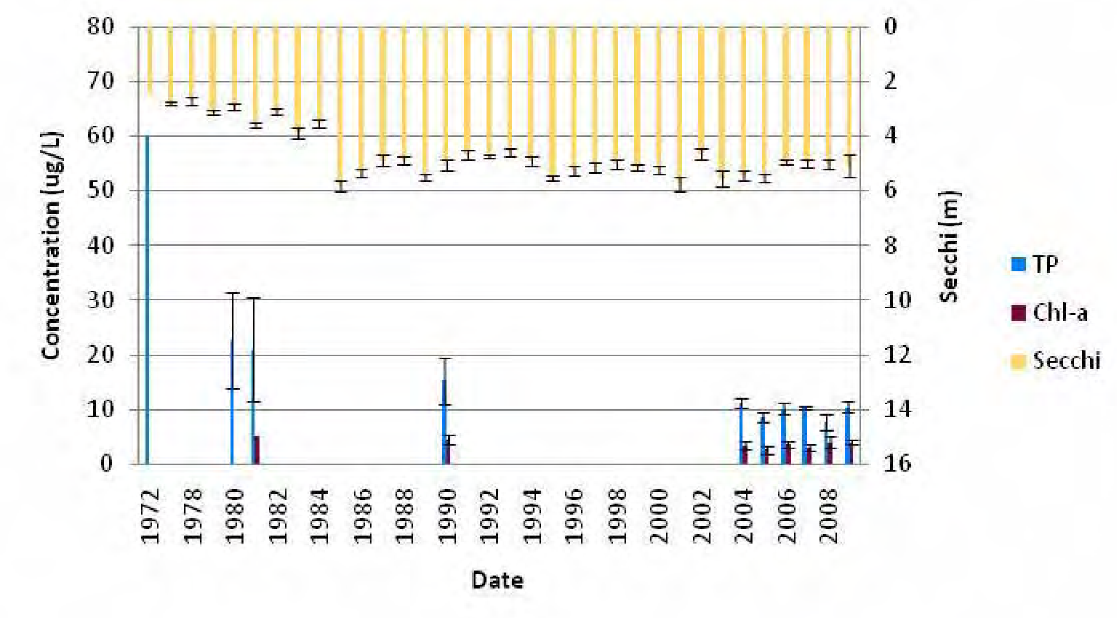
Figure 65: East Lake Sylvia summer water quality data 2008-2009



East Lake Sylvia has a long water quality record; samples were collected in 1972, 1980, 1981, 1990 and then resumed again in 2004 when annual sampling began (Figure 66). Single Secchi values were measured in 1972 and then annually since 1977. TP concentrations have declined in recent years compared to samples taken in the 70s and 80s. During the most recent Secchi transparency trend analysis, it was determined that East Lake Sylvia's clarity was improving, with an estimated increase of 0.8 m per decade. The estimated increase could potentially range from 0.6 to 0.9 m per decade. The lake is well within (better than) the lake eutrophication standards and is considered to be supporting aquatic recreation use (Table 31).

MINLEAP was run for East Lake Sylvia as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. Observed TP and Secchi were significantly better than modeled predictions. Chl-*a* was better than, but not significantly different from the modeled prediction. The lake retains approximately 85% of the TP that enters the basin and has an estimated 9.5 year residence time. Complete modeling results can be found in Appendix B.

Figure 66: East Lake Sylvia long-term water quality data

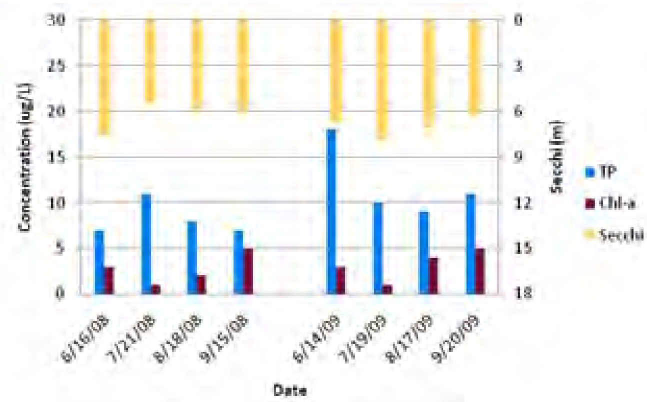


West Lake Sylvia 86-0279-00

West Lake Sylvia a 361 ha lake with a maximum depth of 25 m located 4 miles west of Annandale, MN. The lake as a relatively small 3,241 ha watershed (9:1 watershed to lake ratio) that is dominated by open water, cultivated, and forested land uses. West Lake Sylvia has high recreational use. Like The plant community is diverse and Eurasian watermilfoil was found in 2008 (DNR 2010).

The lake was most recently sampled for TP, chl-*a*, and Secchi during the 2008 and 2009 summer seasons (Figure 67). TP and chl-*a* levels did not exhibit a consistent pattern between the two seasons. Nuisance algal blooms would have been present during the July 2008, June and September 2009 sampling dates.

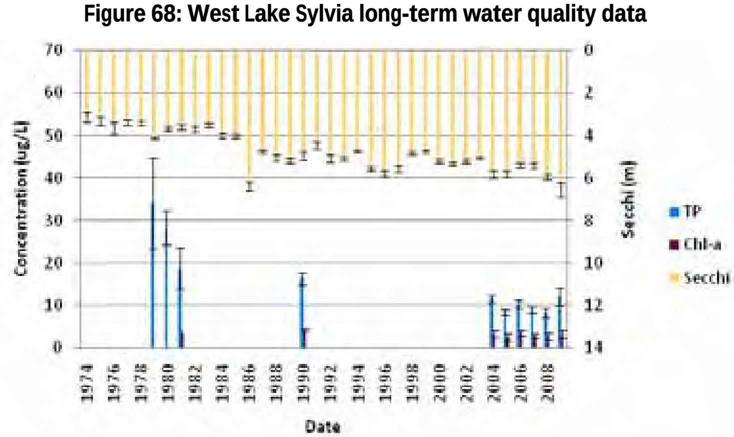
Figure 67: West Lake Sylvia summer water quality data 2008-2009



West Lake Sylvia has a long water quality record; samples were collected in 1979, 1980, 1981, 1990 and then resumed again in 2004 when annual sampling began (Figure 68). Annual Secchi measurements have been taken since 1974. TP concentrations have declined in recent years compared to samples taken in the 70s and 80s. During the most recent Secchi transparency trend analysis, it was determined that West Lake Sylvia's clarity was improving, with an estimated increase of 0.6 m per decade. The estimated increase could potentially range from 0.5 to 0.7 m per decade. The lake is well within (better than) the lake eutrophication standards and is considered to be supporting aquatic recreation use (Table 31).

MINLEAP was run for West Lake Sylvia as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. Observed TP and Secchi were significantly better than modeled predictions. Chl-*a* was better than, but not significantly different from the modeled prediction. The lake retains approximately 84% of the TP that enters the basin and has an estimated 8 year residence time. Complete modeling results can be found in Appendix B.

Figure 68: West Lake Sylvia long-term water quality data



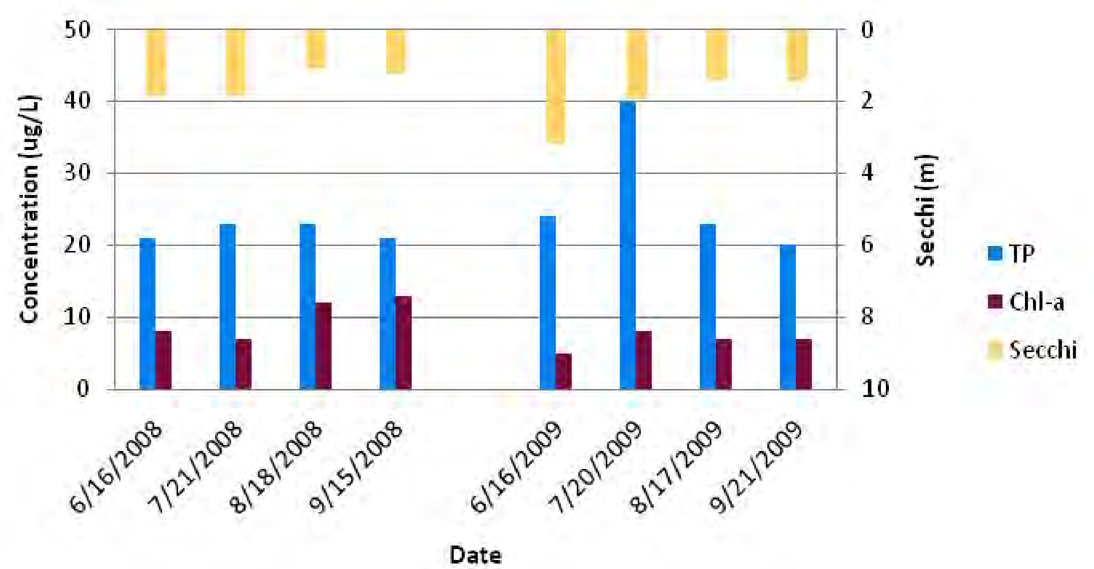
Lake Francis 47-0002-00

Lake Francisis a shallow, 425 ha lake with a maximum depth of 5.2 m located 6 miles southwest of Annandale, MN. The lake as a 4,496 ha watershed (11:1 watershed to lake ratio) that is dominated by open water, forested, and cultivated land uses. Much of the shoreline is developed residential land use. The lake has an abundant and diverse plant community (DNR 2010).

The lake was most recently sampled for TP, chl-*a*, and Secchi during the 2008 and 2009 summer seasons (Figure 69). TP and chl-*a* levels did not exhibit a consistent pattern between the two seasons. Nuisance algal blooms would have been present on all sampling dates. Secchi declined across the season, as expected with shallow lakes. TP and chl-*a* concentrations did not vary significantly across the season; likely due to the upstream TP sink provided by West Lake Sylvia.

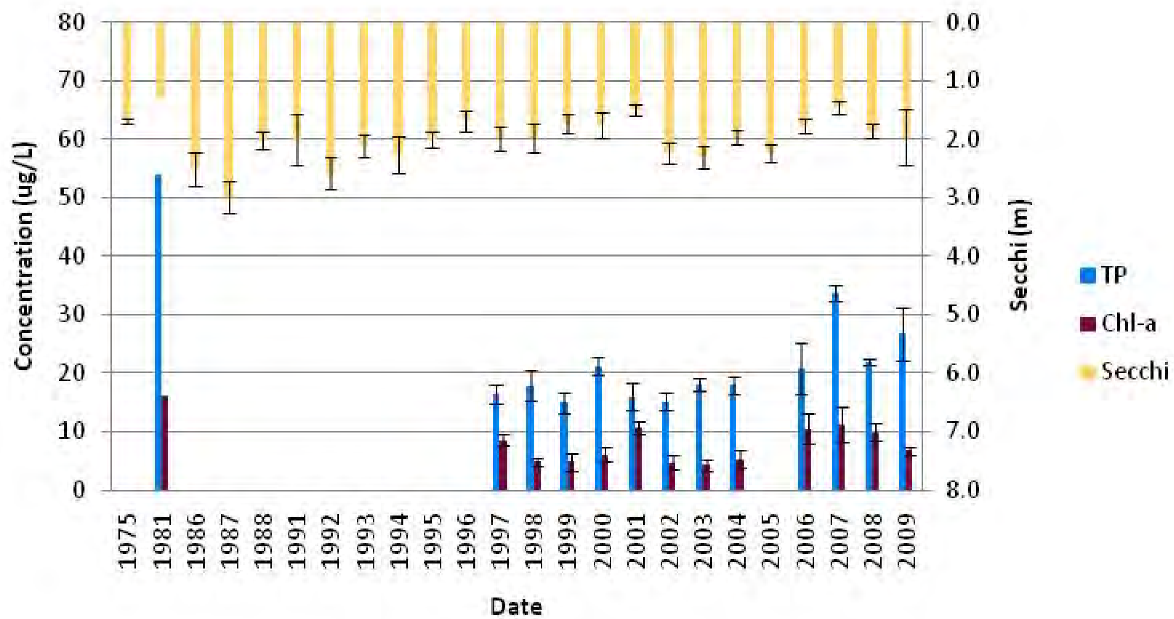
Lake Francis has a long water quality record; samples were collected in 1981, 1997 to 2004, and 2005 to present (Figure 70). Annual Secchi measurements have been taken since 1991. TP and chl-*a* concentrations have declined compared to the 1981 sampling event; however, recent years have seen an increase in the nutrient and algal levels. During the most recent Secchi transparency trend analysis, it was determined that Lake Francis' clarity was declining, with an estimated decrease of 0.1 m per decade. The estimated decrease could potentially range from no change to 0.2 m per decade. The lake is well within (better than) the shallow lake eutrophication standards and is considered to be supporting aquatic recreation use (Table 31).

Figure 69: Lake Francis summer water quality data 2008-2009



MINLEAP was run for Lake Francis as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. Observed TP, chl-*a* and Secchi were significantly better than modeled predictions. This is likely due to the upstream storage capacity for TP in John, East, and West Sylvia Lakes. The lake retains approximately 69% of the TP that enters the basin and has an estimated 1.5 to 2 year residence time. Complete modeling results can be found in Appendix B.

Figure 70: Lake Francis long-term water quality data

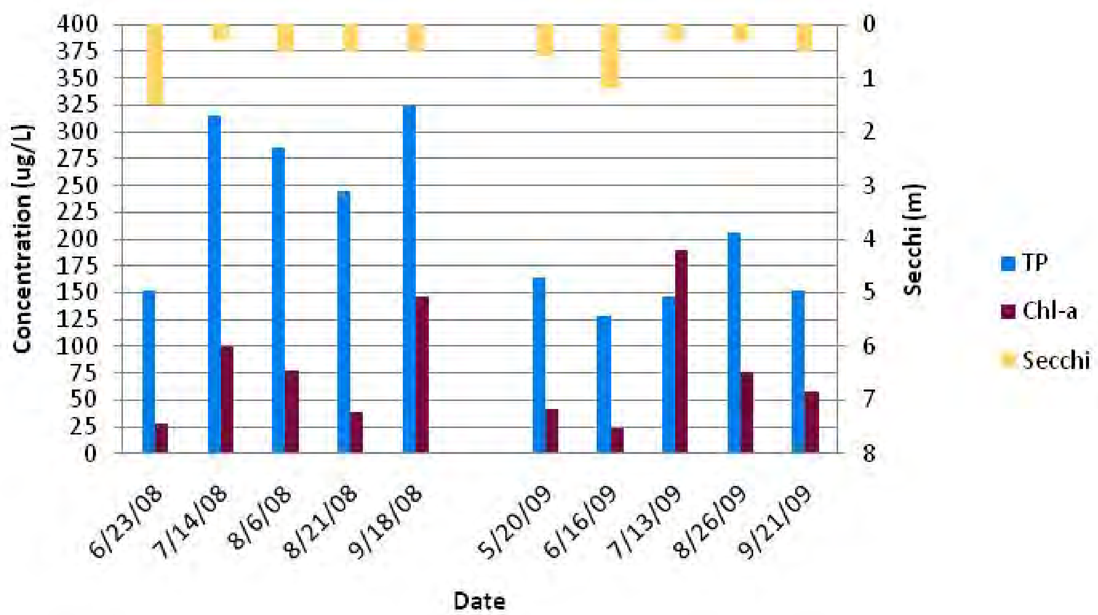


Dean Lake 86-0041-00

Dean Lake is a shallow, 70 ha lake with a maximum depth of 6 m (72% littoral area) located 3 miles southeast of Buffalo, MN. The lake as a 672 ha watershed (10:1 watershed to lake ratio) that is dominated by cultivated and pasture land uses. The lake has a history of winterkills; winter aeration was started in 2002 to help alleviate the problem (DNR 2010).

The lake was most recently sampled for TP, chl-*a*, and Secchi during the 2008 and 2009 summer seasons (Figure 71). TP and chl-*a* levels did not exhibit a consistent pattern between the two seasons. Severe algal blooms would have been present on most sampling dates.

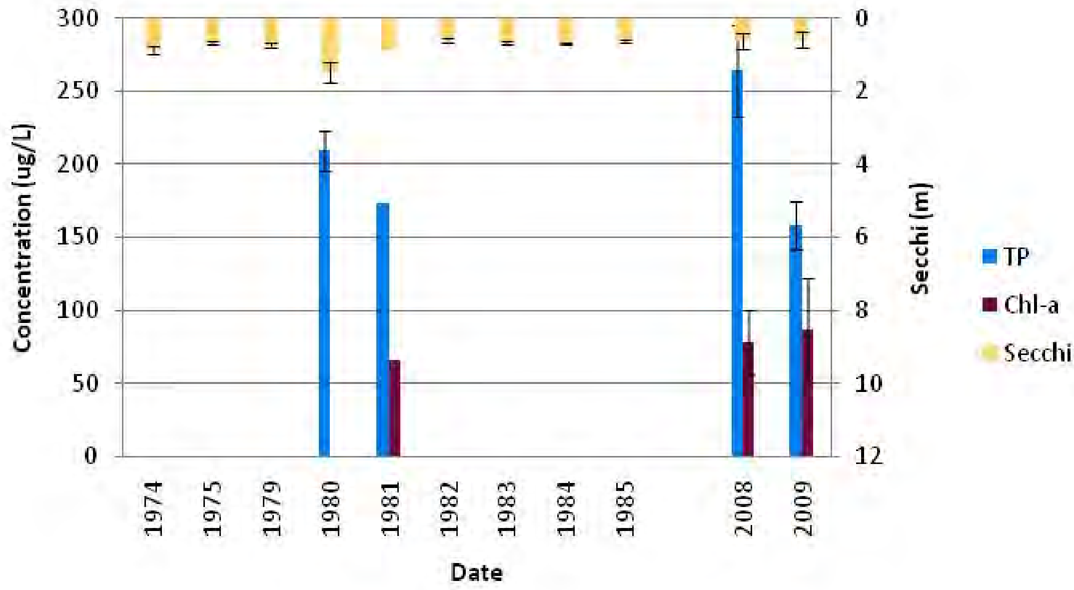
Figure 71: Dean Lake summer water quality data 2008-2009



Dean Lake has a intermittent water quality record; samples were collected in 1980 and 1981, and then in 2008 and 2009 (Figure 72). Secchi transparency was recorded in the 70s and 80s, but then not again until 2008. TP and chl-*a* concentrations have not changed since the sampling events in the 80s. During the most recent Secchi transparency trend analysis, it was determined that Dean Lake's clarity was declining, with an estimated decrease of 0.1 m per decade. The estimated decrease could potentially range from no change to 0.2 m per decade. The lake exceeds (is worse than) the deep and shallow lake eutrophication standards and is considered to be not supporting aquatic recreation use (Table 31). Unless profile data indicates that the lake does not stratify, the lake should be held to the deep lake standards.

MINLEAP was run for Dean Lake as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. Observed TP, chl-*a* and Secchi were significantly worse than modeled predictions. The lake retains approximately 73% of the TP that enters the basin and has an estimated 2 to 2.5 year residence time. Complete modeling results can be found in Appendix B.

Figure 72: Dean Lake long-term water quality data



Lower North Fork Crow River watershed summary

The Lower North Fork Crow River watershed is a very lake rich watershed. The upstream, headwaters lakes are of high quality and are in the least developed portion of the watershed. As you move downstream, land use disturbance increases. Considering the severe degradation in several of the lakes, it would be recommended that this watershed undergo restoration activities to reduce levels of TP entering the lake systems.

Table 31: Summer-mean values compared to NCHF eutrophication standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
Lake John 2000-2009 average	25.5	9.4	2.4
East Lake Sylvia 2000-2009 average	10	3.5	5.2
West Lake Sylvia 2000-2009 average	10	3	5.4
Dean Lake 2000-2009 average	217	82	0.6
NCHF – Aquatic Rec. Use (Class 2B) Shallow Lakes	< 60	< 20	> 1.0
Lake Francis 2000-2009 average	21	7.6	1.9

Sarah Creek HUC-11 Watershed

The Sarah Creek (07010204170) HUC-11 watershed is located in the southeastern portion of the North Fork Crow Watershed in Hennepin County, between Rockford and Loretto, MN. The watershed is 2,227 ha (5,503 acres) and comprises 1% of the total watershed area. It drains from southeast to northwest to the confluence of Sarah Creek with the Crow River near Rockford, MN. The watershed is within the NCHF ecoregion with pasture, agriculture and forest as the dominant land uses (Figure 73). Lake Sarah (East and West Basins) have been assessed for aquatic recreation use support (Table 32).

Table 32: Lakes within the Sarah Creek HUC-11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
HENNEPIN	27019101	West Sarah	138		NS
HENNEPIN	27019102	East Sarah	80	5.8	NS

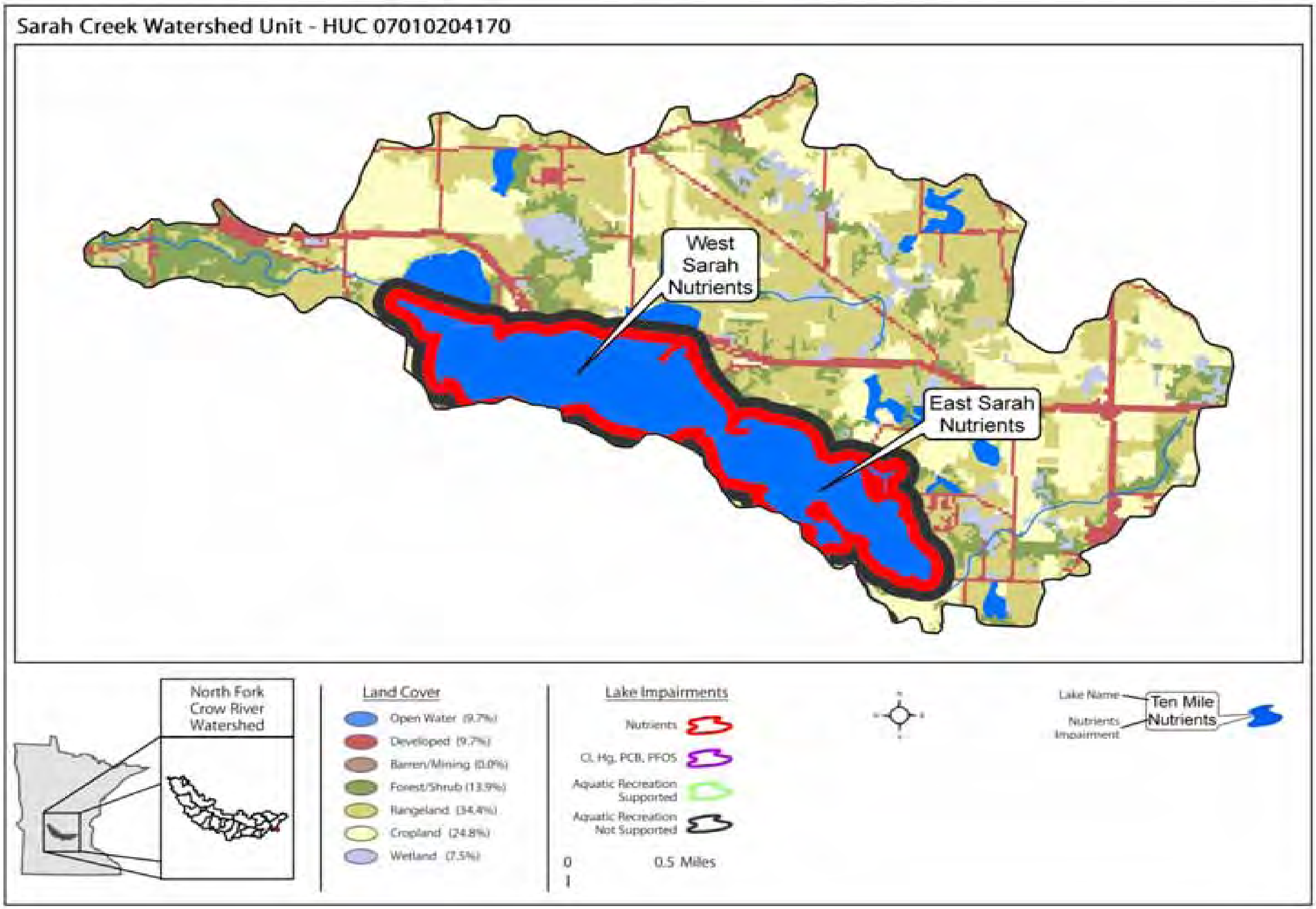
Lake Sarah 27-0191-00

Lake Sarah is a 218 ha lake with a maximum depth of 18.3 m and a mean depth of 5.5 m. The lake is located approximately 18 miles west of Minneapolis, MN. The lake has a 2,227 ha watershed with cultivated and pasture as the dominant land uses.

The TMDL on Lake Sarah started in February 2008; more information regarding that effort may be found at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/upper-mississippi-river-basin-tmdl-projects/project-lake-sarah-excess-nutrients.html.

Due to the more advanced analysis that is currently being completed as part of the TMDL, no further discussion will be provided on Lake Sarah.

Figure 73: Sarah Creek HUC-11 watershed land use and lake assessment status



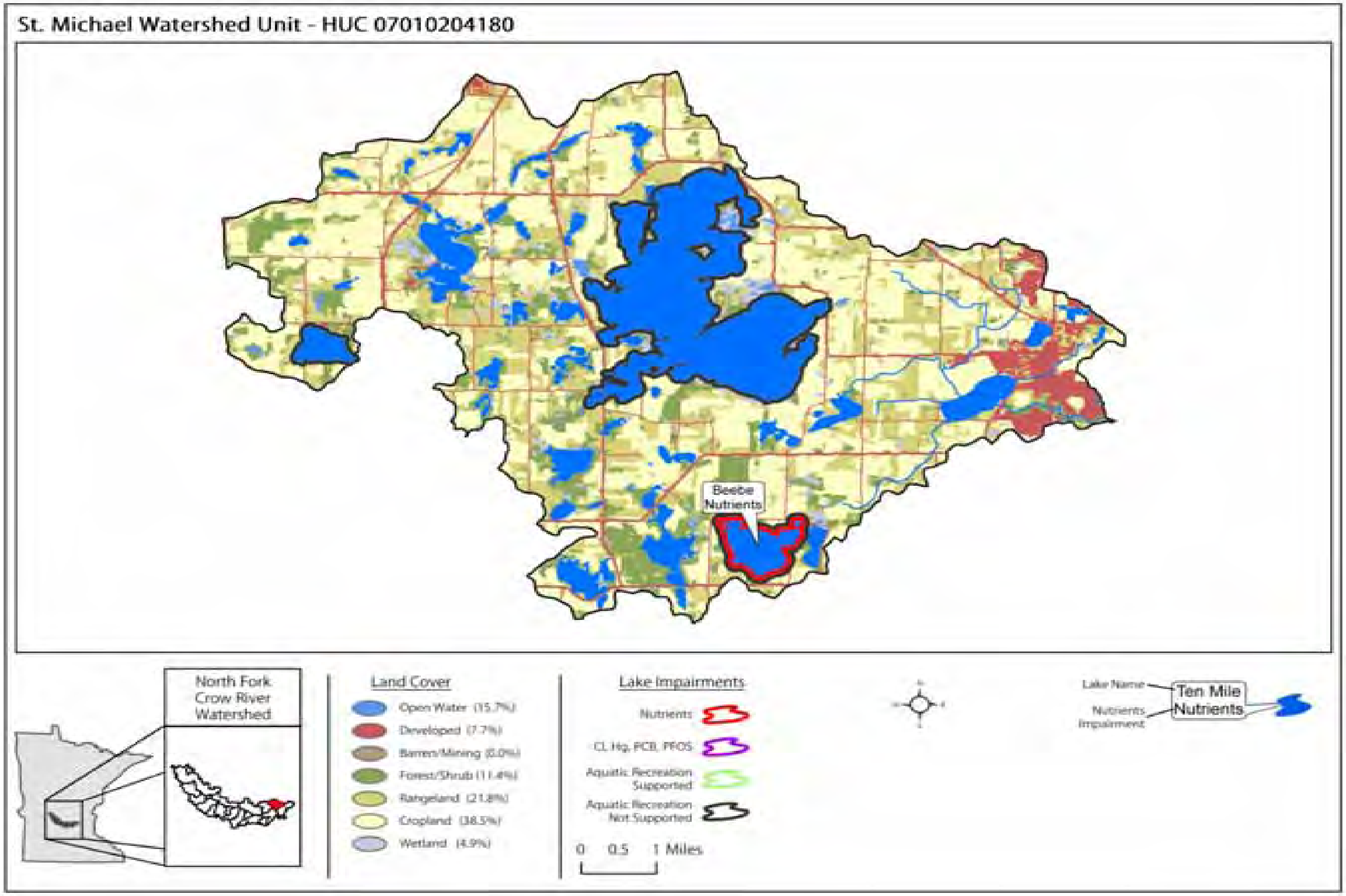
St. Michael HUC-11 Watershed

The St. Michael (07010204180) HUC-11 watershed is located in the northeastern portion of the North Fork Crow Watershed, northwest of St. Michael, MN, in Wright County. The watershed is 13,817 ha (34,142 acres), and comprises 4% of the total watershed area. It drains from northwest to southeast to the confluence of Regal Creek with the Crow River near St. Michael, MN. Pasture, agriculture and forest are the dominant land uses in the watershed, which is entirely within the NCHF ecoregion (Figure 74). Three of the thirteen basins have been assessed for aquatic recreation use support (Table 33).

Table 33: Lakes within the St. Michael HUC-11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
WRIGHT	86002100	Mud	28		
WRIGHT	86002300	Beebe	120	8	NS
WRIGHT	86002900	Schmidt	71		
WRIGHT	86003100	Pelican	945	2.7	NS
WRIGHT	86005100	Constance	67	7	NS
WRIGHT	86005600	Washington	50	4.5	
WRIGHT	86006100	Pohl	14.5		
WRIGHT	86006300	Green Mountain	64		
WRIGHT	86006400	Gilchrist	102	2.7	
WRIGHT	86007800	Slough	10.5		
WRIGHT	86008200	Paradise	13.4		

Figure 74: St. Michael HUC-11 watershed land use and lake assessment status

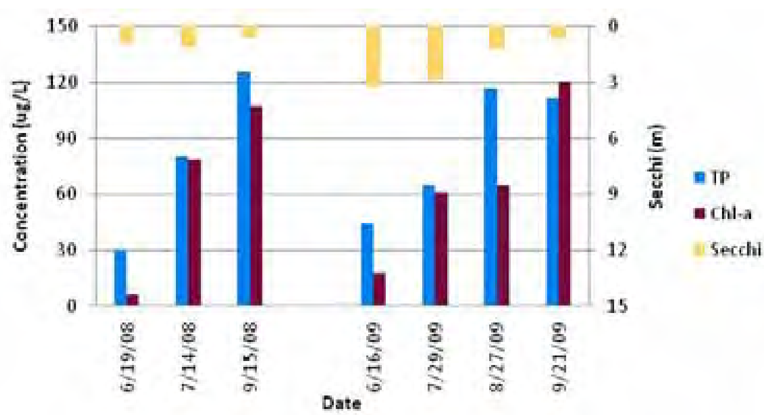


Lake Constance 86-0051-00

Lake Constance is a 67 ha lake with a maximum depth of 6 m located 3 miles north of Buffalo, MN. The lake as a small 375 ha watershed (6:1 watershed to lake ratio) that is dominated by cultivated, pasture, and forested land uses. The lake has a history of winter and summer fish kills. Curly-leaf pondweed is found at nuisance levels on Lake Constance in early summer (DNR 2010).

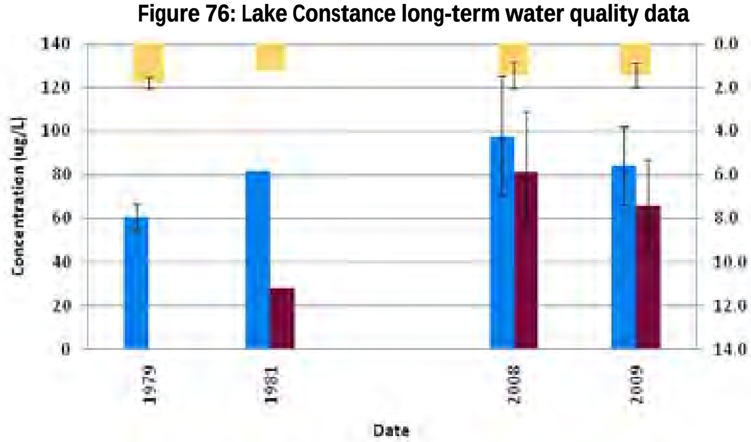
The lake was most recently sampled for TP, chl-*a*, and Secchi during the 2008 and 2009 summer seasons (Figure 75). TP and chl-*a* levels increased across the season and Secchi declines, as expected in shallow lakes. Severe algal blooms would have been present on sampling dates July through September.

Figure 75: Lake Constance summer water quality data 2008-2009



Lake Constance has a limited water quality and Secchi record; samples were collected in 1979 and 1981, and then in 2008 and 2009 (Figure 76). TP concentrations appear to be higher since the sampling events in the 80s. The lake exceeds (is worse than) the shallow and deep lake eutrophication standards for TP and chl-*a* and is considered to be not supporting aquatic recreation use (Table 34). Unless profile data indicates that the lake does not stratify, the lake should be held to the deep lake standards.

Figure 76: Lake Constance long-term water quality data



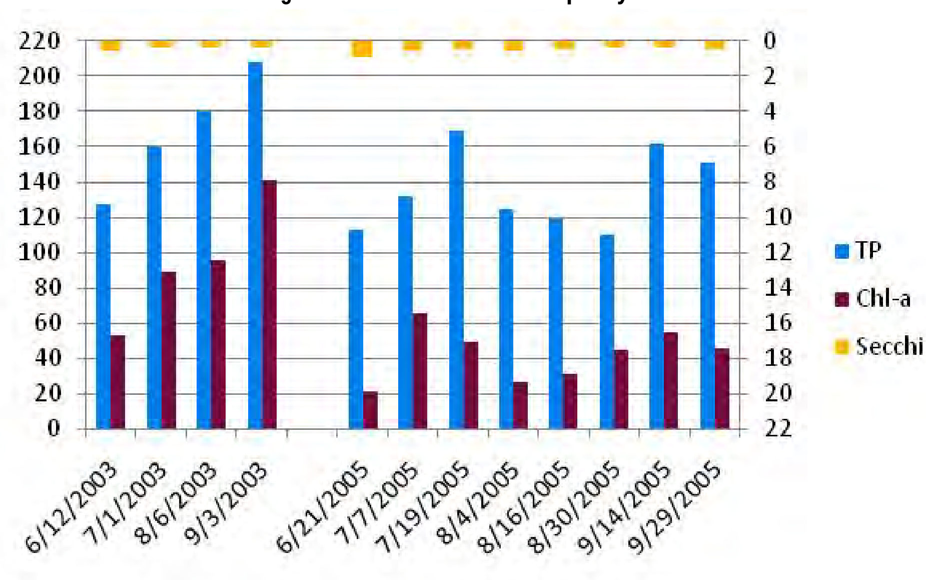
MINLEAP was run for Lake Constance as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. Observed TP, and chl-*a* were significantly worse than modeled predictions. The lake retains approximately 80% of the TP that enters the basin and has an estimated 4.5 to 5 year residence time. Current TP is significantly higher than the predicted background level of 26 ug/L. Complete modeling results can be found in Appendix B.

Pelican Lake 86-0031-00

Pelican Lake is a shallow 944 ha lake with a maximum depth of 4.7 m located 5 miles west of St. Michael, MN. The lake as a 9,344 ha watershed (10:1 watershed to lake ratio) that is dominated by cultivated, pasture, and water land uses. The lake was historically an important destination for waterfowl hunters. Several years of high precipitation (1990s to early 2000s), high groundwater table and lack of a natural outlet allowed water levels to rise and inundate submerged and emergent vegetation. This has reduced the lake's ability to support the diversity of waterfowl that was once found here. The lake is being considered for drawdown; recent years have seen a 1 to 2 foot drop in water level (DNR 2010).

Pelican Lake has a limited water quality record; the lake was only sampled for TP, chl-*a*, and Secchi during the 2003 and 2005 summer seasons. Data was collected at three different sites on the lake for each sampling date; a whole lake average is depicted below in the graph (Figure 77). In 2003, TP and chl-*a* levels increased across the season and Secchi declines, as expected in shallow lakes. In 2005, the water quality did not follow the typical pattern expected; however concentrations appeared to be lower than those seen in 2003. Algal blooms would have been present on sampling dates. The lake exceeds (is worse than) the shallow lake eutrophication standards for TP, chl-*a* and Secchi and is considered to be not supporting aquatic recreation use (Table 34).

Figure 77: Pelican Lake water quality data



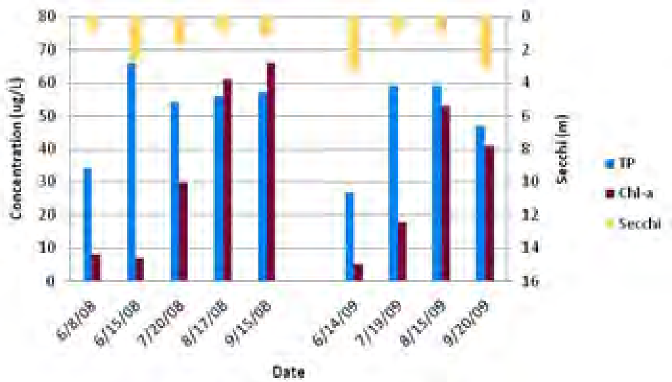
MINLEAP was run for Pelican Lake as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. Observed TP, and chl-*a* were significantly worse than modeled predictions. The lake retains approximately 67% of the TP that enters the basin and has an estimated 1.4 year residence time. The lake is significantly higher in TP than the predicted background concentration of 26 ug/L. Complete modeling results can be found in Appendix B.

Lake Beebe 86-0023-00

Lake Beebe is a 120 ha lake with a maximum depth of 7.2 m located 3 miles northwest of Hanover, MN. The lake as a small 389 ha watershed (3:1 watershed to lake ratio) that is dominated by cultivated, water, and pasture land uses. Lake Beebe is a popular recreation lake. Curly-leaf pondweed and Eurasian watermilfoil are both present in the lake (DNR 2010).

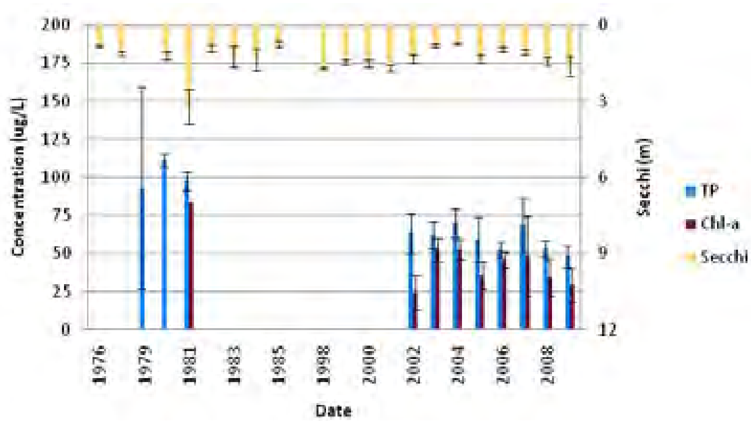
The lake was most recently sampled for TP, chl-*a*, and Secchi during the 2008 and 2009 summer seasons (Figure 78). TP increases to midsummer and then remains elevated; chl-*a* increases across the season. This is similar to the typical pattern seen in shallow lakes, increased nutrient and algal concentrations across the season.

Figure 78: Lake Beebe summer water quality data 2008-2009



Lake Beebe has a good recent water quality and long Secchi record; samples were collected in 1979 to 1981, and then from 2002 to present (Figure 79). Secchi was collected in the 70s and 80s and then from 1998 to present. TP concentrations have declined from the levels observed in the 1979 to 1981 sampling events. During the most recent Secchi trend analysis, no trend was detected in transparency. The lake exceeds (is worse than) the deep lake eutrophication standards for TP and chl-*a* and is considered to be not supporting aquatic recreation use (Table 34).

Figure 79: Lake Beebe long-term water quality data



MINLEAP was run for Lake Beebe as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. Observed TP, and chl-*a* were significantly worse than modeled predictions. The lake retains approximately 85% of the TP that enters the basin and has an estimated 7.5 to 8 year residence time. Complete modeling results can be found in Appendix B.

St Michael HUC-11 watershed summary

Lakes in this watershed tend to be shallow. As such, they have limited abilities to assimilate TP loading. This watershed is less intensively managed for agriculture practices and is more forested than most of the other watersheds in the HUC-8. It is recommended that the watershed move towards restorative practices to reduce the TP loading to the lakes. It will also be important to address internal loading in the lakes to reach aquatic recreation standards.

Table 34: Summer-mean values compared to NCHF eutrophication standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
Lake Beebe 2000-2009 average	59	39.8	1.1
Lake Constance 2000-2009 average	91	73.7	1.4
NCHF – Aquatic Rec. Use (Class 2B) Shallow Lakes	< 60	< 20	> 1.0
Pelican Lake 2000-2009 average	153	59.8	0.4

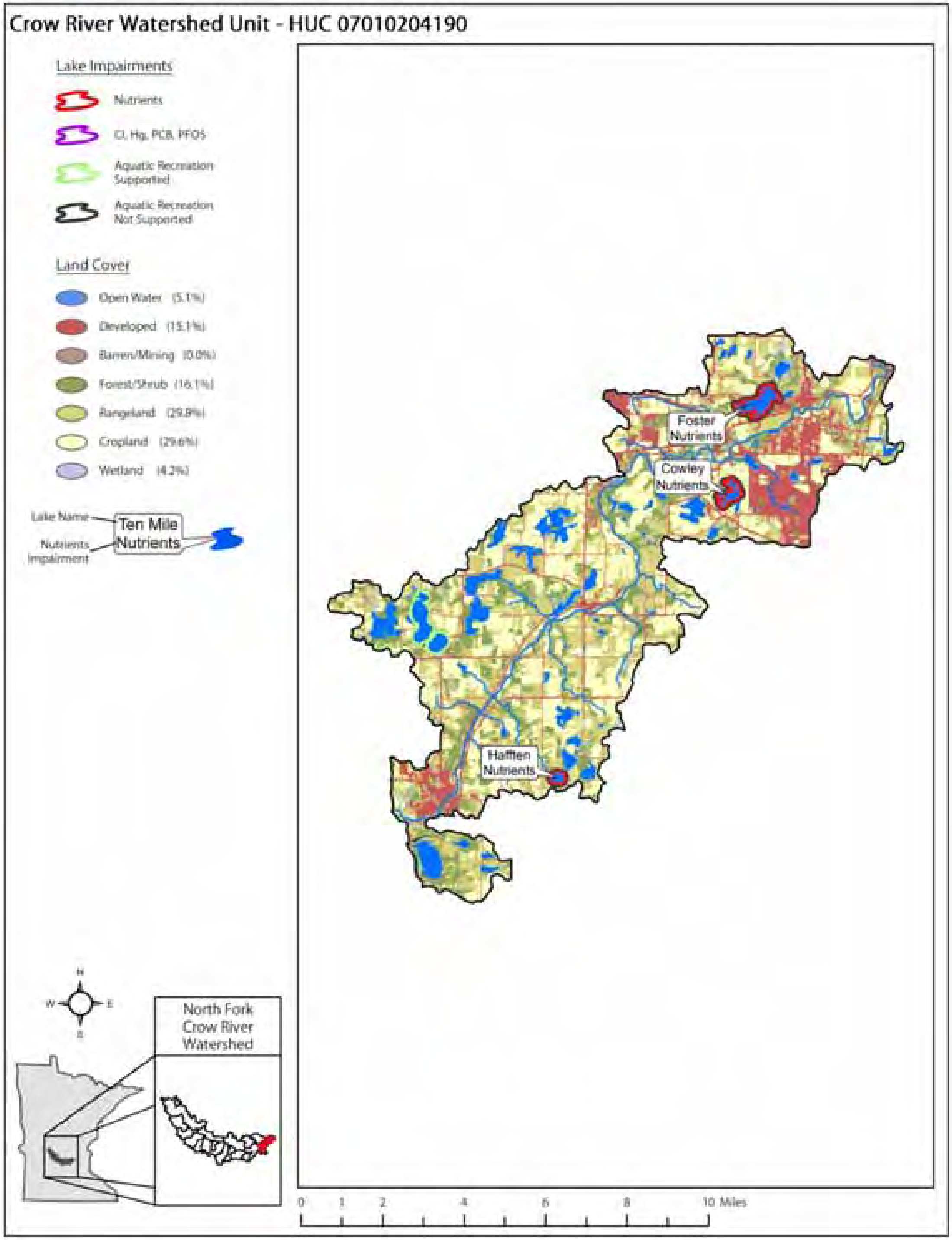
Crow River HUC-11 Watershed

The Crow River (07010204190) HUC-11 watershed is located in the eastern portion of the North Fork Crow Watershed, in Wright and Hennepin counties. The watershed is 18,559 ha (45,860 acres) and comprises 5% of the total watershed area. It drains from southwest to northeast to the confluence of the Crow River with the Mississippi River near Dayton, MN. Pasture and agriculture are the dominant land uses in the watershed (Figure 80). The Crow River HUC-11 watershed is entirely within the boundary of the North Central Hardwood Forest ecoregion. Five of the twenty-one basins have been assessed for aquatic recreation use support (Table 35).

Table 35: Lakes within the Crow River HUC-11 watershed

COUNTY	DNR Lake ID	Lake Name	Lake Area (hectares)	Maximum Depth (meters)	Recreation Assessment
HENNEPIN	27012300	Laura	14		
HENNEPIN	27016900	Cowley	19	2.1	NS
HENNEPIN	27017000	Unnamed	15.8		
HENNEPIN	27017100	Sylvan	44	3	
HENNEPIN	27017700	Prairie	11		
HENNEPIN	27019400	Schwappauf	16		
HENNEPIN	27019600	Schandell	16		
HENNEPIN	27019900	Hafften	16	13.4	NS
HENNEPIN	27020000	Rattail	5	19	
HENNEPIN	27037900	Unnamed	4		
WRIGHT	86000100	Foster	52	3	NS
WRIGHT	86000200	Rice	19		
WRIGHT	86000800	Unnamed	9		
WRIGHT	86000900	Martha	40	6.7	FS
WRIGHT	86001000	Wagner	44		
WRIGHT	86001100	Charlotte	95	14	FS
WRIGHT	86001700	Uhl	35		
WRIGHT	86001900	Gonz	10.5	0.9	
WRIGHT	86002000	Wilhelm	38		
WRIGHT	86002200	Steele	55		
WRIGHT	86002800	Moore	74		

Figure 80: Crow River HUC-11 watershed land use and lake assessment status

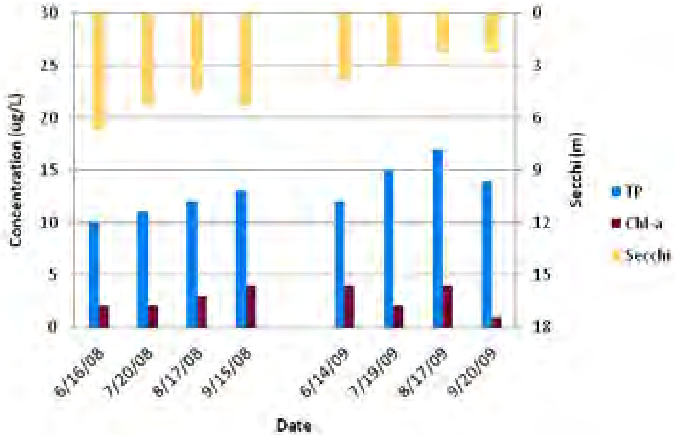


Lake Charlotte 86-0011-00

Lake Charlotte is a 94 ha lake with a maximum depth of 12 m located 4 miles west of Hanover, MN. The lake as a large 1,776 ha watershed (19:1 watershed to lake ratio) that is dominated by cultivated, forested, and pasture land uses.

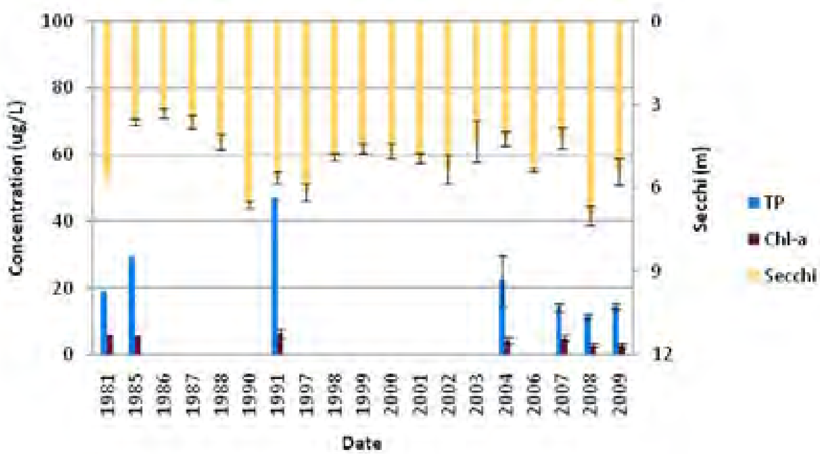
The lake was most recently sampled for TP, chl-*a*, and Secchi during the 2008 and 2009 summer seasons (Figure 81). TP increases slightly across the season and chl-*a* values remain very low throughout the summer. A decline in Secchi is evident across the season, but clarity, even at its lowest, is still greater than 2 meters.

Figure 81: Lake Charlotte summer water quality data 2008-2009



Lake Charlotte has a limited water quality record; samples were collected in 1981, 1985, 1991, 2004 and then from 2007 to present (Figure 82). The Secchi record is much more robust, with samples measured in the 80s and then from 1997 to present. Single TP samples were collected prior to 2004; due to the limited data, it is not possible to determine if TP has reduced in concentration since the earlier values were collected. During the most recent Secchi trend analysis, an improving trend in water clarity was detected, with an estimated increase of 0.4 m per decade. This estimated change could potentially range from no change to an increase of 0.8 m per decade. The lake is within (better than) the deep lake eutrophication standards and is considered to be supporting aquatic recreation use (Table 36).

Figure 82: Lake Charlotte long-term water quality data



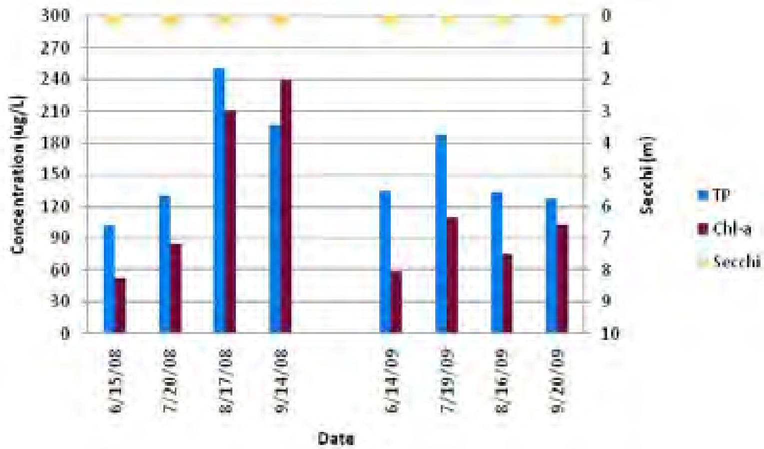
MINLEAP was run for Lake Charlotte as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. Observed TP, and chl-*a* were significantly worse than modeled predictions. The lake retains approximately 73% of the TP that enters the basin and has an estimated 2.6 year residence time. Complete modeling results can be found in Appendix B.

Foster Lake 86-0001-00

Foster Lake is a shallow, 52 ha lake with a maximum depth of 3 m located 3 miles northwest of Rogers, MN. The lake as a large 1,214 ha watershed (23:1 watershed to lake ratio) that is dominated by pasture, cultivated, and forested land uses.

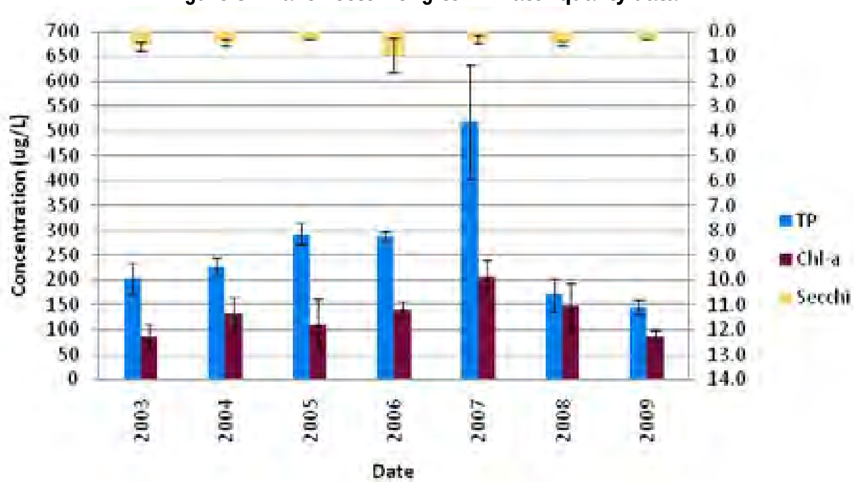
The lake was most recently sampled for TP, chl-*a*, and Secchi during the 2008 and 2009 summer seasons (Figure 83). TP and chl-*a* are elevated and in 2008 both increased across the season, a pattern typical to shallow lakes. Severe algal blooms would have been present on all sampling dates. For both years Secchi was observed at 0.3 meters on all dates.

Figure 83: Lake Foster summer water quality data 2008-2009



Foster Lake a limited water quality and Secchi record; sampling did not being until 2003 and has continued annually to present (Figure 84). TP was significantly worse during the summer of 2007 than other years. Not enough data exists to determine if there is a trend on Foster Lake. The lake greatly exceeds (is worse than) the shallow lake eutrophication standards and is considered to be not supporting aquatic recreation use (Table 36).

Figure 84: Lake Foster long-term water quality data



MINLEAP was run for Lake Foster as a basis for comparing the 2000 to 2009 data with those predicted by the model based on lake depth and size, watershed size, and ecoregion location. Observed TP, and chl-*a* were significantly worse than modeled predictions. The lake retains approximately 55% of the TP that enters the basin and has a 0.6 year residence time. Complete modeling results can be found in Appendix B.

Crow River HUC-11 watershed summary

This watershed is one of the more urbanized watersheds in the HUC-8. Available data indicates that lakes in headwaters regions are of the best quality; those further downstream are more eutrophic. Considering the increasing developed of this watershed (conversion of agricultural and forested land use to urban), it would be recommended that restorative practices are implemented to reduce TP loading to the lakes and prevent further water quality impacts.

Table 36: Summer-mean values compared to NCHF eutrophication standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
Lake Charlotte 2000-2009 average	15	3.5	4.9
NCHF – Aquatic Rec. Use (Class 2B) Shallow Lakes	< 60	< 20	> 1.0
Foster Lake 2000-2009 average	262	130	0.5

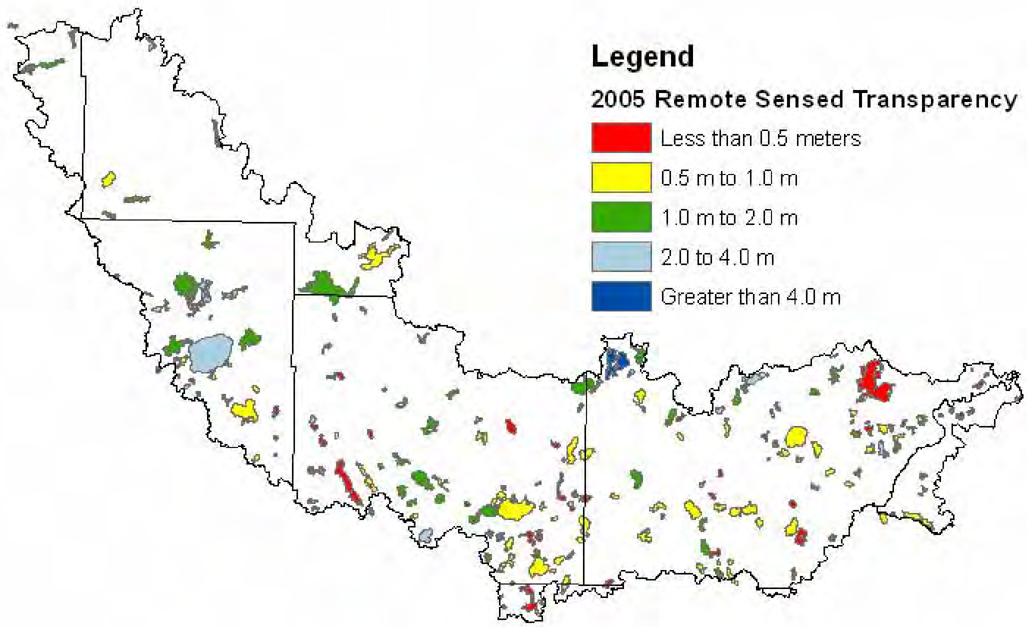
Remote sensing and CLMP trends

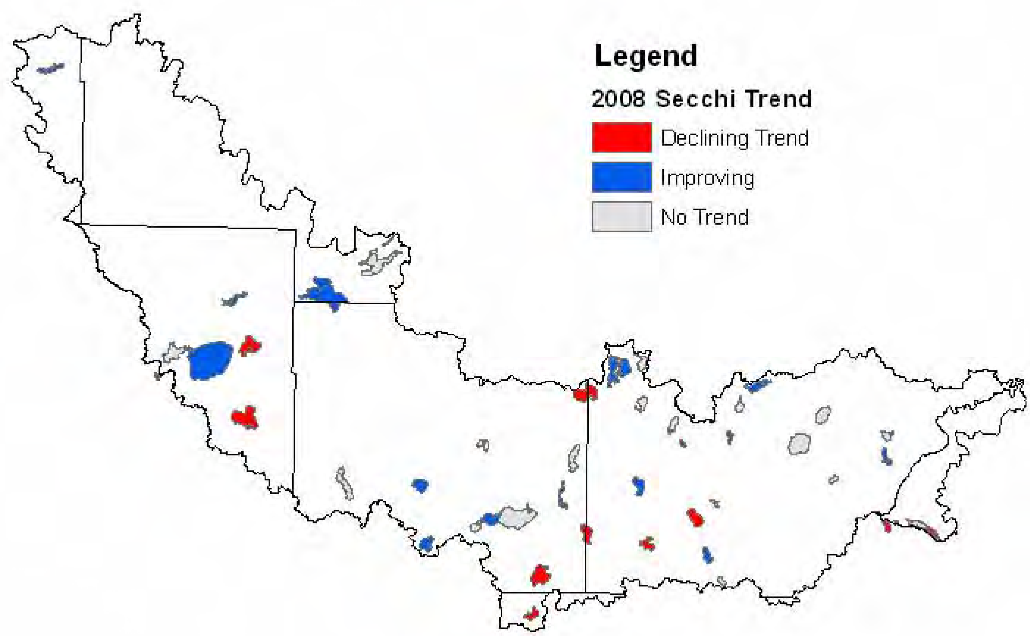
Remote Sensing (RS) data has been collected since the early 1970s. The data was provided by the University of Minnesota Remote Sensing and Geospatial Analysis Laboratory. Satellite inferred transparency values have been summarized in five year increments covering 1985-2005 totaling five inferred Secchi results.

Based on the most recently available RS data (2005), presented in Figure 85, a majority of the lakes within the watershed have water clarity values between 0.5 m and 2 meters in depth. Only 28 lakes have inferred Secchi greater than 2.0 meters, and 39 have inferred Secchi less than 0.5 meters. The lakes in the headwaters regions of the HUC-11s appear to have the greater clarity, while the lakes in the more developed lands have reduced Secchi, similar to what was observed with the water quality data.

Fifty lakes in the watershed met the minimum data requirements for Secchi trend analysis. Lakes must have at least 8 years of data for trends to be calculated. Of those lakes, 17 indicate an improving water clarity trend and 13 indicate a declining trend in water clarity. Twenty lakes did not show a trend in clarity.

Figure 85: North Fork Crow River watershed remote sensed transparency and Citizen Lake Monitoring Program trends





Watershed Summary

Lakes within the North Fork Crow River watershed display a variety of recreational use conditions. Overall, the majority of these lakes possessing assessment level data have been determined to be non-supporting of recreational use. Of the 67 lakes that were assessed, 28 were supporting and 39 were not supporting aquatic recreation use.

According to Table 1, the TP and chl-*a* standards for the support of aquatic recreation in lakes within the NCHF ecoregion are less than 40 µg/L and 14 µg/L respectively for deep lakes and less than 60 µg/L and 20 µg/L respectively for shallow lakes. The TP and chl-*a* standards for the support of aquatic recreation in lakes within the WCBP ecoregion are less than 65 µg/L and 22 µg/L respectively for deep lakes and less than 90 µg/L and 30 µg/L respectively for shallow lakes. For chl-*a* levels at or below 30 µg/L, "nuisance algal blooms" (chl-*a* > 20 µg/L) should occur less than ten percent of the summer and transparency should remain at or above three meters (9.8 feet) over 85 percent of the summer.

Reducing levels of TP will be required in order to reduce the occurrence of algal blooms for lakes within the North Fork Crow River watershed. Alternatively, should in-lake TP concentrations increase, the potential for nuisance algal blooms will also increase. It is important to limit as much external (watershed) phosphorus loading to the lakes as possible to improve or maintain the current concentrations. Many of the shallow lakes in the watershed are already indicating that internal loading is contributing to the increased TP concentrations. The watersheds for each of these non supporting lakes will need to be addressed through a TMDL study to determine the source and extent of pollution problems.

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Appendix A – Lake Morphometric Data

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Watershed Area (ha)	% Littoral
27-0123-00	Laura	HENNEPIN	07010204190	NCHF	14			
27-0169-00	Cowley	HENNEPIN	07010204190	NCHF	19	2		
27-0170-00	Unnamed	HENNEPIN	07010204190	NCHF	16			
27-0171-00	Sylvan	HENNEPIN	07010204190	NCHF	44	3		
27-0177-00	Prairie	HENNEPIN	07010204190	NCHF	11			
27-0191-01	West Sarah	HENNEPIN	07010204170	NCHF	138		2,227	
27-0191-02	East Sarah	HENNEPIN	07010204170	NCHF	80		2,227	
27-0194-00	Schwappauf	HENNEPIN	07010204190	NCHF	16			
27-0196-00	Schandell	HENNEPIN	07010204190	NCHF	16			71
27-0199-00	Hafften	HENNEPIN	07010204190	NCHF	16	13		61
27-0200-00	Rattail	HENNEPIN	07010204190	NCHF	5	19		32
27-0379-00	Unnamed	HENNEPIN	07010204190	NCHF	4			
34-0023-00	Pay	KANDIYOHI	07010204050	NCHF	13			
34-0027-00	Summit	KANDIYOHI	07010204050	WCBP	55	2		
34-0028-00	Unnamed	KANDIYOHI	07010204050	WCBP	9			
34-0040-00	Sperry	KANDIYOHI	07010204050	NCHF	53			
34-0044-00	Diamond	KANDIYOHI	07010204050	NCHF	628	8	7,280	41
34-0046-00	Taits	KANDIYOHI	07010204050	NCHF	5			
34-0049-00	Schultz	KANDIYOHI	07010204050	NCHF	63			
34-0051-00	Wheeler	KANDIYOHI	07010204050	NCHF	104			
34-0056-00	Unnamed	KANDIYOHI	07010204050	NCHF	9			
34-0060-00	Jesse	KANDIYOHI	07010204040	NCHF	31			
34-0062-00	Calhoun	KANDIYOHI	07010204040	NCHF	251	4	3,066	100
34-0066-00	Long	KANDIYOHI	07010204030	NCHF	127	14	982	44
34-0078-00	Bass	KANDIYOHI	07010204050	NCHF	20			62
34-0079-00	Green	KANDIYOHI	07010204040	NCHF	2,239	34	37,716	38
34-0112-00	Woodcock	KANDIYOHI	07010204040	NCHF	46			
34-0113-00	Unnamed	KANDIYOHI	07010204040	NCHF	5			
34-0114-00	Carlson	KANDIYOHI	07010204040	NCHF	11			
34-0116-00	Henderson	KANDIYOHI	07010204040	NCHF	28	17		37
34-0119-00	Elkhorn	KANDIYOHI	07010204040	NCHF	28		622*	35
34-0120-00	Alvig	KANDIYOHI	07010204040	NCHF	29			
34-0126-00	Gina	KANDIYOHI	07010204040	NCHF	20			
34-0141-00	Woodcock	KANDIYOHI	07010204040	NCHF	69	2		
34-0142-00	George	KANDIYOHI	07010204040	NCHF	90		193	
34-0144-00	Unnamed	KANDIYOHI	07010204040	NCHF	5			
34-0146-00	Eight	KANDIYOHI	07010204040	NCHF	22			
34-0148-00	Bear	KANDIYOHI	07010204040	NCHF	56			85
34-0151-00	Unnamed	KANDIYOHI	07010204030	NCHF	6			

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Watershed Area (ha)	% Littoral
34-0154-00	Nest	KANDIYOHI	07010204040	NCHF	396	12	31,842	56
34-0156-00	Unnamed	KANDIYOHI	07010204040	NCHF	8			
34-0157-00	Unnamed	KANDIYOHI	07010204040	NCHF	15			
34-0158-01	Mud	KANDIYOHI	07010204030	NCHF	360		25,922	
34-0158-02	Mud	KANDIYOHI	07010204030	NCHF	329		25,922	
34-0158-03	Crow River Mill Pond(East	KANDIYOHI	07010204030	NCHF	13		25,922	
34-0158-04	Crow River Mill Pond(Mid)	KANDIYOHI	07010204030	NCHF	8		25,922	
34-0161-00	Unnamed	KANDIYOHI	07010204010	NCHF	10			
34-0243-00	Skull	KANDIYOHI	07010204030	NCHF	8			
34-0391-00	Unnamed	KANDIYOHI	07010204040	NCHF	6			
34-0510-00	Unnamed	KANDIYOHI	07010204010	NCHF	7			
34-0611-00	Unnamed	KANDIYOHI	07010204040	NCHF	17			
43-0070-00	Longanans	MCLEOD	07010204110	NCHF	26			
43-0071-00	Todd	MCLEOD	07010204110	NCHF	87	2		
43-0073-00	Hook	MCLEOD	07010204110	NCHF	131	5		99
43-0074-00	Emily	MCLEOD	07010204110	NCHF	31			
43-0081-00	Echo	MCLEOD	07010204110	NCHF	34			
43-0102-00	Dettmans	MCLEOD	07010204110	NCHF	6			
43-0108-00	Campbells	MCLEOD	07010204110	NCHF	11			
47-0001-00	Maple	MEEKER	07010204110	NCHF	55			100
47-0002-00	Francis	MEEKER	07010204160	NCHF	425	6	4,496	95
47-0004-00	Byron	MEEKER	07010204120	NCHF	137			
47-0005-00	Butternut	MEEKER	07010204110	NCHF	31			
47-0007-00	Unnamed	MEEKER	07010204110	NCHF	8			
47-0008-00	Pigeon	MEEKER	07010204110	NCHF	101			
47-0009-00	Unnamed	MEEKER	07010204110	NCHF	31			
47-0014-00	Spencer	MEEKER	07010204110	NCHF	57			
47-0015-00	Jennie	MEEKER	07010204110	NCHF	428	4	5,001	100
47-0016-00	Wolf	MEEKER	07010204110	NCHF	107	4		
47-0017-00	Collins Lake	MEEKER	07010204110	NCHF	23			
47-0019-00	Little Wolf	MEEKER	07010204110	NCHF	25			
47-0023-00	Arvilla	MEEKER	07010204100	NCHF	53			100
47-0025-00	Little Swan	MEEKER	07010204110	NCHF	20		116*	44
47-0026-00	Long	MEEKER	07010204110	NCHF	66	9	398	66
47-0029-00	Hart	MEEKER	07010204100	NCHF	23			
47-0031-00	Mud	MEEKER	07010204110	NCHF	39			

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Watershed Area (ha)	% Littoral
47-0032-00	Spring	MEEKER	07010204110	NCHF	80	9		76
47-0033-00	Unnamed	MEEKER	07010204110	NCHF	4			
47-0035-00	Sellards	MEEKER	07010204100	NCHF	40			100
47-0036-00	Little Spring	MEEKER	07010204110	NCHF	28			
47-0037-00	Boo	MEEKER	07010204110	NCHF	14			
47-0038-00	Big Swan	MEEKER	07010204110	NCHF	261	10	20,363	54
47-0040-00	Mud	MEEKER	07010204160	NCHF	27			
47-0043-00	Heenan Lake	MEEKER	07010204110	NCHF	11			
47-0044-00	Jewitt	MEEKER	07010204110	NCHF	102	2		
47-0045-00	Fallon	MEEKER	07010204110	NCHF	89	2		
47-0046-00	Washington	MEEKER	07010204100	NCHF	979	5	9,136	93
47-0047-00	Unnamed	MEEKER	07010204100	NCHF	16			
47-0048-00	Powers	MEEKER	07010204100	NCHF	101			
47-0050-00	Manuella	MEEKER	07010204100	NCHF	117	16	4,496	37
47-0055-00	Birch	MEEKER	07010204100	NCHF	20			
47-0057-00	Porter	MEEKER	07010204110	NCHF	41			
47-0064-00	Erie	MEEKER	07010204110	NCHF	75	10	239	46
47-0068-00	Stella	MEEKER	07010204100	NCHF	241	23	3,069	51
47-0069-00	North Buckley	MEEKER	07010204100	NCHF	4			
47-0070-00	South Buckley	MEEKER	07010204100	NCHF	25			
47-0073-00	East Andrew Nelson	MEEKER	07010204070	NCHF	16			
47-0074-00	Turtle	MEEKER	07010204100	NCHF	19			
47-0076-00	Darwin	MEEKER	07010204100	NCHF	63			
47-0077-00	Stevens	MEEKER	07010204100	NCHF	11			
47-0080-00	Casey	MEEKER	07010204100	NCHF	34			
47-0082-00	Dunns	MEEKER	07010204080	NCHF	63	6	2,260	61
47-0085-00	Mud	MEEKER	07010204090	NCHF	50			
47-0087-00	Rice	MEEKER	07010204080	NCHF	28			
47-0088-00	Richardson	MEEKER	07010204080	NCHF	48	14	2,057	41
47-0101-00	Andrew Nelson	MEEKER	07010204070	NCHF	36			
47-0102-00	Round	MEEKER	07010204070	NCHF	106	2		100
47-0116-00	Hoosier	MEEKER	07010204070	WCBP	42			
47-0119-00	Minnie-Belle	MEEKER	07010204100	WCBP	240	15	783	31
47-0130-00	Unnamed	MEEKER	07010204060	WCBP	12			
47-0133-00	Chicken	MEEKER	07010204070	WCBP	41			
47-0134-01	Ripley (east portion)	MEEKER	07010204070	WCBP	54			

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Watershed Area (ha)	% Littoral
47-0134-02	Ripley (west portion)	MEEKER	07010204070	WCBP	241		3,343	
47-0132-00	Unnamed	MEEKER	07010204070	WCBP	10			
47-0136-00	West Hanson	MEEKER	07010204070	WCBP	21			
47-0137-00	Harold	MEEKER	07010204070	WCBP	49			
47-0138-00	Youngstrom	MEEKER	07010204070	WCBP	67			
47-0140-00	Minnesota	MEEKER	07010204070	WCBP	47			
47-0142-00	Towers	MEEKER	07010204070	NCHF	21			
47-0143-00	Mary	MEEKER	07010204070	NCHF	37			
47-0144-00	Half Moon	MEEKER	07010204070	NCHF	7			
47-0147-00	Schultz	MEEKER	07010204070	NCHF	18			
47-0148-00	Unnamed	MEEKER	07010204070	WCBP	24			
47-0151-00	Horseshoe	MEEKER	07010204090	NCHF	8	1		
47-0154-00	Thoen	MEEKER	07010204070	WCBP	85			
47-0155-00	Pigeon	MEEKER	07010204090	NCHF	11			
47-0173-00	Popple	MEEKER	07010204060	WCBP	18			
47-0177-00	Long	MEEKER	07010204060	WCBP	282	3	7,353	100
47-0178-00	Sather	MEEKER	07010204060	WCBP	27			
47-0179-00	Moe	MEEKER	07010204060	WCBP	16			
47-0183-00	Hope	MEEKER	07010204060	WCBP	118		1,856	100
47-0189-00	Unnamed	MEEKER	07010204060	WCBP	12			
47-0191-00	Unnamed (Grove)	MEEKER	07010204060	WCBP	13			
47-0192-00	Lund	MEEKER	07010204060	WCBP	45			
47-0193-00	Wilcox	MEEKER	07010204050	NCHF	24			
47-0194-00	Miller	MEEKER	07010204050	NCHF	32			
47-0198-00	Peterson	MEEKER	07010204050	NCHF	54			96
47-0199-00	Helga	MEEKER	07010204050	WCBP	47			
47-0201-00	Emma	MEEKER	07010204090	NCHF	24			
47-0205-00	Whitney	MEEKER	07010204050	NCHF	22			
47-0338-00	Unnamed	MEEKER	07010204110	NCHF	26			
61-0017-00	Unnamed	POPE	07010204010	NCHF	9			
61-0019-00	Mud	POPE	07010204010	NCHF	13			
61-0020-00	Lincoln	POPE	07010204010	NCHF	11			
61-0023-00	Grove	POPE	07010204010	NCHF	144	9	3,922	69
61-0024-00	McCloud	POPE	07010204010	NCHF				
61-0032-00	Alice	POPE	07010204010	NCHF	90	3		
61-0310-00	Unnamed	POPE	07010204010	NCHF	46			
73-0144-00	Pirz	STEARNS	07010204010	NCHF	27		348*	
73-0196-00	Rice	STEARNS	07010204010	NCHF	27		70,075	58

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Watershed Area (ha)	% Littoral
73-0200-01	Mud	STEARNS	07010204010	NCHF	613	13	74,488	100
73-0200-02	Koronis (main lake)	STEARNS	07010204010	NCHF	55	2	74,542	
73-0258-00	George	STEARNS	07010204010	NCHF	1191	39		
73-0277-00	Unnamed	STEARNS	07010204020	NCHF	127			
73-0278-00	Tamarack	STEARNS	07010204010	NCHF	30			
73-0279-00	Crow	STEARNS	07010204030	NCHF	113	1		
73-0281-00	Fish	STEARNS	07010204030	NCHF	91	1		
73-0285-00	Raymond	STEARNS	07010204020	NCHF	70	1		
86-0001-00	Foster	WRIGHT	07010204190	NCHF	26			100
86-0002-00	Rice	WRIGHT	07010204190	NCHF	52	3		
86-0008-00	Unnamed	WRIGHT	07010204190	NCHF	20			
86-0009-00	Martha	WRIGHT	07010204190	NCHF	40		177	74
86-0010-00	Wagner	WRIGHT	07010204190	NCHF	40	7		
86-0011-00	Charlotte	WRIGHT	07010204190	NCHF	44		1,776	40
86-0017-00	Uhl	WRIGHT	07010204190	NCHF	95	14		
86-0019-00	Gonz	WRIGHT	07010204190	NCHF	35			
86-0020-00	Wilhelm	WRIGHT	07010204190	NCHF	10	1		
86-0021-00	Mud	WRIGHT	07010204180	NCHF	39			
86-0022-00	Steele	WRIGHT	07010204190	NCHF	28			
86-0023-00	Beebe	WRIGHT	07010204190	NCHF	55		389	61
86-0028-00	Moore	WRIGHT	07010204190	NCHF	120	8		
86-0029-00	Schmidt	WRIGHT	07010204180	NCHF	74			
86-0031-00	Pelican	WRIGHT	07010204180	NCHF	71		9,344	
86-0033-00	Unnamed	WRIGHT	07010204160	NCHF	945	3		
86-0039-00	Unnamed	WRIGHT	07010204160	NCHF	4			
86-0041-00	Dean	WRIGHT	07010204160	NCHF	4		672	72
86-0043-00	Unnamed (Rooney)	WRIGHT	07010204160	NCHF	70	7		
86-0044-00	Mud	WRIGHT	07010204160	NCHF	24			
86-0046-00	Crawford	WRIGHT	07010204160	NCHF	43		184	98
86-0049-00	Mary	WRIGHT	07010204160	NCHF	43	6		
86-0051-00	Constance	WRIGHT	07010204180	NCHF	137	2	375	54
86-0053-01	Little Pulaski	WRIGHT	07010204140	NCHF	67	7		
86-0053-02	Pulaski (main bay)	WRIGHT	07010204140	NCHF	291	27	1,349	
86-0056-00	Washington	WRIGHT	07010204180	NCHF	50	5		100
86-0061-00	Pohl	WRIGHT	07010204180	NCHF	14			100
86-0063-00	Green Mountain	WRIGHT	07010204180	NCHF	64			

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Watershed Area (ha)	% Littoral
86-0064-00	Gilchrist	WRIGHT	07010204180	NCHF	102	3		
86-0078-00	Slough	WRIGHT	07010204180	NCHF	11			
86-0082-00	Paradise	WRIGHT	07010204180	NCHF	13			
86-0086-00	Fountain	WRIGHT	07010204160	NCHF	171	5		
86-0089-00	Tamarack	WRIGHT	07010204140	NCHF	23	8		85
86-0090-00	Buffalo	WRIGHT	07010204140	NCHF	620	10	12,473	49
86-0097-00	Carrigan	WRIGHT	07010204150	NCHF	54			
86-0100-00	Lauzers	WRIGHT	07010204150	NCHF	29			
86-0102-00	Pooles	WRIGHT	07010204160	NCHF	30	2		
86-0103-00	Ida	WRIGHT	07010204150	NCHF	33	9		76
86-0106-00	Little Waverly	WRIGHT	07010204130	NCHF	135	3		
86-0107-00	Deer	WRIGHT	07010204140	NCHF	69	8		77
86-0108-00	Goose	WRIGHT	07010204140	NCHF	20	4		100
86-0109-00	Fadden	WRIGHT	07010204140	NCHF	7	15		57
86-0112-00	Malardi	WRIGHT	07010204160	NCHF	39			
86-0114-00	Waverly	WRIGHT	07010204130	NCHF	197	20		
86-0116-00	Birch	WRIGHT	07010204140	NCHF	41	8		76
86-0120-00	Ramsey	WRIGHT	07010204140	NCHF	124	24		49
86-0122-00	Light Foot	WRIGHT	07010204140	NCHF	25	7		87
86-0123-00	North Twin	WRIGHT	07010204140	NCHF	18			47
86-0124-00	Unnamed (Pauman)	WRIGHT	07010204140	NCHF	8			
86-0126-00	South Twin	WRIGHT	07010204140	NCHF	15			83
86-0132-00	Abbie	WRIGHT	07010204140	NCHF	45			
86-0134-01	Upper Maple	WRIGHT	07010204140	NCHF	293	21	1,192	
86-0134-02	Mud	WRIGHT	07010204140	NCHF	46	3		
86-0134-03	Maple (Northeast Bay)	WRIGHT	07010204140	NCHF	0	9		51
86-0177-00	Yaeger	WRIGHT	07010204130	NCHF	39			
86-0178-00	Dog	WRIGHT	07010204150	NCHF	41	8		78
86-0179-00	Mains	WRIGHT	07010204160	NCHF	5			
86-0180-00	School Section	WRIGHT	07010204130	NCHF	14	1		
86-0181-00	Little Rock	WRIGHT	07010204160	NCHF	17			58
86-0182-00	Rock	WRIGHT	07010204160	NCHF	73	11		57
86-0184-00	Dutch	WRIGHT	07010204130	NCHF	63	9		100
86-0188-00	Emma	WRIGHT	07010204130	NCHF	73	4		73
86-0190-00	Ann	WRIGHT	07010204130	NCHF	151	6		29
86-0192-00	Round	WRIGHT	07010204130	NCHF	17	8		71

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Watershed Area (ha)	% Littoral
86-0193-00	Mary	WRIGHT	07010204150	NCHF	74	14	195	47
86-0194-00	Long	WRIGHT	07010204130	NCHF	20	1		
86-0199-00	Howard	WRIGHT	07010204130	NCHF	295	11	1,726	100
86-0200-00	Spring	WRIGHT	07010204130	NCHF	22			
86-0203-00	Unnamed	WRIGHT	07010204160	NCHF	45			
86-0204-00	Taylor	WRIGHT	07010204160	NCHF	20			
86-0206-00	Doefler	WRIGHT	07010204130	NCHF	36			44
86-0214-00	White	WRIGHT	07010204160	NCHF	47			
86-0217-00	Granite	WRIGHT	07010204160	NCHF	143	10		32
86-0218-00	Maxim	WRIGHT	07010204160	NCHF	19			89
86-0221-00	Camp	WRIGHT	07010204160	NCHF	48	16		38
86-0250-00	Smith	WRIGHT	07010204120	NCHF	74	2		
86-0255-00	Shakopee	WRIGHT	07010204120	NCHF	46	0		
86-0263-00	Cokato	WRIGHT	07010204120	NCHF	221	16	11,855	34
86-0264-00	Brooks	WRIGHT	07010204120	NCHF	39	6		62
86-0271-00	Moose	WRIGHT	07010204160	NCHF	32	13		72
86-0273-00	French	WRIGHT	07010204160	NCHF	137	16		47
86-0274-00	Dans	WRIGHT	07010204160	NCHF	30	8		70
86-0278-00	Goose	WRIGHT	07010204160	NCHF	36	2		
86-0279-00	West Lake Sylvia	WRIGHT	07010204160	NCHF	360	27	3,241	33
86-0288-00	John	WRIGHT	07010204160	NCHF	160	9	1,452	86
86-0289-00	East Lake Sylvia	WRIGHT	07010204160	NCHF	271	24	2,051	26
86-0293-00	Collinwood	WRIGHT	07010204110	NCHF	253	9	13,185	60
86-0295-00	Swan	WRIGHT	07010204110	NCHF	25	1		
86-0296-00	Beaver Dam	WRIGHT	07010204110	NCHF	8			

*estimated values

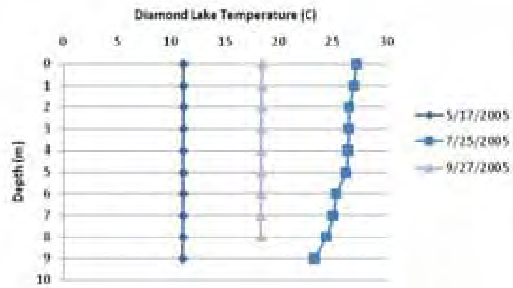
Appendix B – MINLEAP modeling results

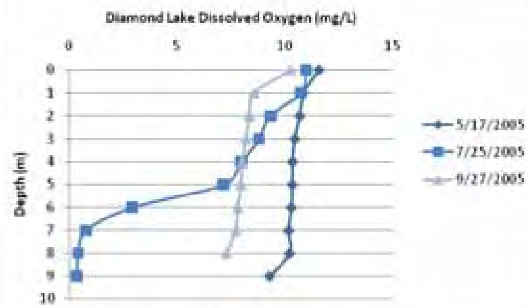
Lake ID	Lake Name	Obs TP	MINLEAP TP	Obs Chl-a	MINLEAP Chl-a	Obs Secchi	MINLEAP Secchi	Average TP Inflow	TP Load	Background TP	P Retention	Outflow	Residence Time	Areal Load
		ug/L	ug/L	ug/L	ug/L	m	m	ug/L	kg/yr	ug/L	%	hm3/yr	years	m/yr
27-0169-00	Cowley													
27-0191-01	West Sarah													
27-0191-02	East Sarah													
27-0199-00	Hafften													
34-0044-00	Diamond													
34-0062-00	Calhoun	32	66	11	30	1.3	1.0	164	617	38.8	60	3.76	0.8	1.5
34-0066-00	Long	19	33	5	11	4.0	1.9	174	203	24.5	81	1.16	5.5	0.92
34-0079-00	Green	16	36	5	12	3.7	1.8	159	7497	20.6	78	47.02	3.9	2.1
34-0119-00	Elkhorn	13	48	3	19	4.0	1.4	157	123	24.3	69	0.78	1.8	2.8
34-0154-00	Nest							150	6169			41.04	0.4	10.36
34-0158-01	Mud	52	110	8	63	0.6	0.7	151	5026	58.2	27	33.37	0.1	9.27
34-0158-02	Mud	36	105	8	59	1.7	0.7	150	5023	42.7	30	33.4	0.1	10.15
34-0158-03	Crow River Mill Pond (E)	36	135	8	85	1.8	0.6	148	4989	35.4	9	33.69	0.1	259.13
34-0158-04	Crow River Mill Pond (M)	31	138	6	88	1.9	0.6	148	4988	35.4	7	33.69	0.1	421.14
43-0073-00	Hook													
47-0002-00	Francis	21	50	8	20	1.9	1.3	167	911	31.5	70	5.46	1.9	1.29
47-0015-00	Jennie	61	50	28	20	1.6	1.3	165	1008	28.9	69	6.12	1.7	1.43
47-0025-00	Little Swan	14	20	4	5	4.0	2.9	276	47	27.8	93	0.17	26.5	0.19
47-0026-00	Long	37	37	10	13	2.0	1.7	183	84	28.5	80	0.46	4.3	0.69
47-0032-00	Spring													
47-0038-00	Big Swan	91	73	47	35	1.1	1.0	150	3946	23.7	51	26.24	0.5	10.05
47-0046-00	Washington	26	48	10	19	1.1	1.4	169	1863	29	72	11	2.1	1.12

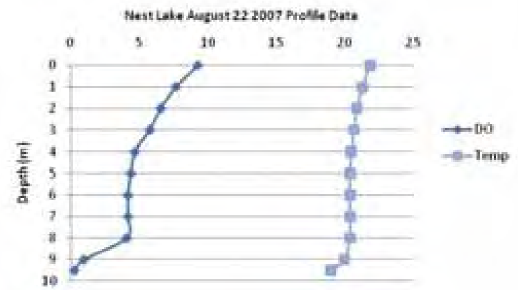
Lake ID	Lake Name	Obs TP	MINLEAP TP	Obs Chl-a	MINLEAP Chl-a	Obs Secchi	MINLEAP Secchi	Average TP Inflow	TP Load	Background TP	P Retention	Outflow	Residence Time	Areal Load
		ug/L	ug/L	ug/L	ug/L	m	m	ug/L	kg/yr	ug/L	%	hm3/yr	years	m/yr
47-0050-00	Manuella	19	54	7	23	2.0	1.2	153	878	21.9	64	5.74	1.2	4.91
47-0064-00	Erie	30	30	11	9	2.0	2.1	222	54	26.9	87	0.24	9.3	0.32
47-0068-00	Stella	21	39	10	14	2.1	1.7	163	616	22.8	76	3.77	3.4	1.57
47-0082-00	Dunns	106	64	43	28	1.0	1.1	153	442	22.9	58	2.88	0.8	4.57
47-0088-00	Richardson	68	56	32	24	1.1	1.2	152	401	20.4	63	2.63	1.1	5.48
47-0119-00	Minnie-Belle	27	33	5	11	3.5	1.9	558	474	18.8	94	0.85	22.6	0.35
47-0134-02	Ripley (west portion)	34	114	9	67	2.1	0.7	568	2371	28.4	80	4.18	1.7	1.73
47-0177-00	Long													
47-0183-00	Hope													
61-0023-00	Grove	34	62	12	27	2.0	1.1	155	770	29.2	60	4.97	0.9	3.45
73-0144-00	Pirz	26	43	7	16	3.0	1.5	163	70	26.4	73	0.43	2.5	1.59
73-0196-00	Rice	60	80	30	40	1.6	0.9	150	13548	24.1	47	90.55	0.3	14.77
73-0200-01	Mud	54	138	10	88	0.6	0.6	148	14337	47.8	7	96.78	0.0	175.97
73-0200-02	Koronis (main lake)	40	56	18	23	2.2	1.2	151	14470	19.7	63	95.83	1.1	8.05
86-0001-00	Foster	262	69	130	32	0.5	1.0	156	239	28.5	56	1.53	0.6	2.95
86-0009-00	Martha	24	34	8	11	2.0	1.9	198	38	24.1	83	0.19	6.2	0.49
86-0011-00	Charlotte	15	41	4	15	4.9	1.6	158	352	18.7	74	2.22	2.8	2.34
86-0023-00	Beebe	59	28	39	8	1.1	2.2	221	88	22.7	87	0.4	10.9	0.33
86-0031-00	Pelican	153	53	60	22	0.4	1.3	168	1899	28.0	69	11.3	1.6	1.2
86-0041-00	Dean	217	43	82	16	0.6	1.5	169	137	23.8	74	0.81	2.7	1.16
86-0046-00	Crawford	22	53	4	22	4.0	1.3	200	40	34.6	73	0.2	2.1	0.47
86-0051-00	Constance	91	33	74	11	1.4	1.9	186	79	22.3	82	0.43	6	0.64
86-0053-02	Pulaski (main bay)	19	18	6	5	3.9	3.1	195	291	15.6	91	1.49	21.7	0.51

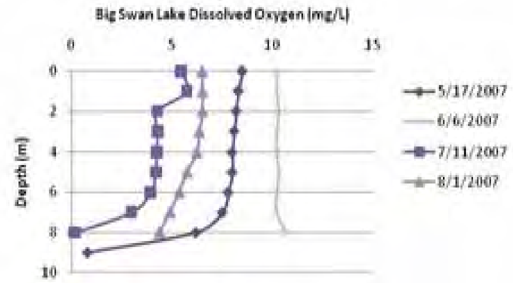
Lake ID	Lake Name	Obs TP	MINLEAP TP	Obs Chl-a	MINLEAP Chl-a	Obs Secchi	MINLEAP Secchi	Average TP Inflow	TP Load	Background TP	P Retention	Outflow	Residence Time	Areal Load
		ug/L	ug/L	ug/L	ug/L	m	m	ug/L	kg/yr	ug/L	%	hm3/yr	years	m/yr
86-0086-00	Fountain													
86-0090-00	Buffalo													
86-0106-00	Little Waverly													
86-0107-00	Deer													
86-0112-00	Malardi													
86-0114-00	Waverly													
86-0120-00	Ramsey													
86-0134-01	Upper Maple	21	25	8	7	3.0	2.4	203	261	22.9	87	1.29	11.6	0.44
86-0182-00	Rock													
86-0184-00	Dutch													
86-0188-00	Emma													
86-0190-00	Ann													
86-0193-00	Mary	26	21	10	6	2.4	2.8	243	45	22.5	91	0.19	21.8	0.25
86-0199-00	Howard	82	30	33	9	1.3	2.1	184	364	22.9	84	1.98	7.3	0.67
86-0217-00	Granite													
86-0221-00	Camp													
86-0250-00	Smith													
86-0263-00	Cokato	54	59	22	25	1.9	1.2	151	2305	22.1	61	15.21	1.0	6.88
86-0264-00	Brooks													
86-0273-00	French													
86-0279-00	W Lake Sylvia	10	26	3	8	5.4	2.3	170	662	18.4	85	3.89	8.8	1.08
86-0288-00	John	26	41	9	15	2.4	1.6	170	297	25.8	76	1.74	3.1	1.09
86-0289-00	E Lake Sylvia	10	24	4	7	5.2	2.5	175	424	18.2	86	2.42	11.1	0.89
86-0293-00	Collinwood	99	70	47	33	1.6	1.0	152	2564	25.4	54	16.91	0.5	6.68

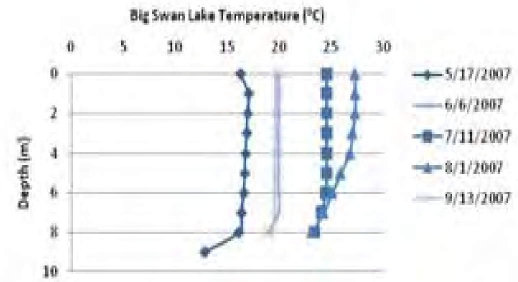
Appendix C – lake temperature and dissolved oxygen profile data

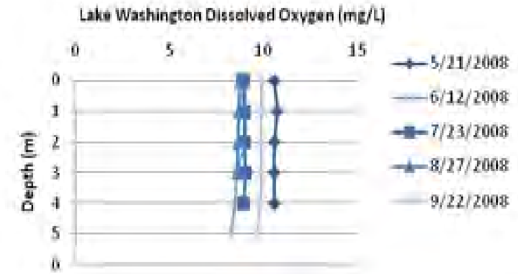

Diamond Lake Temperature (C)
Depth (m)
5/17/2005
7/25/2005
9/27/2005

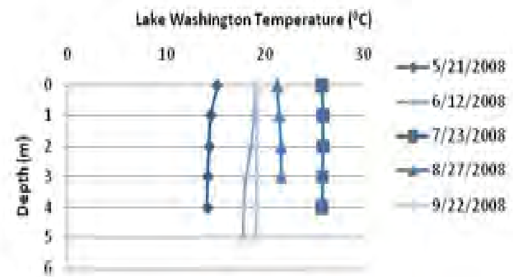

Diamond Lake Dissolved Oxygen (mg/L)
Depth (m)
5/17/2005
7/25/2005
9/27/2005

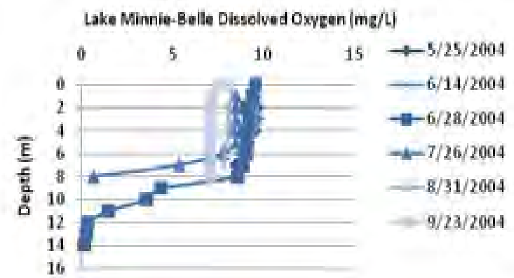

Nest Lake August 22 2007 Profile Data
Depth (m)
DO
Temp

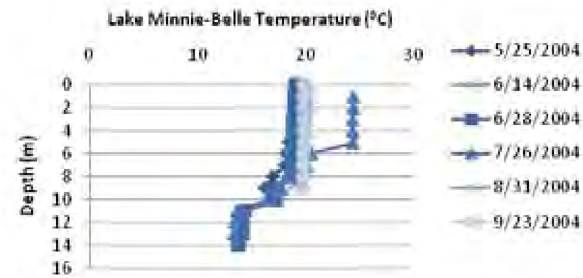

Big Swan Lake Dissolved Oxygen (mg/L)
Depth (m)
5/17/2007
6/6/2007
7/11/2007
8/1/2007

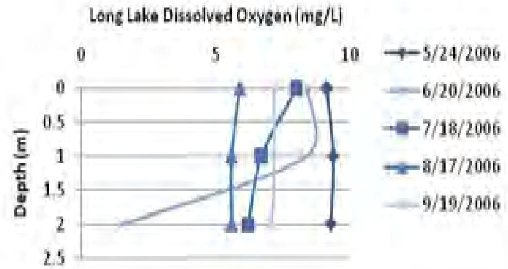

Big Swan Lake Temperature (°C)
Depth (m)
5/17/2007
6/6/2007
7/11/2007
8/1/2007
9/13/2007

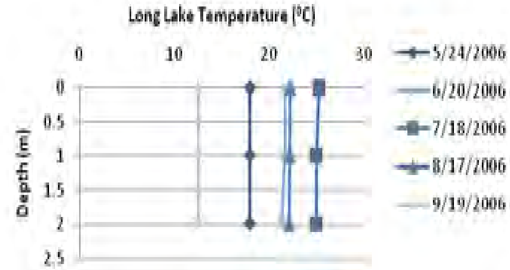

Lake Washington Dissolved Oxygen (mg/L)
Depth (m)
5/21/2008
6/12/2008
7/23/2008
8/27/2008
9/22/2008

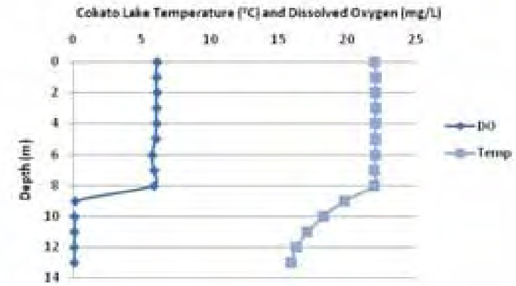

Lake Washington Temperature (°C)
Depth (m)
5/21/2008
6/12/2008
7/23/2008
8/27/2008
9/22/2008

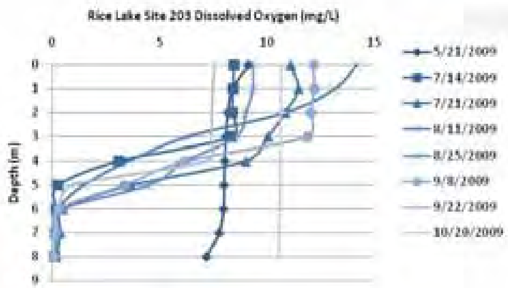

Lake Minnie-Belle Dissolved Oxygen (mg/L)
Depth (m)
5/25/2004
6/14/2004
6/28/2004
7/26/2004
8/31/2004
9/23/2004

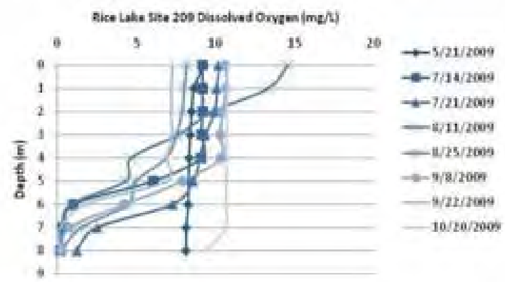

Lake Minnie-Belle Temperature (°C)
Depth (m)
5/25/2004
6/14/2004
6/28/2004
7/26/2004
8/31/2004
9/23/2004

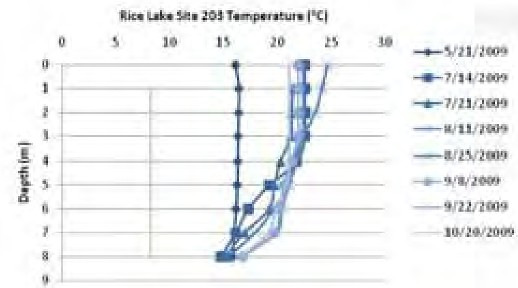

Long Lake Dissolved Oxygen (mg/L)
Depth (m)
5/24/2006
6/20/2006
7/18/2006
8/17/2006
9/19/2006

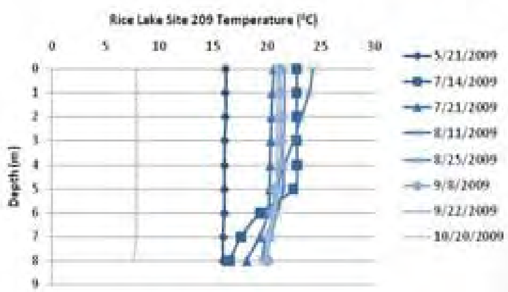

Long Lake Temperature (°C)
Depth (m)
5/24/2006
6/20/2006
7/18/2006
8/17/2006
9/19/2006

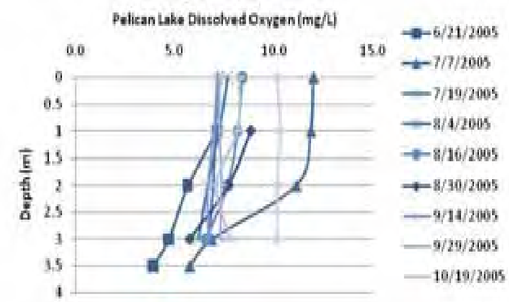

Cokato Lake Temperature (°C) and Dissolved Oxygen (mg/L)
Depth (m)
DO
Temp

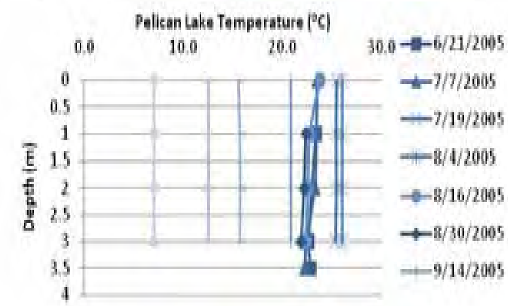

Rice Lake Site 203 Dissolved Oxygen (mg/L)
Depth (m)
5/21/2009
7/14/2009
7/21/2009
8/11/2009
8/25/2009
9/8/2009
9/22/2009
10/20/2009

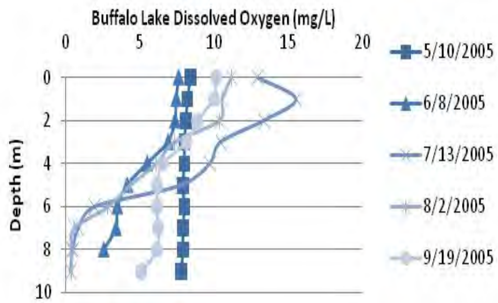

Rice Lake Site 209 Dissolved Oxygen (mg/L)
Depth (m)
5/21/2009
7/14/2009
7/21/2009
8/11/2009
8/25/2009
9/8/2009
9/22/2009
10/20/2009

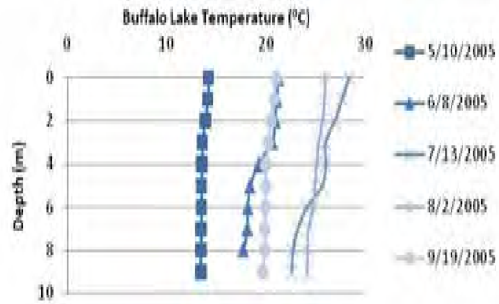

Rice Lake Site 203 Temperature (°C)
Depth (m)
5/21/2009
7/14/2009
7/21/2009
8/11/2009
8/25/2009
9/8/2009
9/22/2009
10/20/2009

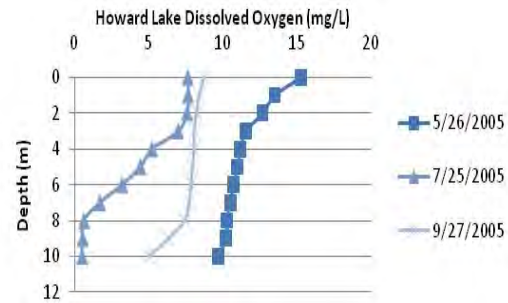

Rice Lake Site 209 Temperature (°C)
Depth (m)
5/21/2009
7/14/2009
7/21/2009
8/11/2009
8/25/2009
9/8/2009
9/22/2009
10/20/2009

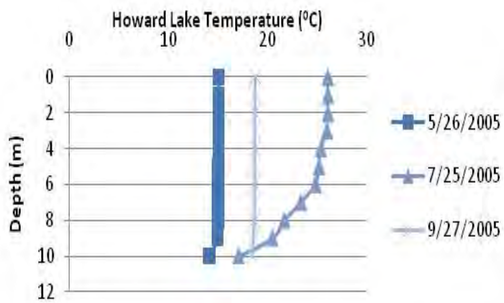

Pelican Lake Dissolved Oxygen (mg/L)
Depth (m)
6/21/2005
7/7/2005
7/19/2005
8/4/2005
8/16/2005
8/30/2005
9/14/2005
9/29/2005
10/19/2005

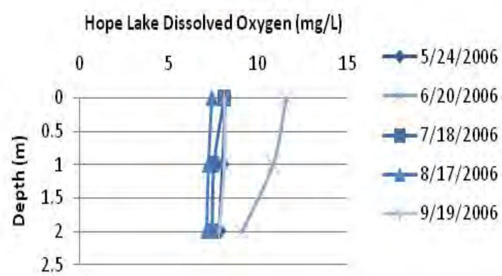

Pelican Lake Temperature (°C)
Depth (m)
6/21/2005
7/7/2005
7/19/2005
8/4/2005
8/16/2005
8/30/2005
9/14/2005

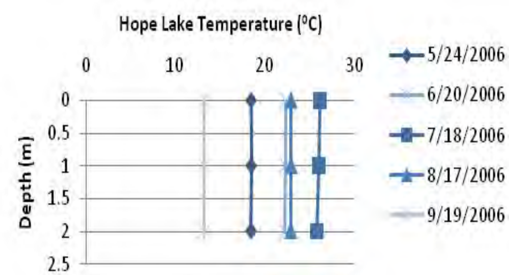

Buffalo Lake Dissolved Oxygen (mg/L)
0
5
10
15
20
Depth (m)
0
2
4
6
8
10
5/10/2005
6/8/2005
7/13/2005
8/2/2005
9/19/2005

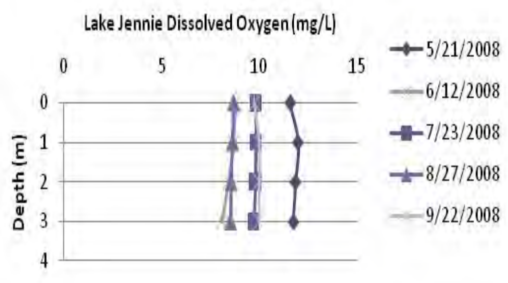

Buffalo Lake Temperature (°C)
0
10
20
30
Depth (m)
0
2
4
6
8
10
5/10/2005
6/8/2005
7/13/2005
8/2/2005
9/19/2005

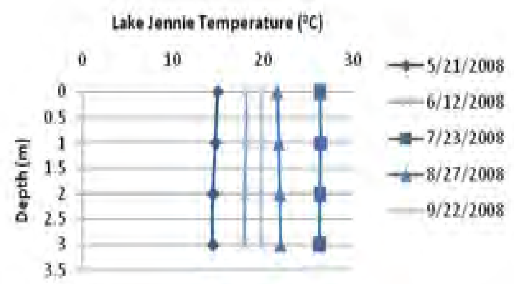

Howard Lake Dissolved Oxygen (mg/L)
0
5
10
15
20
Depth (m)
0
2
4
6
8
10
12
5/26/2005
7/25/2005
9/27/2005

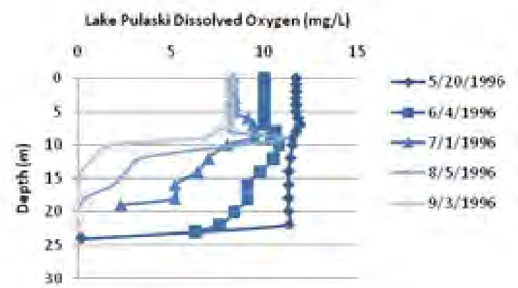

Howard Lake Temperature (°C)
0
10
20
30
Depth (m)
0
2
4
6
8
10
12
5/26/2005
7/25/2005
9/27/2005

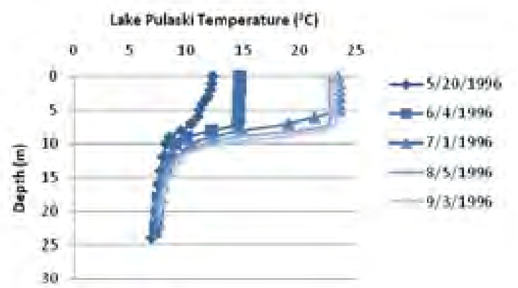

Hope Lake Dissolved Oxygen (mg/L)
0
5
10
15
Depth (m)
0
0.5
1
1.5
2
2.5
5/24/2006
6/20/2006
7/18/2006
8/17/2006
9/19/2006


Hope Lake Temperature (°C)
0
10
20
30
Depth (m)
0
0.5
1
1.5
2
2.5
5/24/2006
6/20/2006
7/18/2006
8/17/2006
9/19/2006


Lake Jennie Dissolved Oxygen (mg/L)
0
5
10
15
0
1
2
3
4
Depth (m)
5/21/2008
6/12/2008
7/23/2008
8/27/2008
9/22/2008


Lake Jennie Temperature (°C)
0
10
20
30
0
0.5
1
1.5
2
2.5
3
3.5
Depth (m)
5/21/2008
6/12/2008
7/23/2008
8/27/2008
9/22/2008


Lake Pulaski Dissolved Oxygen (mg/L)
0
5
10
15
0
5
10
15
20
25
30
Depth (m)
5/20/1996
6/4/1996
7/1/1996
8/5/1996
9/3/1996


Lake Pulaski Temperature (°C)
0
5
10
15
20
25
0
5
10
15
20
25
30
Depth (m)
5/20/1996
6/4/1996
7/1/1996
8/5/1996
9/3/1996