Cedar Lake and McMahon (Carl's) Lake Total Maximum Daily Load Report

Prepared for
Scott Watershed Management Organization (WMO) and Minnesota Pollution Control Agency

Funded by
Scott Watershed Management Organization (WMO) and Minnesota Pollution Control Agency Clean Water Partnership Program

December 2011

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Executive Summary

Cedar and McMahon (Carl's) Lakes are currently listed on the Minnesota Pollution Control Agency's (MPCA) 2010 303(d) Impaired Waters List due to excessive nutrients (phosphorus). Cedar Lake is one of the largest lakes in Scott County. The lake has a surface area of 779 acres, a maximum depth of approximately 13 feet, and a mean depth of 6.9 feet. Cedar Lake is considered a shallow lake, with the littoral area covering the entire lake surface. Cedar Lake is used primarily for motor boating, canoeing, fishing, picnicking, and aesthetic viewing. Cedar Lake provides some limited wildlife habitat.

McMahon (Carl's) Lake, also in Scott County, is a shallow lake with a surface area of 130 acres and maximum and mean depths of 14 feet and 8.5 feet, respectively. McMahon (Carl's) Lake is used primarily for canoeing, fishing, picnicking, and aesthetic viewing. McMahon (Carl's) Lake provides some wildlife habitat as well.

The direct Cedar Lake watershed comprises a total of 2,472 acres (not including the lake) and drains portions of unincorporated areas near the city of New Prague. Cedar Lake receives a portion of the flow from Sand Creek via a diversion weir near the south end of the lake. The tributary watershed for this portion of the creek is 7,169 acres. However, during 2007 the diversion weir was blocked, limiting flow entering Cedar Lake from Sand Creek.

McMahon (Carl's) Lake has a smaller direct watershed (393 acres, not including the lake) draining unincorporated areas surrounding the lake. There are no stream discharges to the lake.

Cedar Lake and McMahon (Carl's) Lake are located in the North Central Hardwood Forests (NCHF) ecoregion, but are within approximately 10 to 15 miles of the boundary of the NCHF and the Western Corn Belt Plains (WCBP) ecoregions. The standards for the NCHF ecoregion will apply for these lakes. However, it should be noted that local water resources professionals question the appropriateness, reasonableness, and attainability of this standard for these lakes. In the future it may be appropriate to consider applying the WCBP ecoregion standards, provided beneficial uses are met, and at that time a request for a site-specific standard would be expected to be made to the MPCA and the US Environmental Protection Agency (EPA). The balanced TMDL equation is provided in this report for the NCHF ecoregion and, for future reference, the WCBP ecoregion TMDL endpoints are provided as well. The historical growing season water quality (10-year averages) for each lake is compared to the MPCA shallow lake eutrophication standards for both the WCBP and NCHF ecoregions (Table EX-1).

The MPCA projected schedule for Total Maximum Daily Load (TMDL) report completion, as indicated on Minnesota's 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of these TMDLs. The Cedar Lake and McMahon (Carl's) Lake TMDLs were scheduled to begin in 2008 and be complete in 2012. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the water body; technical capability and willingness locally to assist with each TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

Table EX-1 Cedar Lake and McMahon Lake 10-Year Average Water Quality Parameters

Water Quality Parameter	MPCA Shallow Lake Eutrophication Standards		Cedar Lake 10-year (1999-2008) Growing Season (mid-May through Sept.) Average	McMahon Lake 10-year (1999-2008) Growing Season (mid-May through Sept.) Average
	Western Corn Belt Plains	North Central Hardwood Forests		
Total Phosphorus (µg/L)	90 µg/L	60 µg/L	170 µg/L	85 µg/L
Chlorophyll *a* (µg/L)	30 µg/L	20 µg/L	71 µg/L	70 µg/L
Secchi disc (m)	0.7 m	1.0 m	1.28 m	0.88 m

A significant source of background information for this TMDL report is contained in the Cedar Lake Improvement District report *Management Alternatives Report on the Diagnostic-Feasibility Study for Cedar Lake* (Barr Engineering Company, 1987), coupled with the Scott Watershed Management Organization (Scott WMO) Annual Water Quality Reports for 2005 and 2006.

The TMDL equation is defined as follows:

TMDL = Wasteload Allocation (WLA) + Load Allocation (LA) + Margin of Safety (MOS) + Reserve Capacity.

For Cedar Lake, the Load Capacity using the WCBP standard as the endpoint is 1979.6 pounds (lbs) of total phosphorus (TP) per growing season.

The TMDL equation used to derive this Load Capacity for Cedar Lake is:

<u>Expressed as growing season (Mid-May through September) totals:</u>

TMDL = 2.4 lbs. TP (WLA) + 1977.2 lbs. TP (LA) + 0 lbs. TP (MOS) + 0 lbs. (Reserve Capacity) = 1979.6 lbs per growing season

<u>Expressed in daily terms (growing season load/138 days)</u>

TMDL = 0.017 lbs/day (WLA) + 14.327 (LA) +0 (MOS) + 0 (Reserve Capacity) = 14.344 lbs per day, on average, over the growing season

For Cedar Lake, the Load Capacity using the NCHF standard as the endpoint is 921.8 pounds (lbs) of total phosphorus (TP) per growing season.

The TMDL equation used to derive this Load Capacity for Cedar Lake is:

<u>Expressed as growing season (Mid-May through September) totals:</u>

TMDL = 2.4 lbs. TP (WLA) + 919.4 lbs. TP (LA) + 0 lbs. TP (MOS) + 0 lbs. (Reserve Capacity) = 921.8 lbs per growing season

<u>Expressed in daily terms (growing season load/138 days)</u>

TMDL 0.017 lbs/day (WLA) + 6.662 (LA) +0 (MOS) + 0 (Reserve Capacity) = 6.679 lbs per day, on average, over the growing season

The Wasteload Allocation represents a 0% reduction in load to Cedar Lake. The Load Allocation represents a 68% (WCBP) or an 85% (NCHF) total phosphorus reduction. This will be achieved through a 72% (WCBP) or an 89% (NCHF) reduction of internal phosphorus load in Cedar Lake through management of sediment phosphorus loading, the invasive macrophyte curlyleaf pondweed, and fisheries management and carp control. Loading from the direct watershed will be reduced by 25% under each endpoint through best management practices (BMPs).

For McMahon (Carl's) Lake, the Load Capacity using the WCBP standard as the endpoint is 584.20 pounds (lbs) of total phosphorus (TP) per growing season.

The TMDL equation used to derive this Load Capacity for McMahon (Carl's) Lake is:

Expressed as growing season (Mid-May through September) totals:

TMDL = 0.67 lbs. TP (WLA) + 583.53 lbs. TP (LA) + 0 lbs. TP (MOS) + 0 lbs. (Reserve Capacity) = 584.20 lbs per growing season

Expressed in daily terms (growing season load/138 days)

TMDL = 0.0049 lbs/day (WLA) + 4.2285 (LA) +0 (MOS) + 0 (Reserve Capacity) = 4.2334 lbs per day, on average, over the growing season

For McMahon (Carl's) Lake, the Load Capacity using the NCHF standard as the endpoint is 112.21 pounds (lbs) of total phosphorus (TP) per growing season.

The TMDL equation used to derive this Load Capacity for McMahon (Carl's) Lake is:

Expressed as growing season (Mid-May through September) totals:

TMDL = 0.51 lbs. TP (WLA) + 111.70 lbs. TP (LA) + 0 lbs. TP (MOS) + 0 lbs. (Reserve Capacity) = 112.21 lbs per growing season

Expressed in daily terms (growing season load/138 days)

TMDL = 0.0037 lbs/day (WLA) + 0.8094 (LA) +0 (MOS) + 0 (Reserve Capacity) = 0.8131 lbs per day, on average, over the growing season

The Margin of Safety for each lake is implicitly included in the equation as a result of calibrated modeling parameters, conservative modeling assumptions and the fact that the lake is being managed for the "worst-case scenario" water quality condition when external and internal load conditions are considered.

The reserve capacity for each lake is set at zero because no further development, at urban densities required to be part of the future WLA, is expected within the tributary watersheds through 2030 (2030 Scott County Comprehensive Land Use Plan Update).

1.0 Introduction

Cedar Lake and McMahon (Carl's) Lake (DNR IDs 70-0091 and 70-0050, respectively) are located in the lower portion of the Minnesota River Basin (Figure 1) and near the border of the North Central Hardwood Forest and Western Corn Belt Plains Ecoregions. McMahon (Carl's) Lake lies within an enclosed watershed receiving runoff only from the direct watershed while Cedar Lake receives flow from a tributary to Sand Creek via an inlet structure in addition to inflows from the direct watershed.

Cedar and McMahon Lakes are currently listed on the Minnesota Pollution Control Agency's (MPCA) 2008 303(d) Impaired Waters List due to excessive nutrients (phosphorus) and require a Total Maximum Daily Load (TMDL) report. The lakes were first listed on the MPCA's 303(d) list in 2002. The TMDL reports for both lakes have a target start date of 2008 and a target completion date of 2012.

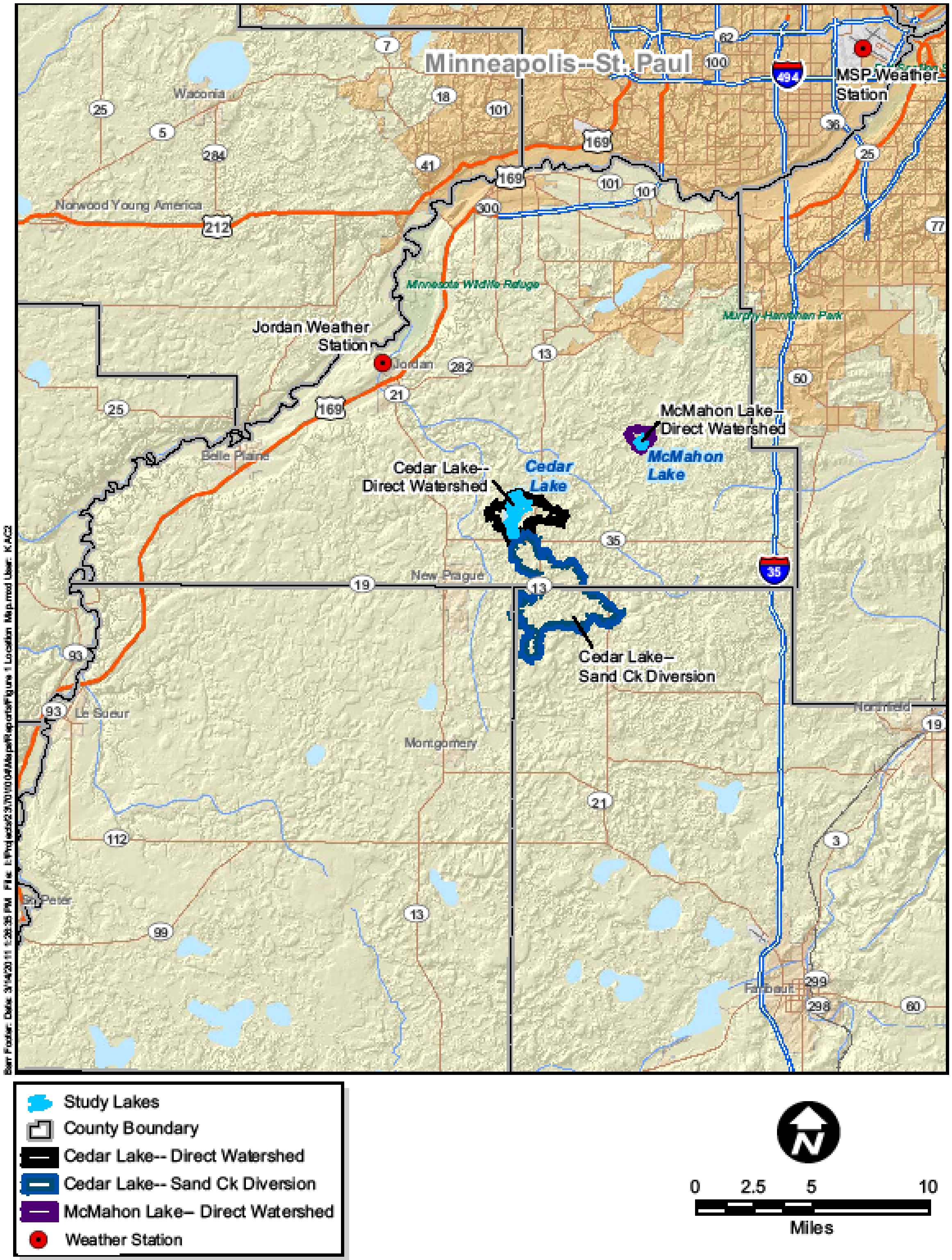
The MPCA's projected schedule for TMDL completions, as indicated on Minnesota's 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the water body; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

In 1984, the University of Minnesota Limnological Research Center completed a study titled "The Hydrology and Limnology of Cedar Lake Implications for Lake Restoration" (Pfannkuch and Shapiro 1984), some of which was included in the "Management Alternatives Report on the Diagnostic Feasibility Study for Cedar Lake" conducted by Barr Engineering in 1987. The purpose of the1987 report was to review the previous feasibility analysis completed by the University of Minnesota and discuss the additional diagnostic work prescribed by the MPCA for Cedar Lake. In 1999, the Cedar Lake Sewer District was established and upgrades to the sewer system occurred in 2001.

Current monitoring and study of these lakes is being coordinated by the Scott Watershed Management Organization (Scott WMO). The Scott WMO, formed in 2000, is a special purpose unit of local government that manages water resources under the Metropolitan

Surface Water Management Act (1982). The act requires local units of government in the seven-county metropolitan area to prepare and implement comprehensive surface water management plans through membership in a watershed management organization (WMO). Watershed management organizations are based on watershed boundaries. More information can be found about the Scott WMO on their website (www.co.scott.mn.us).

Figure 1-1 Site Location Map



2.0 Background Information

2.1 Applicable Water Quality Standards

Impaired waters are listed and reported to the citizens of Minnesota and to the EPA in the 305(b) report and the 303(d) list, named after relevant sections of the Clean Water Act. Assessment of waters for the 305(b) report identifies candidates for listing on the 303(d) list of impaired waters. The purpose of the 303(d) list is to identify impaired water bodies for which a plan will be developed to remedy the pollution problem(s) (the TMDL—this document).

The basis for assessing Minnesota lakes for impairment due to eutrophication includes the narrative water quality standard and assessment factors in Minnesota Rules 7050.0150. The MPCA has completed extensive planning and research efforts to develop quantitative lake eutrophication standards for lakes in different ecoregions of Minnesota that would result in achievement of the goals described by the narrative water quality standards. To be listed as impaired by the MPCA, the monitoring data must show that the standards for both total phosphorus (the causal factor) and either chlorophyll *a* or Secchi disc depth (the response factors) are not met (MPCA, 2007a). Both lakes were originally listed based on the eutrophication criteria for the NCHF ecoregion.

Cedar Lake and McMahon (Carl's) Lake are located in the NCHF ecoregion, but are within approximately 10 to 15 miles of the boundary of the NCHF and the WCBP ecoregions. The standards for the NCHF ecoregion will apply for these lakes. However, it should be noted that local water resources professionals question the appropriateness, reasonableness, and attainability of this standard for these lakes. In the future it may be appropriate to consider applying the WCBP ecoregion standards, provided beneficial uses are met, and at that time a request for a site-specific standard would be expected to be made to the MPCA and the US Environmental Protection Agency (EPA). The balanced TMDL equation is provided in this report for the NCHF ecoregion and, for future reference, the WCBP ecoregion TMDL endpoints are provided as well (Table 1-1).

Table 1-1 MPCA Shallow Lake Eutrophication Standards for Total Phosphorus, Chlorophyll *a* and Secchi Disc (WCBP and NCHF)

303(d) Classification	MPCA Shallow Lake Eutrophication Standard	
	WCBP	NCHF
Total Phosphorus (µg/L)	90	60
Chlorophyll-a (µg/L)	30	20
Secchi disc (m)	0.7	1.0

Source: Minnesota Rule 7050.0222 Subp. 4. Class 2B Waters

2.2 General Lake Characteristics

Cedar Lake and McMahon Lake are Minnesota Department of Natural Resources (DNR)-protected waters (DNR ID#70-0091 and 70-0050, respectively) located in unincorporated areas near the city of New Prague (Figure 1-1). Cedar Lake is one of the largest lakes in Scott County with a surface area of 779 acres, a maximum depth of approximately 13 feet, and a mean depth of 6.9 feet (Figure 2-1). The lake is used primarily for motor boating, canoeing, fishing, picnicking, and aesthetic viewing. Cedar Lake also provides some limited wildlife habitat.

McMahon Lake is a shallow lake with a surface area of 130 acres and maximum and mean depths of 14 feet and 8.5 feet, respectively (Figure 2-2). McMahon Lake is used primarily for canoeing, fishing, picnicking, and aesthetic viewing and the lake provides wildlife habitat as well.

By MPCA (2007b) definition, Cedar and McMahon Lakes are considered to be shallow lakes (a maximum depth of less than 15 feet and/or at least 80 percent of the lake less than 15 feet deep). The direct tributary watershed areas in comparison to each lake’s surface area are relatively small (Cedar Lake = 2.1:1, McMahon Lake = 3.1:1).

Both lakes are polymictic meaning they mix multiple times throughout the year. Each water body can stratify for short periods during the growing season, followed by destratification that mixes the water column. At times, this mixing may entrain phosphorus that is released from the lake sediment (internal loading) into the water column, making more phosphorus available to algae. Another internal source of phosphorus to Cedar and McMahon Lakes is curlyleaf pondweed. This invasive macrophyte proliferates in the early-summer and dies off in mid-summer, releasing substantial amounts of phosphorus into the water column. In addition, common carp are present in Cedar Lake adding to the internal phosphorus load via bioturbation of sediment and excretion.

The immediate Cedar Lake watershed comprises a drainage area of 2,472 acres (including the lake surface area) and drains unincorporated areas near the city of New Prague. Development immediately around the lake is sewered. Cedar Lake receives both direct drainage from the immediate watershed and a portion of the flow from a tributary to Sand Creek which enters from a diversion weir system south of the lake. Information on each of these contributing watershed areas is presented below.

- **Direct—**This 1,862 acre drainage area (including Cedar Lake) surrounds the lake.
- **Diversion—**The approximate contributing area upstream of the diversion structure at Sand Creek (south of the lake, Figure 1) is 7,169 acres and extends into Rice County. Only a portion of the flow from the tributary to Sand Creek is diverted to Cedar Lake however.
- **St. Patrick Wetland**—The watershed area to the east of Cedar Lake drains into the St. Patrick Wetland and then enters Cedar Lake. The approximate area of this watershed, including the wetland area, is 610 acres.

McMahon has a small, tributary watershed surrounding the lake as the main source of runoff to the lake.

- **Direct—**This 552 drainage area (including McMahon Lake) surrounds the lake.

Figure 2-1 Cedar Lake Bathymetry (units in feet)

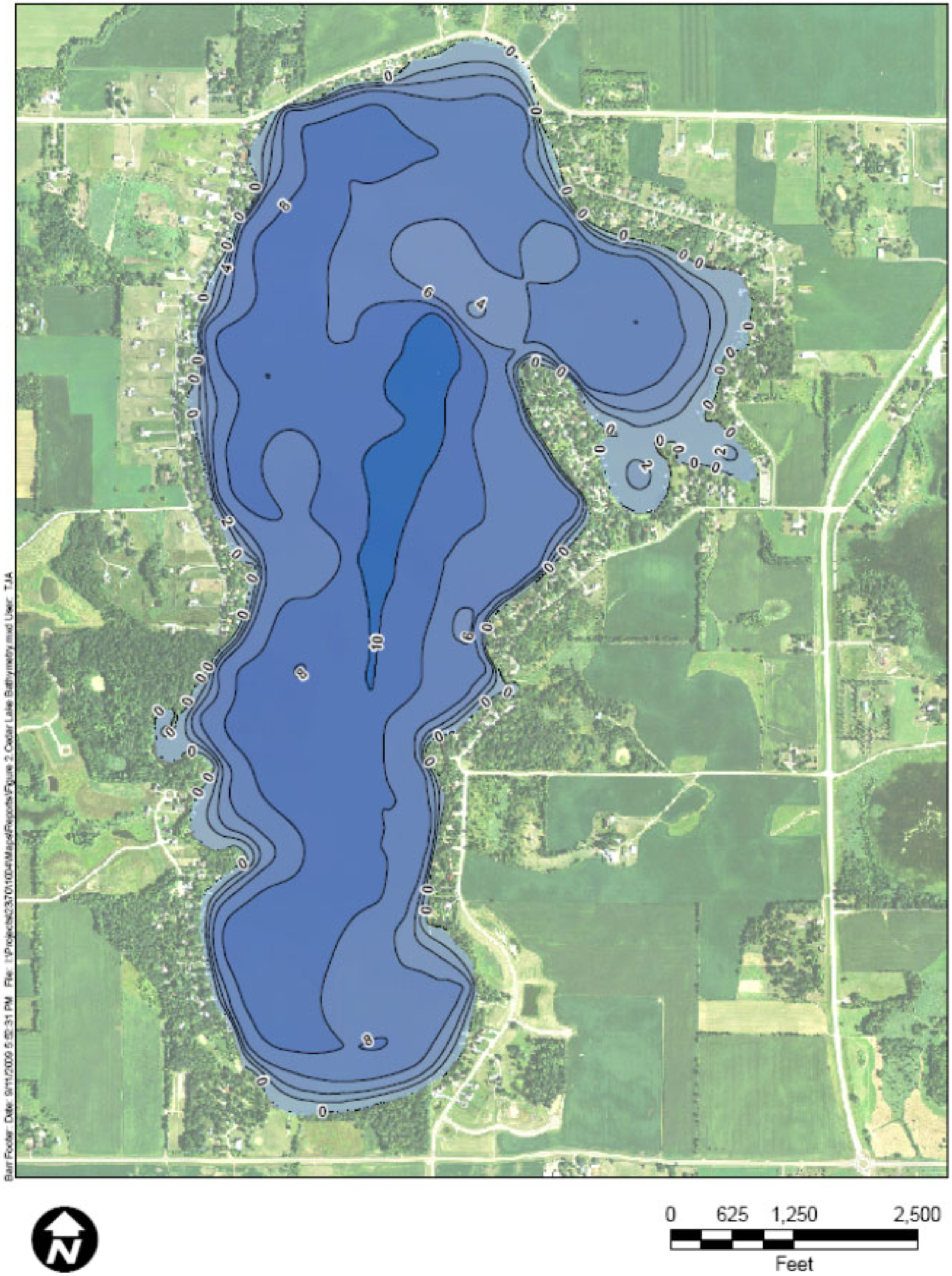
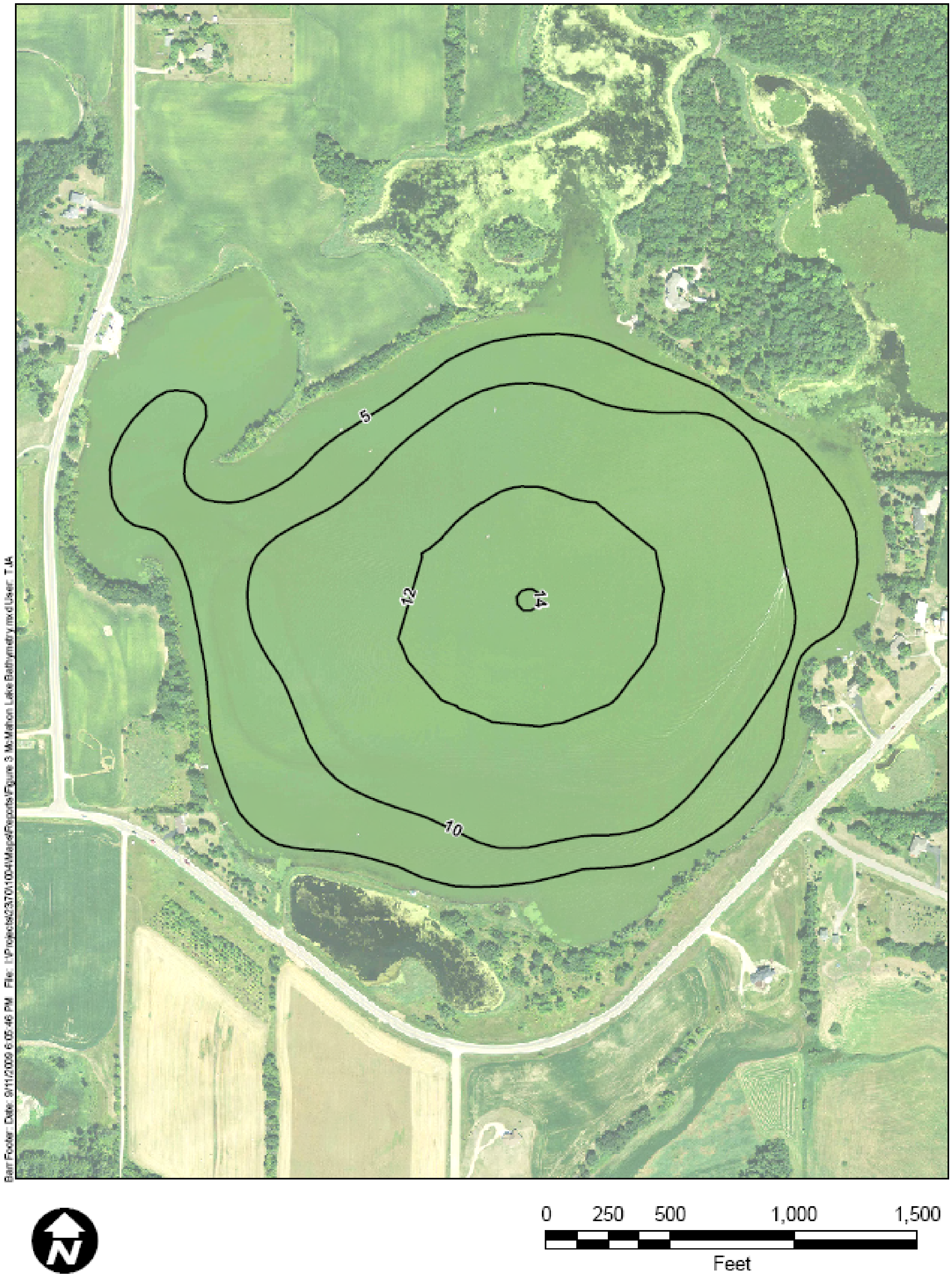


Figure 2-2 McMahon Lake Bathymetry (units in feet)



2.3 General Watershed Characteristics

Land use in each watershed is generally a mix of agriculture, woodland, low density urban areas, and open water or wetlands. The land uses in the tributary watersheds to each lake can be summarized as follows:

Land use in the Cedar Lake direct watershed and St. Patrick Wetland watershed includes:

- Open Water (including Cedar Lake) 33%
- Agricultural 21%
- Pasture/Range/Open/Non-Ag 14%
- Woodland 12%
- Rural Residential 12%
- Wetland 8%

Land use in the portion of the Sand Creek watershed which is tributary to Cedar Lake includes:

- Agricultural 52%
- Pasture/Range/Open/Non-Ag 22%
- Woodland 13%
- Rural Residential 10%
- Wetland 3%

Land use in the McMahon Lake direct tributary watershed includes:

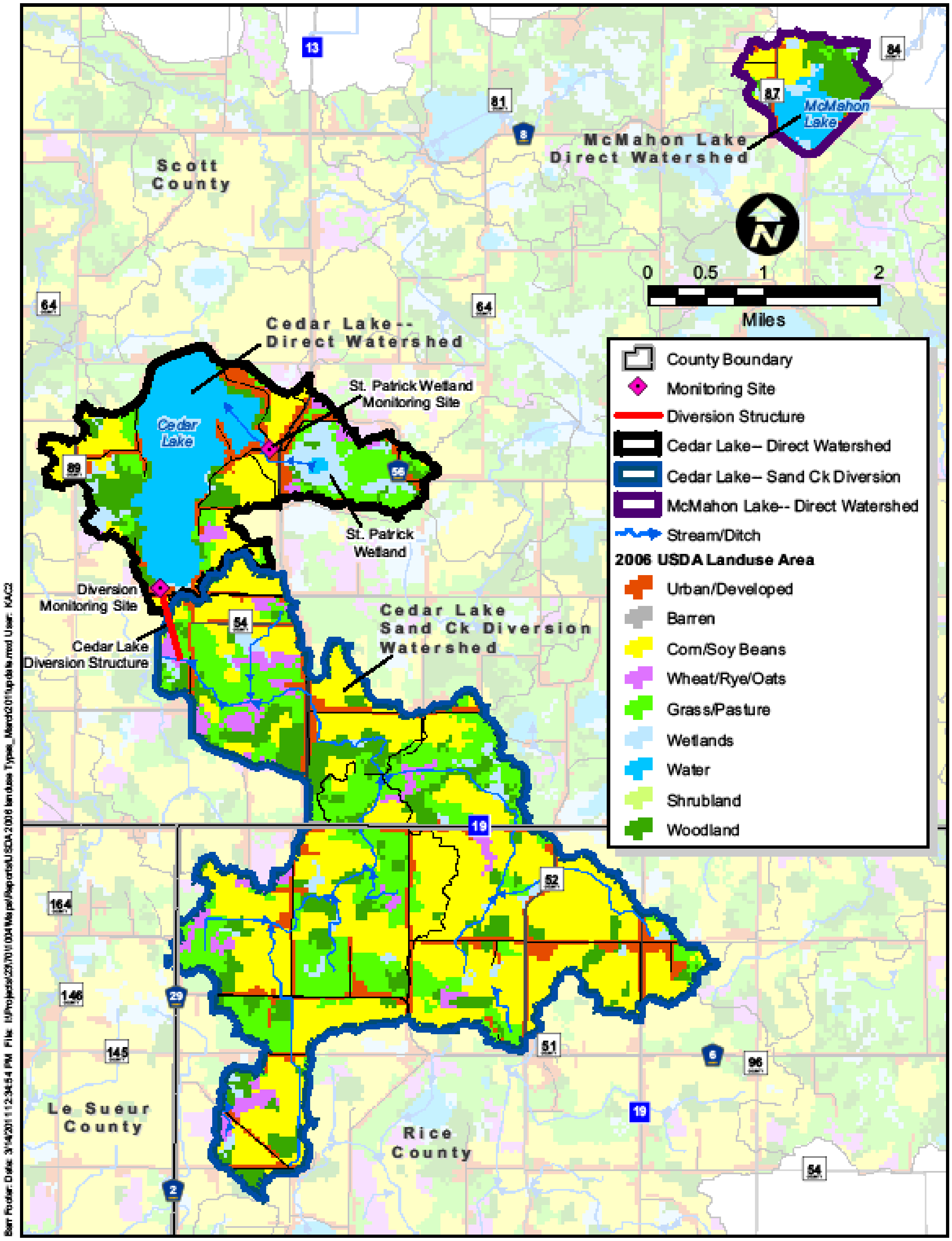
- Open Water (including McMahon Lake) 29%
- Woodland 23%
- Agricultural 21%
- Rural Residential 13%
- Wetland 9%
- Pasture/Range/Open/Non-Ag 6%

There are no significant stormwater outfalls to either lake but Cedar Lake does receive a portion of Sand Creek flow through a constructed diversion that diverts creek flow into the lake at the southern end. In general, only a small portion of the creek is diverted to the lake via a ditch (County Ditch 2). This occurs during the wetter periods of the year, specifically when the elevation in the ditch exceeds 944.2 feet.

The non-point, watershed-derived sources of phosphorus are a reflection of the land uses and primarily include fertilizer applied to agricultural land and residential properties and natural background phosphorus in soil and vegetation.

Figure 2-3 shows the land use used to model TP loads from the tributary watersheds for each lake.

Figure 2-3 Cedar and McMahon Lake Watersheds—Existing Land Use



3.0 Cedar and McMahon Lakes Excess Nutrient Impairments

3.1 Surface Water Quality Conditions for Excess Nutrients

Historical (1976 to 2008 for Cedar, 1984 to 2008 for McMahon) concentrations of TP, chlorophyll *a* (Chl a) and Secchi disc depth (SD) for the lakes are discussed below. For the purposes of this TMDL report, growing season mean (mid-May through September) concentrations of TP, Chl a and SD were used to evaluate water quality. This time period was chosen because it corresponds to the eutrophication criteria, it spans the months in which the lakes are most used by the public, and the months during which water quality is the most likely to suffer due to excessive nutrients leading to nuisance levels of algal growth (the critical condition). Additional, relevant water quality, sediment, and macrophyte data are included in Appendices A, B and C.

3.1.1 Cedar Lake

Figures 3-1 and 3-2 show the growing season means for TP, Chl a, and SD measurements for Cedar Lake. The mean surface water concentrations of TP in Cedar Lake have ranged from 118 µg/L (1990) to 439 µg/L (1979) over the past 34 years, giving the lake a hypereutrophic classification. The mean growing season TP concentration over the last 10 years (1999 to 2008) is 170 µg/L.

The growing season average Chl a concentrations have ranged from 39 µg/L (2005) to 151 µg/L (2001) over the past 9 years, giving the lake a hypereutrophic classification. Full season Chl a monitoring began in 2005 with limited data collected during 2001 (August and September only). The mean growing season Chl a concentration over the last 10 years (1999-2008) is 71 µg/L.

The growing season averages for SD have ranged from 0.6 meters (1989) to 2.6 meters (1994) over the past 34 years, giving the lake a hypereutrophic classification in some years and either a eutrophic or mesotrophic classification in others. The mean growing season SD transparency over the last 10 years (1999-2008) is 1.28 meters.

Figure 3-3 shows the average seasonal variability in water quality parameters throughout the growing season in Cedar Lake. Averages of water quality parameters were calculated for each month using available data for the 10 year period of 1999-2008. Lower TP and Chl a concentrations are typically seen in the late spring and early summer, while higher concentrations typically occur later in the summer months (generally an indication of internal phosphorus loading). Figure 3-4 shows the relationship between SD and TP measurements taken throughout the year (1985-2008) in Cedar Lake. At lower TP concentrations (less than 60 µg/L), small changes can result in significant changes in water column transparency. At higher TP concentrations, TP changes result in relatively smaller changes in water column transparency.

Figure 3-5 shows the relationship between Chl a and TP concentrations throughout the year in Cedar Lake.

Table 3-1 summarizes the historical water quality information compared to the recommended shallow lake listing criteria. Season averages of water quality in individual years, as well as sample sizes used to calculate the averages, are included in Appendix A. Because the causal water quality factor (TP) and one of the response factors (Chl a) exceed the Listing Criteria on average over the last 10 years, Cedar Lake was listed as “Non-Supporting” on the 305(b) list and as “Impaired” on the 303(d) list (2002).

Table 3-1 Cedar Lake Historical Nutrient Related Water Quality Parameters

Water Quality Parameter	MPCA Shallow Lake Eutrophication Standards (WCBP Ecoregion)	MPCA Shallow Lake Eutrophication Standards (NCHF Ecoregion)	Cedar Lake Historical (1976-2008) Growing season Average	Cedar Lake 10-Year (1999-2008) Growing season Average
Total Phosphorus (µg/L)	90	60	236	170
Chlorophyll *a* (µg/L)	30	20	71	71
Secchi disc (m)	0.7	1.0	1.36	1.28

3.1.2 McMahon Lake

Figures 3-6 and 3-7 show the growing season means for TP, Chl a, and SD measurements for McMahon Lake. The mean surface water concentrations of TP in McMahon Lake have ranged from 46 µg/L (2007) to 112 µg/L (2001) over the past 26 years, giving the lake a eutrophic to hypereutrophic classification. The mean growing season TP concentration over the last 10 years (1999 to 2008) is 85 µg/L.

Figure 3-1 Cedar Lake Growing Season (mid-May through September) Mean Total Phosphorus and Chlorophyll *a* Concentrations 1976-2008

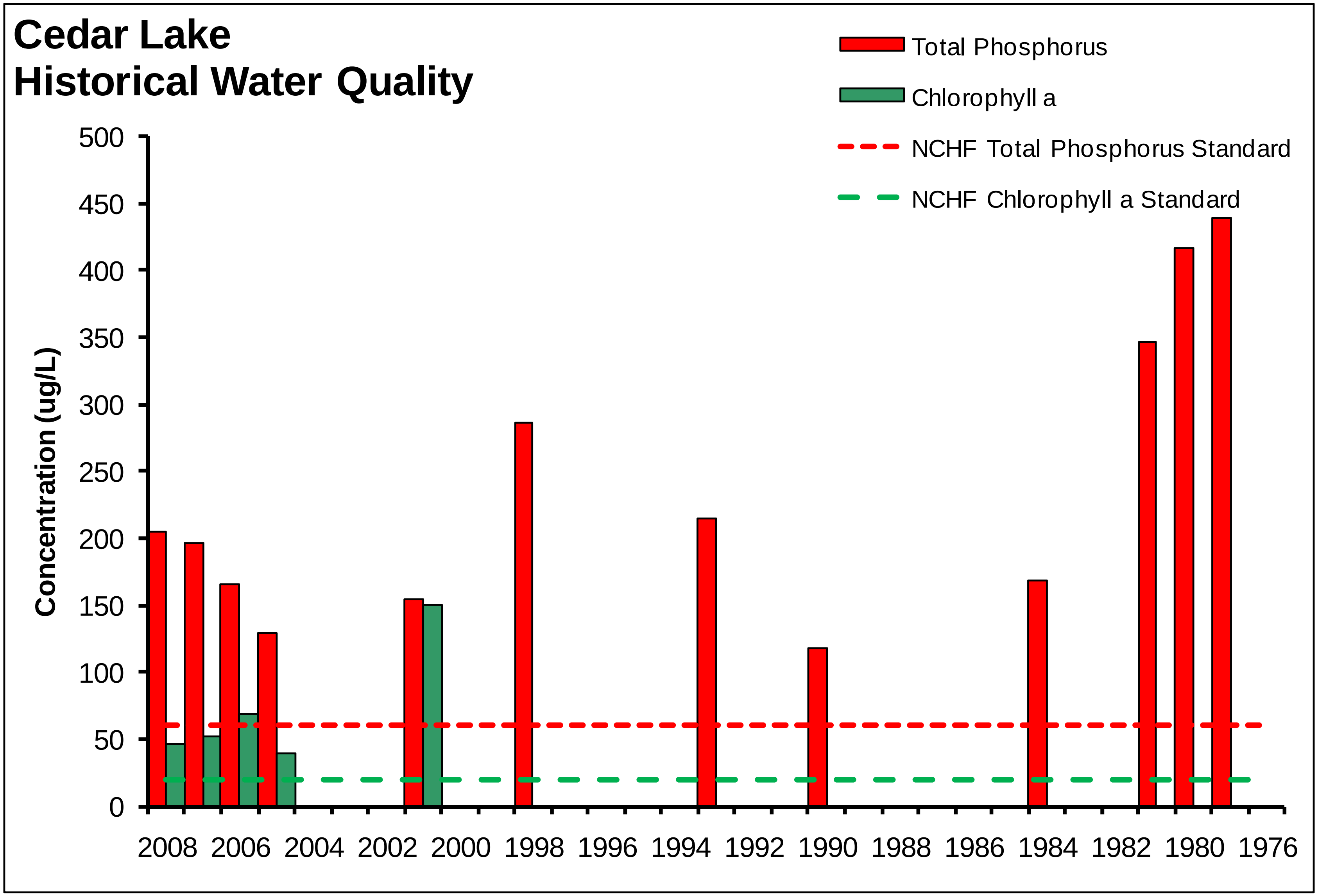


Figure 3-2 Cedar Lake Growing Season (mid-May through September) Mean Secchi Disc Depths 1976-2008

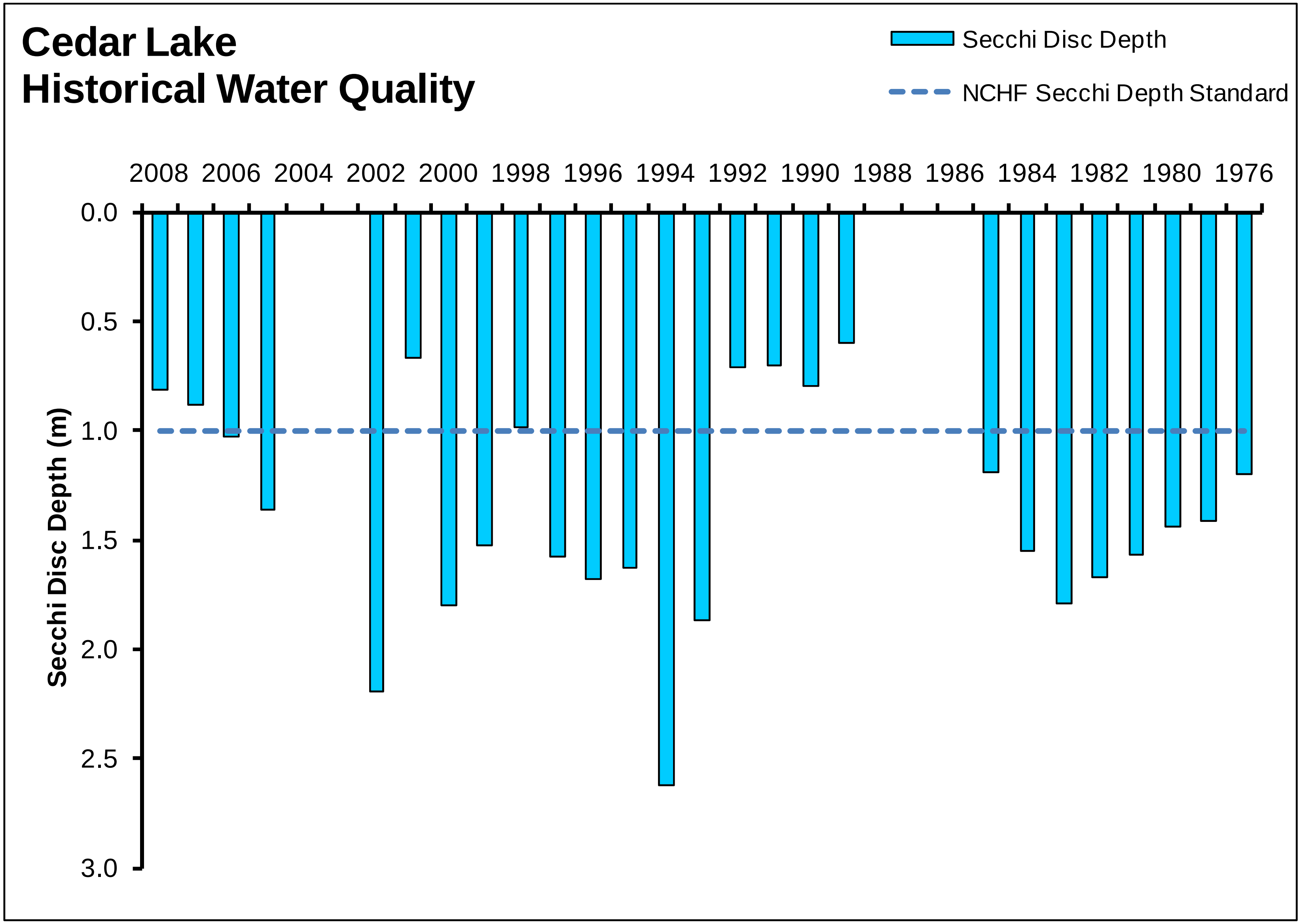
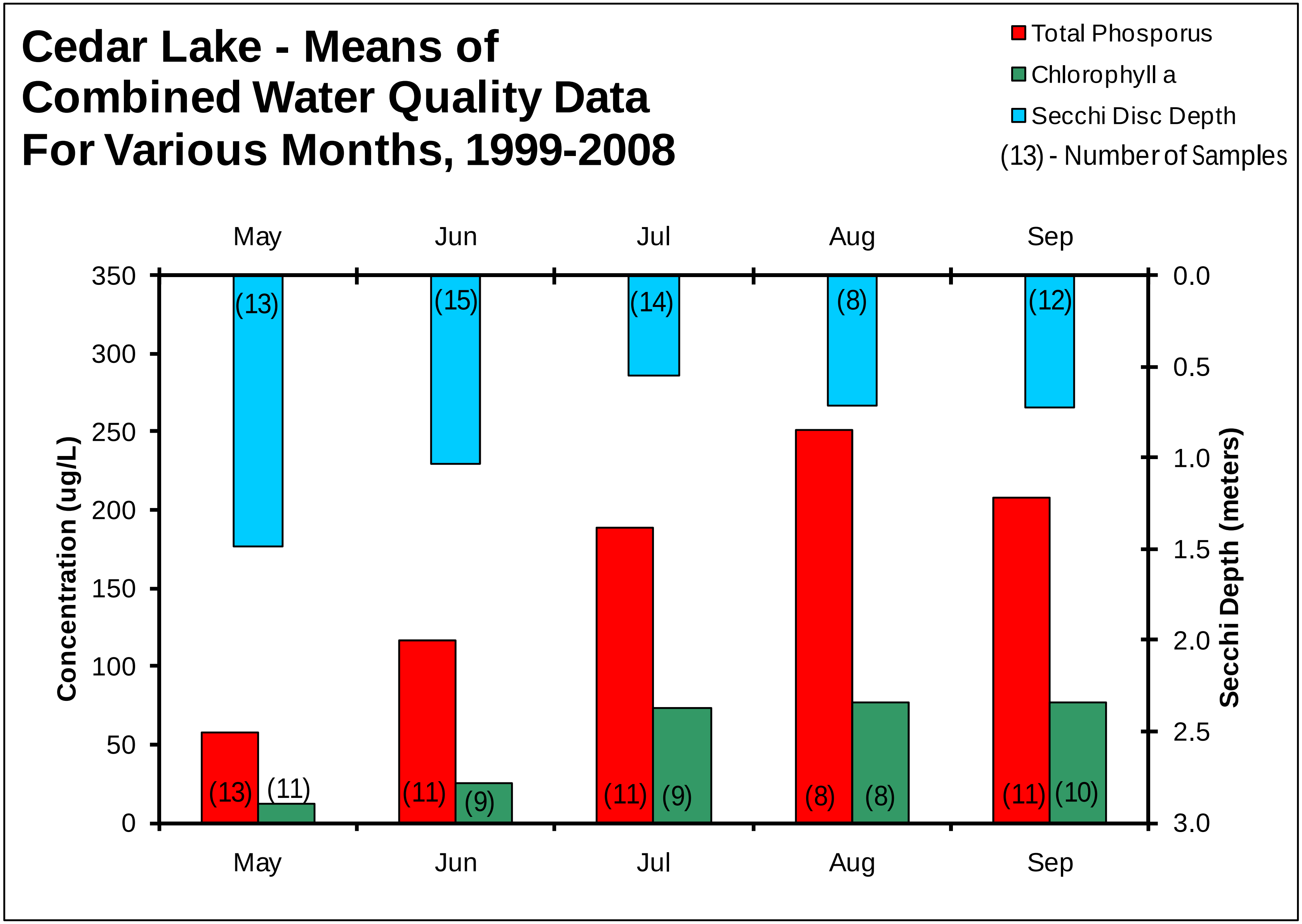


Figure 3-3 Cedar Lake Seasonal Water Quality (1999-2008).



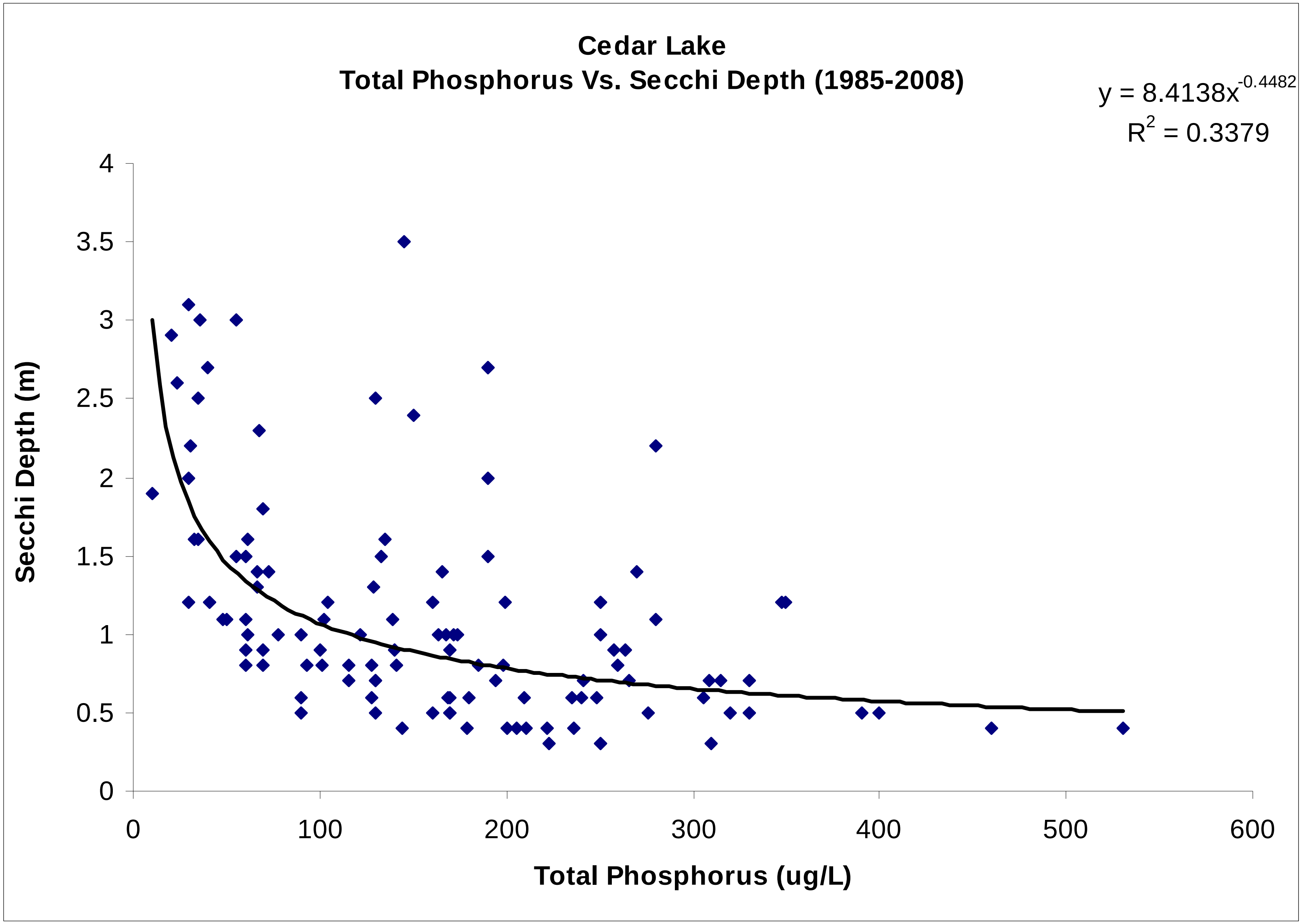


Figure 3-4 Cedar Lake Secchi Disc Transparency—Total Phosphorus Relationship 1985-2008

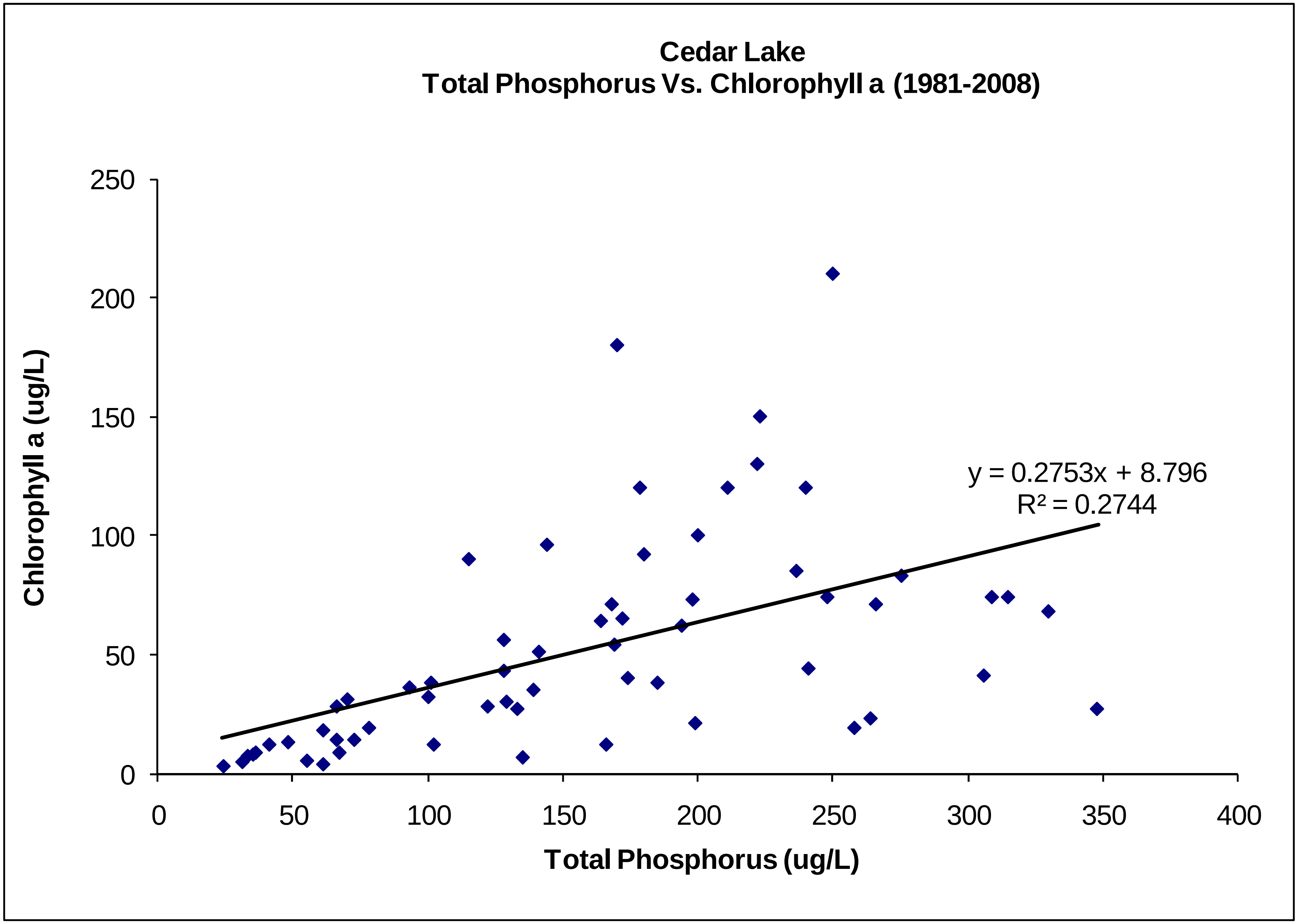


Figure 3-5 Lake Growing Season Chlorophyll *a*—Growing Season Total Phosphorus Relationship 1981-2008

The growing season average Chl a concentrations have ranged from 41 µg/L (2007) to 92 µg/L (2001) over the past 9 years, giving the lake a hypereutrophic classification. Full season Chl a monitoring began in 2005 with limited data collected during 2001 (August and September only). The mean growing season Chl a concentration over the last 10 years (1999-2008) is 70 µg/L.

The growing season averages for SD have ranged from 0.82 meters (2001) to 1.7 meters (1995) over the past 26 years, giving the lake a hypereutrophic classification in some years and a eutrophic classification in others. The mean growing season SD transparency over the last 10 years (1999-2008) is 0.88 meters.

Figure 3-8 shows the seasonal variability in water quality parameters throughout the year in McMahon Lake. Averages of water quality parameters were calculated for each month using available data for the 10 year period of 1999-2008. Lower TP and Chl a concentrations are seen in the late spring and early summer (similar to Cedar Lake), while higher TP and Chl a concentrations typically occur later in the summer months (generally an indication of internal phosphorus loading).

Figure 3-9 shows the relationship between SD and TP measurements taken in all years (1995-2008) in McMahon Lake. At lower TP concentrations (less than 60 µg/L), small changes can result in significant changes in water column transparency. At higher TP concentrations, TP changes result in relatively smaller changes in water column transparency.

Figure 3-10 shows the relationship between Chl a and TP measurements in McMahon Lake. Chl a and TP show an increasing correlation using the available data for the lake.

Table 3-2 summarizes this historical water quality information compared to the recommended shallow lake listing criteria for McMahon Lake. Season averages of water quality in individual years, as well as sample sizes used to calculate the averages, are included in Appendix A. The 10-year average for TP (the causal factor) in McMahon Lake is below the Listing Criterion for the WCBP ecoregion. Because TP and at least one of the response factors exceed the Listing Criteria, on average, over the last 10 years for the North Central Hardwood Forests ecoregion, McMahon Lake is listed as “Non-Supporting” on the 2004 305(b) list and as “Impaired” on the 303(d) list (McMahon Lake was first added to the impaired waters list in 2002).

Table 3-2 McMahon Lake Historical Nutrient Related Water Quality Parameters

Water Quality Parameter	MPCA Shallow Lake Eutrophication Standards (WCBP Ecoregion)	MPCA Shallow Lake Eutrophication Standards (NCHF Ecoregion)	McMahon Lake Historical (1984-2008) Growing season Average	McMahon Lake 10-Year (1999-2008) Growing season Average
Total Phosphorus (µg/L)	90	60	89	85
chlorophyll *a* (µg/L)	30	20	70	70
Secchi disc depth (m)	0.7	1.0	1.04	0.88

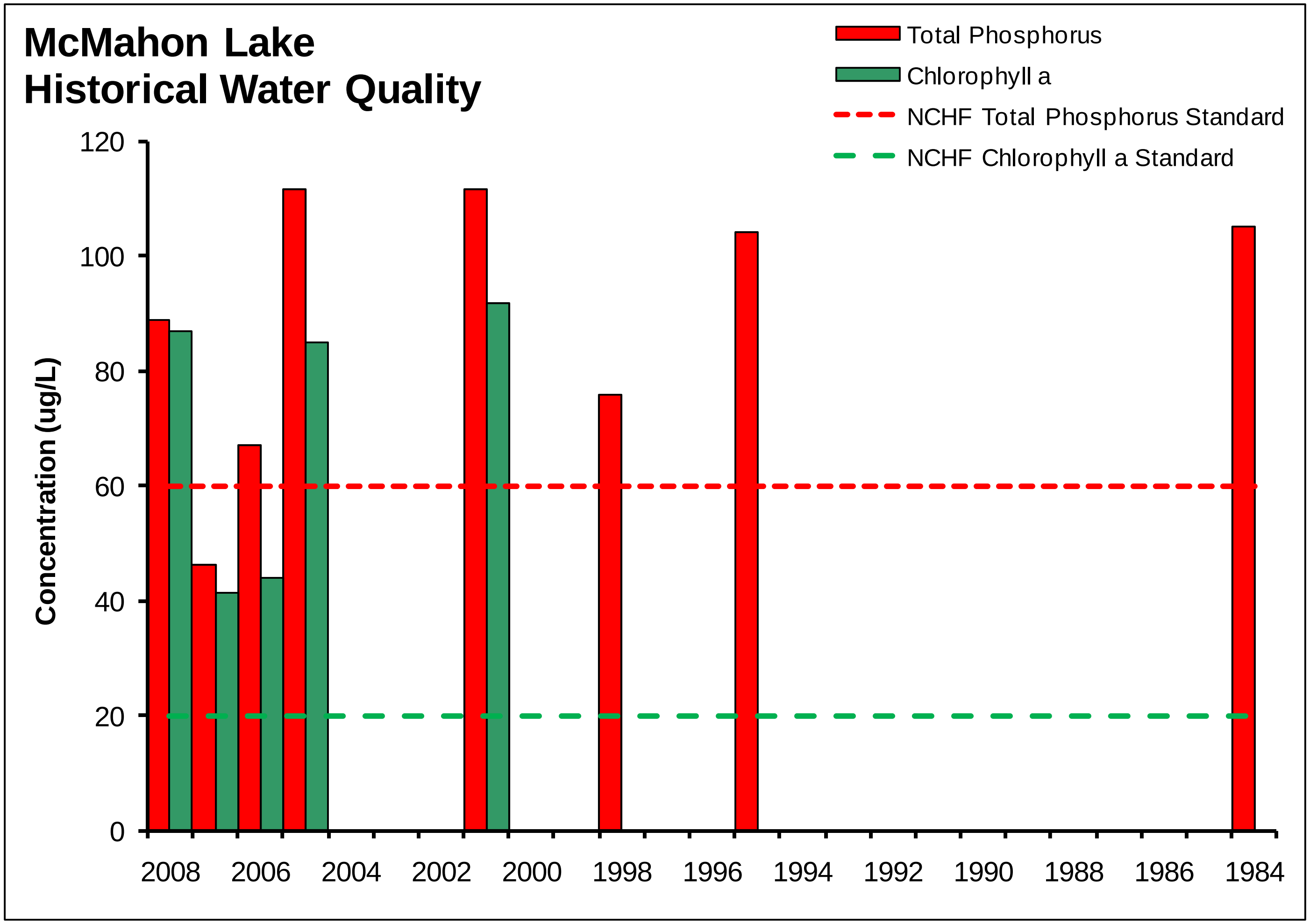


Figure 3-6 McMahon Lake Growing Season (mid-May through September) Mean Total Phosphorus and Chlorophyll *a* Concentrations 1984-2008

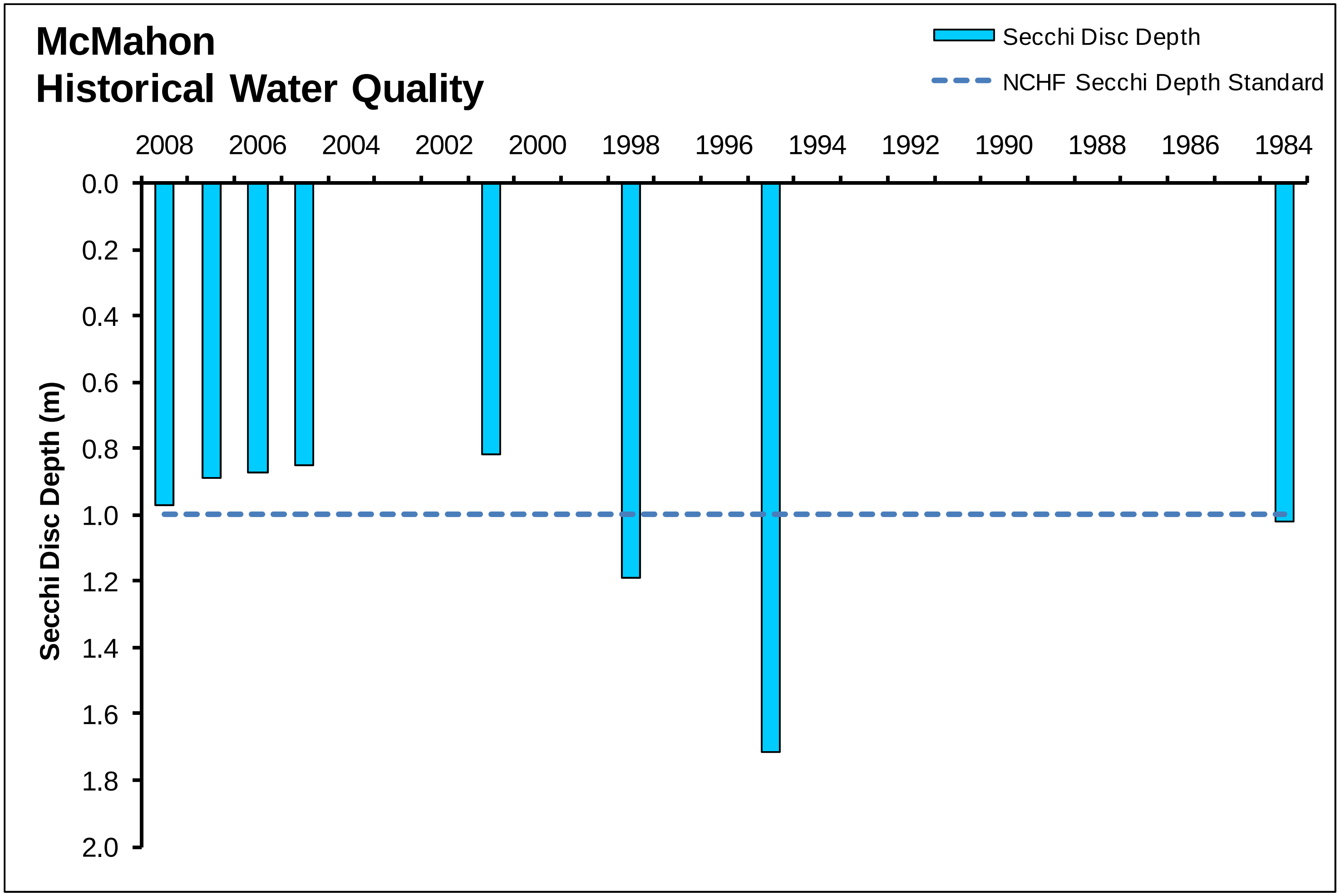


Figure 3-7 McMahon Lake Growing Season (mid-May through September) Mean Secchi Disc Depths 1984-2008

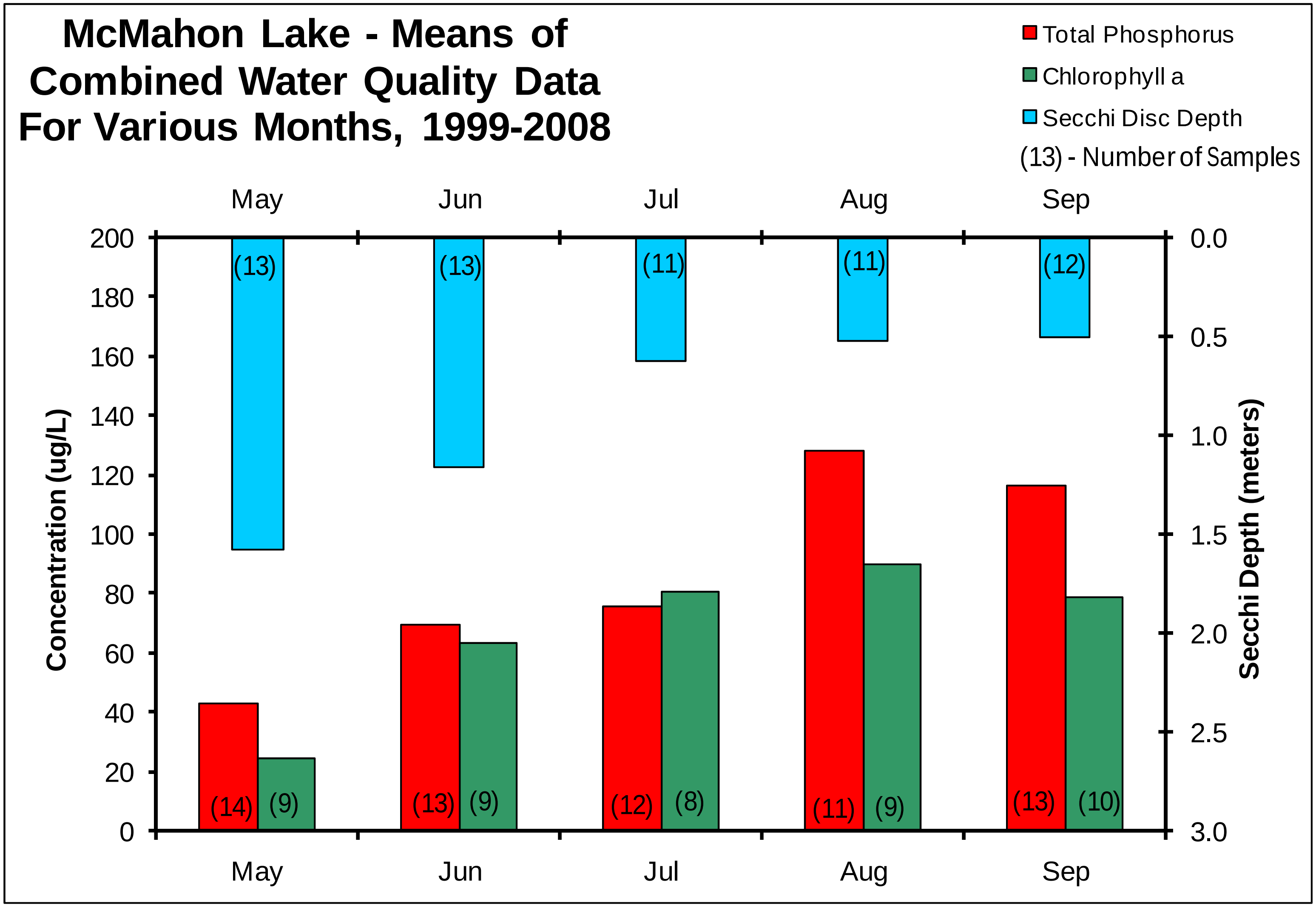


Figure 3-8 McMahon Lake Seasonal Water Quality (1999-2008).

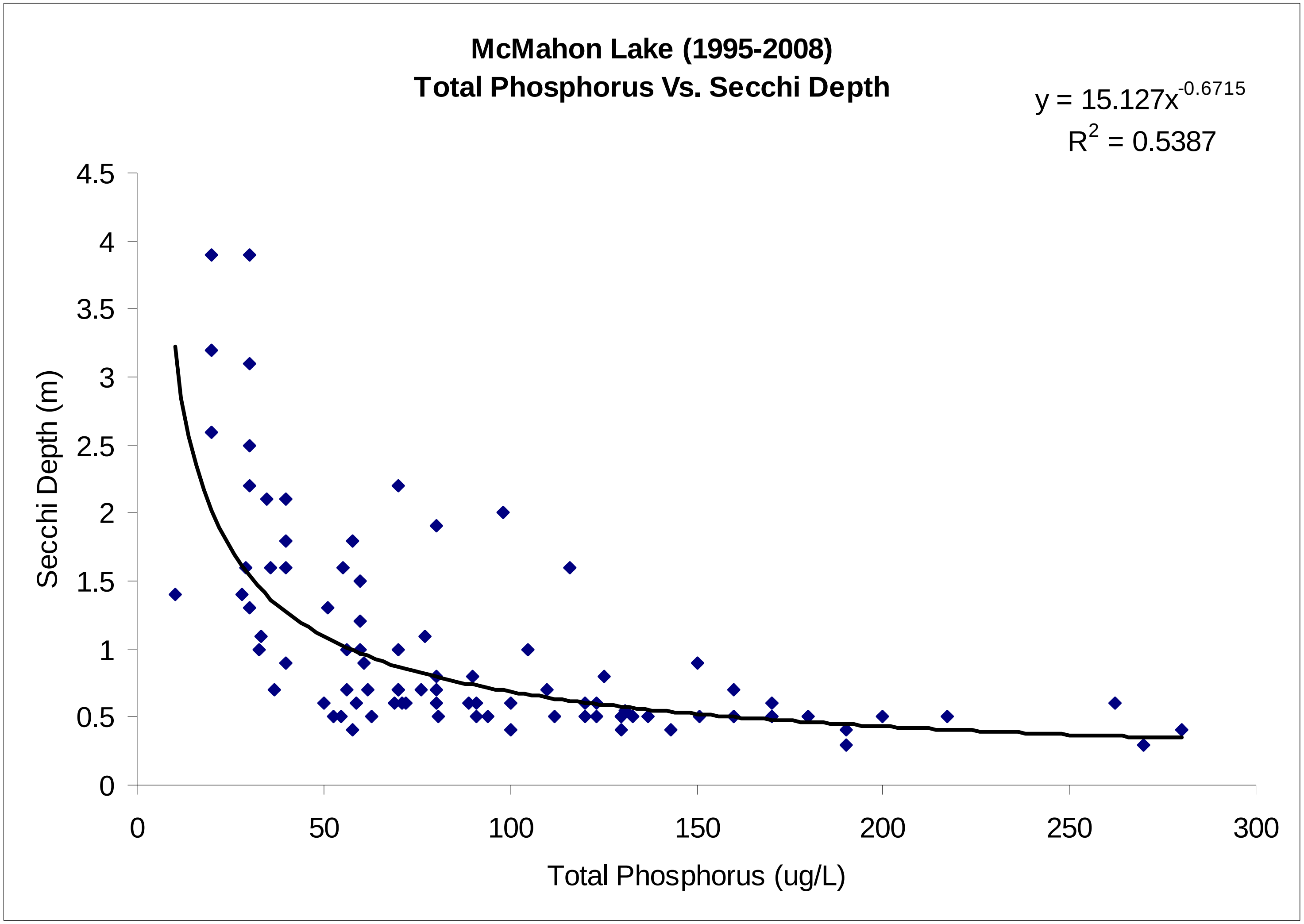


Figure 3-9 McMahon Lake Secchi Disc Transparency—Total Phosphorus Relationship 1995-2008

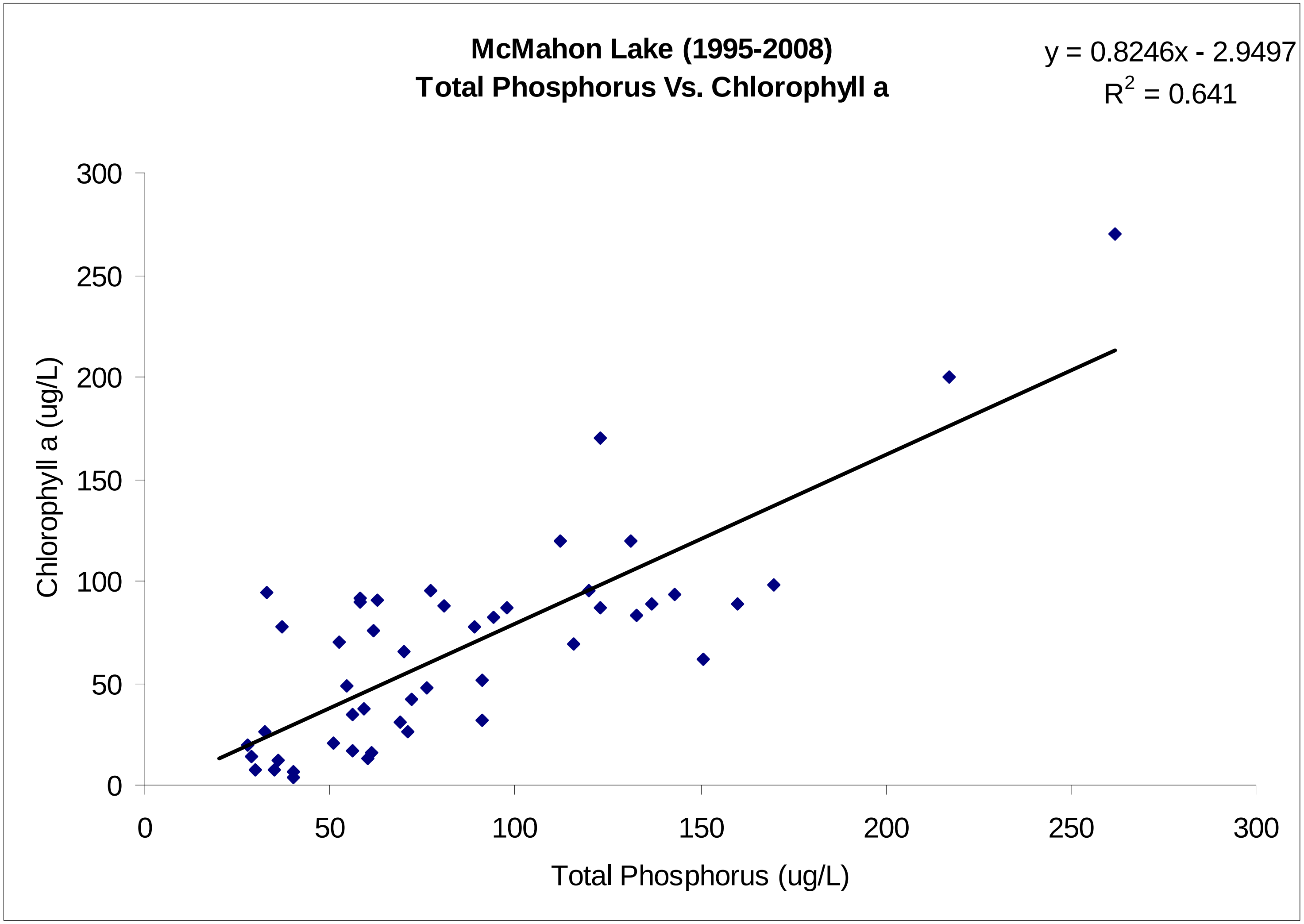


Figure 3-10 McMahon Lake Growing Season Chlorophyll a—Growing Season Total Phosphorus Relationship 1995-2008

3.2 TMDL Modeling Methodology

3.2.1 Water Quality Modeling

Water quality modeling provided the means to estimate TP sources to Cedar and McMahon Lakes and the resultant water quality in each lake. Water quality modeling included:

- Watershed yield and land use based runoff coefficients (Barr, 2004) were used to estimate the water and TP loads from the direct tributary watershed for each lake.
- A stormwater runoff model (P8 Urban Catchment Model; IEP, Inc., 1990) was then used to simulate the estimated water and TP loads on a daily basis from the direct watersheds.
- Incorporation of monitoring data (flow and nutrients) for the St. Patrick Wetland.
- Use of flow data at the diversion weir and TP data (grab samples) from a tributary to Sand Creek, just below the tributary inflow point to the diversion weir. This was not done for 2007 because the diversion weir was plugged during the year.
- An in-lake mass balance model that incorporated the water and TP loads from all potential sources and generated the resultant in-lake TP concentration.

The P8 Urban Catchment Model, export coefficients, and the in-lake mass balance model are described in more detail below.

3.2.2 P8 Urban Catchment Model and Land Use Based Export Coefficients

While portions of the Cedar Lake watershed had flow and phosphorus concentrations monitored, a portion of the watershed was not monitored, and the watershed of McMahon Lake was not monitored. Water and phosphorus loads from these unmonitored portions of the watershed were estimated using a combination of data obtained from the Detailed Assessment of Phosphorus Sources to Minnesota Watersheds (Barr 2004) and the P8 Urban Catchment Model. P8 is a useful diagnostic tool for evaluating and designing watershed improvements and BMPs because it can estimate the treatment effect of several different kinds of potential BMPs. P8 tracks stormwater runoff as it carries phosphorus across watersheds and incorporates the treatment effect of detention ponds, infiltration basins, flow splitters, etc. on the TP loads that ultimately reach downstream water bodies. P8 accounts for phosphorus attached to a range of particulate sizes, each with their own settling velocity, tracking their removal accordingly.

P8 also uses long-term climatic data so that watershed runoff and BMPs can be evaluated for varying hydrologic conditions. In this study, P8 was used to generate runoff patterns resulting from storm events for the unmonitored portions of each lake's watershed for the water years 2007 and 2008. These years were used because detailed monitoring was conducted during this time, providing more detailed information on the lack of flow from the diversion (2007), and flow from the diversion (2008).

The total annual runoff volumes for the unmonitored portions of the watersheds were calibrated to expected watershed yield based on the total annual precipitation and runoff characteristics of the region described in the Detailed Assessment of Phosphorus Sources to Minnesota Watersheds (Barr 2004). While this provided an estimate of the annual runoff per area given an annual precipitation total, it did not provide estimates of daily runoff volume that is needed for the modified Vollenweider model used for this TMDL. Therefore, P8 was used to generate runoff patterns on a daily timestep. The daily runoff values were optimized so that the total annual runoff matched the total annual runoff described in the Detailed Assessment of Phosphorus Sources to Minnesota Watersheds (Barr 2004).

Key input parameters used in the P8 model for each watershed were:

- Drainage area information: size, impervious area (both directly and indirectly connected).
- Hourly precipitation, obtained from the Minneapolis-St. Paul airport, adjusted using the daily total rainfall depths observed a local gauge (Jordan NWS station).

Phosphorus export coefficients described in the Detailed Assessment of Phosphorus Sources to Minnesota Watersheds (Barr 2004) were then used to develop the phosphorus loads for each watershed. Export coefficients and phosphorus runoff relationships used to develop phosphorus loads from each watershed are listed below in Table 3-3.

Table 3-3 Phosphorus Export Coefficients for Watershed Land Use Types for Cedar and McMahon Lakes

Land Use	Export Coefficient
Agricultural (kg/ha/yr)	0.54
Grassland/Open (kg/ha/yr)	0.151
Wooded (kg/ha/yr)	0.13

The export coefficients in Table 3-3 are derived for average year precipitation in the Minnesota River Basin. Precipitation during the water year was slightly lower than average (28 inches) for the area during both 2007 (26 inches) and 2008 (25 inches). The following regression relationship (Barr 2004) was used to determine phosphorus loading in rural residential areas:

TP concentration in runoff (μg/L) = -14.4(% impervious) - 5.7*(Precipitation) + 1075*

The TP concentration for runoff from developed areas was calculated using the relationship above and then multiplied by the total annual precipitation, the area of developed land, and the calculated runoff coefficient to determine the phosphorus load from these areas (shown below).

*Basin Load = TP concentration*Contributory Area*Runoff Coefficient*Total Annual Rainfall Depth*

Where:

- Concentration is based upon the regression equation for runoff from developed areas
- Contributory area includes the total area for the land class
- Runoff coefficient = 0.05 + 0.009*% Impervious
- Annual rainfall depth is the annual precipitation during the water year

Water quality grab sample and flow monitoring data were used to estimate water volume and phosphorus loading to Cedar Lake from both the St. Patrick Wetland and the Sand Creek tributary bringing flow through the diversion structure (Figure 1-1). Flow and phosphorus between the measured points (collected every one to two weeks) were interpolated.

3.2.3 In-Lake Mass Balance Modeling

In-lake modeling for each lake was accomplished through the creation of a daily time-step mass balance model that tracked the flow of water and phosphorus through the lake over a range of climatic conditions. The model was constructed for the water year as well as the growing season (critical condition) in each lake. Essentially, the following modified version of Vollenweider's (1969) mass balance equation was used:

$$TP = (L + L_{int}) / (\bar{z} * (\rho + \sigma))$$

Where:

$\bar{z}$	=	average lake depth in meters
ρ	=	flushing rate in yr^{-1}
σ	=	sedimentation rate in yr^{-1}
L	=	areal loading rate in $mg/(m^2*yr)$
$Lint$	=	internal loading rate in $mg/(m^2*yr)$

A difference between Vollenweider's equation and the model used for this TMDL is that the parameters in the above equation were used on a daily timestep basis as opposed to an annual basis. Also, the magnitude of the net internal phosphorus load to the lake surface was deduced by comparing the observed water quality in the lake to the water quality predicted by the in-lake model under existing conditions.

A daily time step model was chosen for these TMDLs because of the high variability (over two orders of magnitude) in the nutrient related water quality parameters causing exceedance of the standards during the growing season. Using a daily time step model (instead of an annual model, e.g. Bathtub), allowed for the determination of the critical components causing water quality standard exceedance, especially during the late summer period. Using a daily time step model also allows for lake response modeling of management methods during the periods of standard exceedance. Modeling in this manner will help ensure that beneficial use can be obtained throughout the growing season.

Key input parameters to the in-lake model included the external load of total phosphorus (from the direct watershed only) obtained from land use export coefficients. Also, daily values for average lake depth, lake volume, and the flushing rate were calculated using a daily water balance in an Excel spreadsheet that incorporated P8 distributions for watershed inflows, observed daily precipitation data, observed lake level measurements, and daily evaporation rates that were estimated using the Meyer Model (Barr Engineering Company, undated) for each year. The Meyer Model uses an empirical equation for estimating evaporation from a water body (Meyer 1944):

$E = C (e_0 – e_a) (1+ W/10)$, where
C = 0.36 for a lake
E = daily evaporation in inches
e_0 = the saturation vapor pressure at the water surface temperature in millibars
e_a = the vapor pressure of the air in millibars
W = the wind velocity in mph measured about 25 feet above water surface

Key calibration parameters for the in-lake model included selection of the sedimentation rate and estimation of the net internal load that affects the phosphorus concentration in the water column during the growing season. The internal load production from sediment, carp and curlyleaf pondweed senescence was determined using empirical relationships based on the mass or density of each component, as described in detail under the Calibration subsection.

Lake mixing and anoxic conditions can create an environment in the lake that is conducive to internal loads at times. At other times, the lake does not experience a significant internal load (generally spring and fall). Monitoring data (phosphorus, temperature, and dissolved oxygen profiles) provided useful information in determining when the lake is susceptible to internal loading from the sediment. Selected monitoring data, outside of information provided in the text, are shown in Appendix B.

The sedimentation rates for the lakes were calibrated using in-lake TP monitoring data from well mixed periods without the conditions necessary for internal phosphorus loading. At these times (generally in spring after turnover), phosphorus concentration in the surface waters of the lake is only affected by sedimentation, flushing, and incoming external loads of phosphorus from the watershed and atmosphere. This was accomplished by setting the internal loading rate (L_{int}) in the above equation by Vollenweider to zero and adjusting the settling rate so that the calculated, in-lake phosphorus concentration matched the monitored phosphorus during the spring period.

Calibrating the Internal Load of Phosphorus

The magnitude of the internal sediment loads in each lake were verified by calculating the potential release rate of TP from the lake sediment (using sediment data) and comparing that to the internal load determined from the modified Vollenwieder model. In 2007, sediment cores from Cedar and McMahon Lakes were collected and analyzed for mobile phosphorus and labile organic phosphorus (mobile P content). Knowing the mobile P content and depth distribution, a regression equation relating mobile P and the maximum possible sediment TP release rate was used to estimate sediment release rate of TP during anoxic conditions at the sediment surface (Pilgrim et al. 2007). This maximum possible release rate was compared to the internal loading rate calculated by deduction in each respective lake with the modified Vollenwieder model to confirm that the deduced load was reasonable. The release rates used in the modified Vollenwieder modeling for each lake compare well with the potential loading rates calculated with the sediment data (Appendix C).

The potential TP load from senescing curlyleaf pondweed (Table 3-4) was calculated using data from aquatic plant surveys conducted during 2007 (Blue Water Science 2008, Appendix D) and studies documenting expected phosphorus contribution from plant breakdown to the water column (James et al. 2007; James et al 2002). Internal phosphorus loading due to carp excretion and sediment mixing was estimated using the empirical relationship between carp density and total phosphorus defined by Lamarra (1975). Carp density in Cedar Lake (approximately 400 lbs/acre) was based on Minnesota Department of Natural Resources (DNR) fishery survey data and a relationship developed between DNR fishery survey data and measured in-lake carp density from Lake Susan (Przemek Bajer, personal communication, U of MN).

Loading rates used in the models over the growing season (mid-May through September) for each internal loading component are show in Table 3-4 below and compared to the results estimated from sediment analysis and macrophyte surveys, as described above.

Table 3-4 Internal Loading Component Rates for Cedar and McMahon Lakes

Internal Load Component	Cedar Lake Loading Rate (mg/m2/d)		McMahon Lake Loading Rate (mg/m2/d)	
	Modeled Value	Estimated Range	Modeled	Estimated Rage
Sediment*	3.2	0.52-3.7	2.1	1.8-5.6
Carp*	2.4	NA	NA	
Curlyleaf pondweed*	0.3	0.4-0.9	0.1	0.03-0.3

*Based on total load divided by number of growing season days (138) across entire lake area

3.3 Modeling Results

Water quality in both Cedar and McMahon Lakes is generally dominated by internal loading processes. Although both lakes are shallow and mix frequently, internal loading from the sediment contributes a substantial phosphorus load to each lake. Curlyleaf pondweed is also present in both lakes and Cedar Lake has a significant population of common carp, both of which contribute to the internal loading of phosphorus. Data from years 2006 through 2008 were used to calibrate models and determine phosphorus loads to each lake. Water year was used for each analysis running from October 1 through September 30 but only the growing season is used for the TMDL calculated for each lake.

3.3.1 Cedar Lake In-Lake Model

Both years 2007 and 2008 were similar for Cedar Lake in that internal phosphorus loading sources were the dominant fractions (Table 3-5). This can also be inferred qualitatively by the historical seasonal data shown for Cedar Lake (Figure 3-3) where TP and Chl a increase throughout the summer while SD decreases. Table 3-5 presents the existing water, external and internal TP budgets over the water year in Cedar Lake that were calculated using monitoring data, P8 and runoff coefficients, and in-lake models. (Note: the diversion weir was plugged by a beaver dam in 2007 allowing for no flow that year. This dam was removed late in 2007, allowing flow in 2008 when water levels were high enough in the ditch.)

Table 3-5 Water, Total Phosphorus and Net Internal Load Budgets in Cedar Lake during 2007 and 2008 Water Years

Calibration Year	Water Load Over the Water Year (AF)	External Total Phosphorus Load Over the Water Year (lbs)	Internal Total Phosphorus Load Over the Water Year (lbs)
2007	2297	959	6320
2008	2801	1368	5784

Figure 3-11 and 3-12 show the daily time step calibration models for Cedar Lake during 2007 and 2008 during the growing season. Both years show a similar pattern of lower phosphorus concentrations in the spring followed by a steady increase in phosphorus concentrations throughout the summer months. The blockage of the diversion weir appears to have had a minor impact when comparing phosphorus loads and surface water phosphorus concentrations between years.

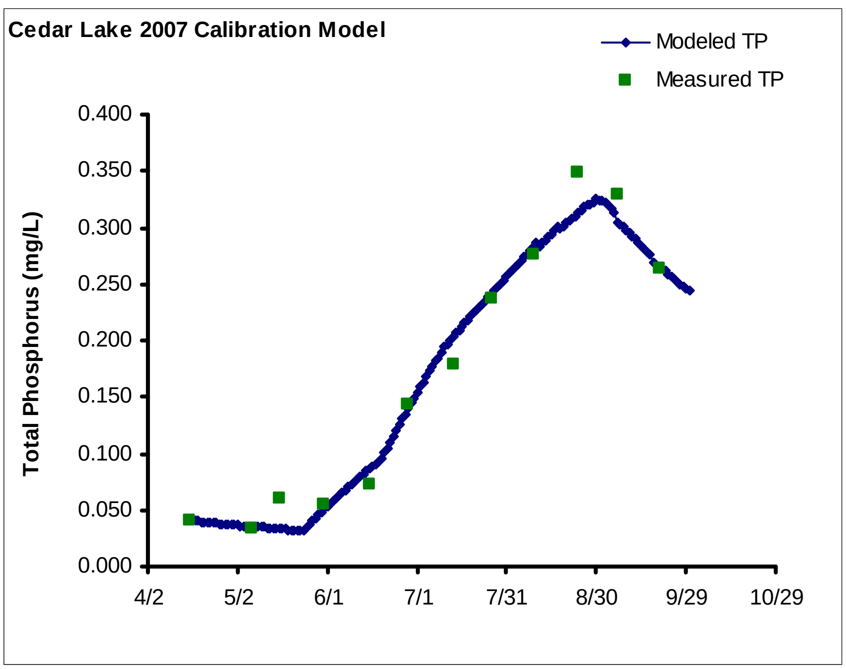


Figure 3-11 Total Phosphorus Calibration Model for the Growing Season in Cedar Lake 2007

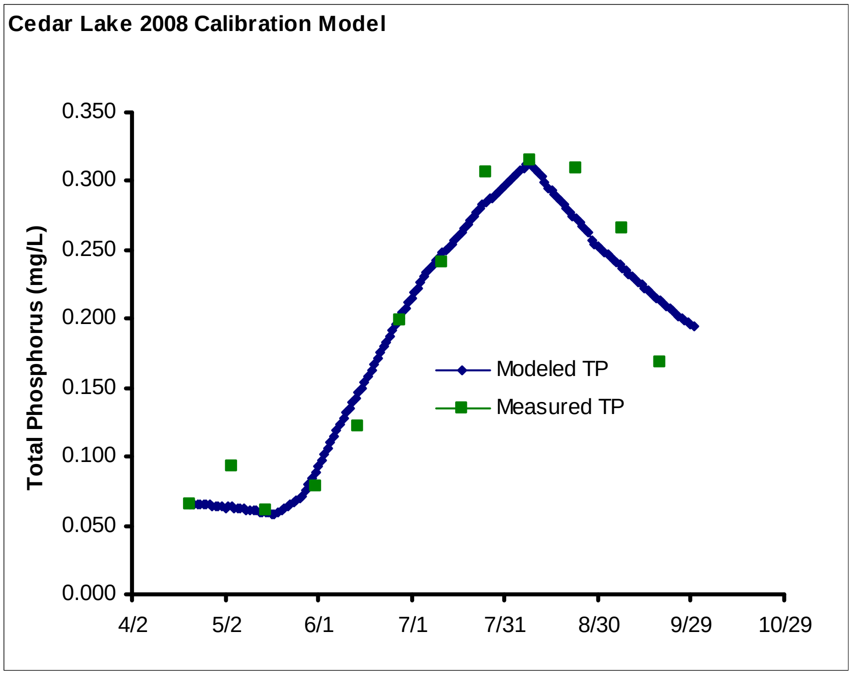


Figure 3-12 Total Phosphorus Calibration Model for the Growing Season in Cedar Lake 2008

Model fit for both lakes was good. Growing season averages for each lake model were less than 1% different from growing season averages for the monitoring data. The modeled average versus the monitoring average for Cedar Lake was 0.209 mg/L versus 0.207 mg/L and 0.87 mg/L versus 0.87 mg/L, respectively. Relative fit between each monitoring point and the modeled value, represented by determining the r^2 value for monitored versus modeled data points, was 0.79 for McMahon Lake and 0.95 for Cedar Lake.

3.3.2 Cedar Lake Phosphorus Sources and Contributions

During 2007, the diversion weir that diverts flow from a tributary ditch to Sand Creek to Cedar Lake was blocked and the lake received drainage only from the directly connected watershed areas. The weir was unplugged in the fall of 2007 and flow from Sand Creek was again allowed to enter Cedar Lake when creek elevations were above the diversion weir elevation.

Figure 3-13 shows the relative contributions of phosphorus to Cedar Lake, during 2007, from different sources based on the modeling detailed in Section 3.3.1. During the 2007 growing season, internal sources of phosphorus contributed 96% of the total phosphorus load to Cedar

Lake. Both sediment release and bioturbation and excretion from carp were the dominant internal sources, contributing approximately 3,285 pounds and 2,754 pounds of phosphorus, respectively. External loading from the direct watershed and the St. Patrick Wetland (east side of Cedar Lake), contributed 2.7% of the total phosphorus load to the lake. Precipitation contributed 1.4% of the phosphorus load to the lake via direct deposition on the lake surface.

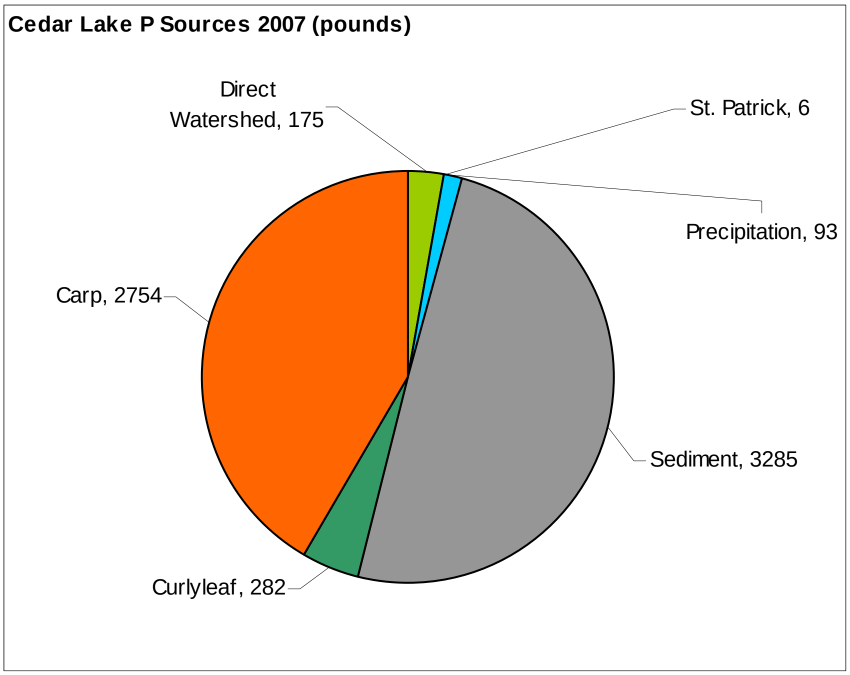


Figure 3-13 Phosphorus Sources to Cedar Lake during the 2007 Growing Season

Figure 3-14 shows the relative contribution of phosphorus to Cedar Lake during the 2008 growing season. Although slightly lower percentagewise during 2008, internal loading of phosphorus was still the dominant contributor of phosphorus to the lake (93%). Sediment phosphorus release and bioturbation and excretion from carp were the two highest internal loading sources contributing 3,137 and 2,351 pounds, respectively, during the year. External loading, including input from the direct watershed, St. Patrick wetland, and the diversion weir, accounted for 5.1 percent of the total phosphorus load to the lake. Precipitation contributed approximately 1.6% of the phosphorus load to the lake via direct deposition on the lake surface. Table 3-16 lists the phosphorus loads to Cedar Lake for both 2007 and 2008.

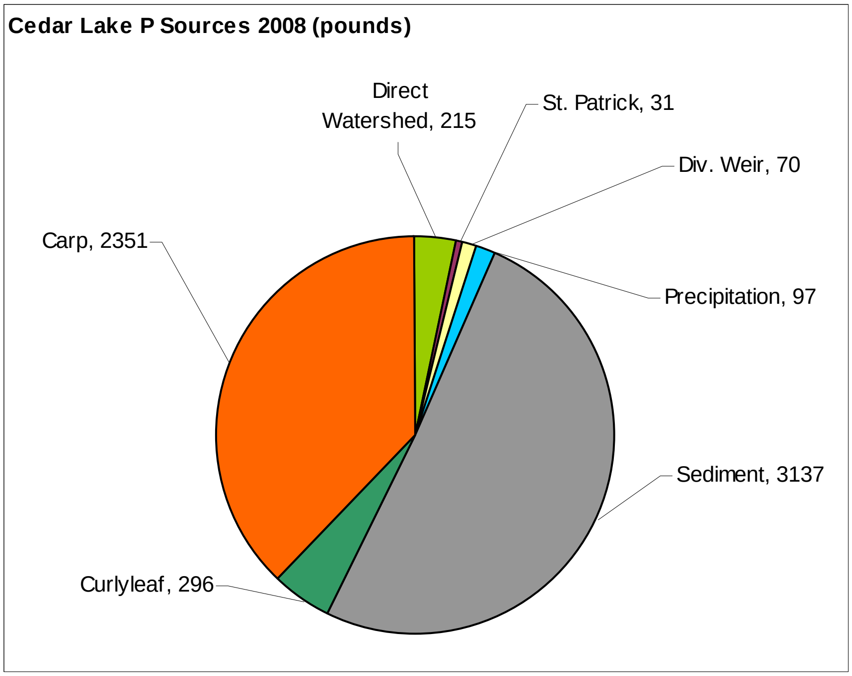


Figure 3-14 Phosphorus Sources to Cedar Lake during the 2008 Growing Season

Table 3-6 Cedar Lake Phosphorus Sources and Loads during 2007 and 2008 Growing Seasons

Phosphorus Source		2007		2008	
		Pounds	Percent	Pounds	Percent
Internal	Sediment	3,285	49.8	3,137	50.6
	Carp	2,754	41.8	2,351	37.9
	Curlyleaf Pondweed	282	4.3	296	4.8
External	Diversion Weir	NA	NA	70	1.1
	St. Patrick Wetland	6	0.09	31	0.5
	Direct Watershed	175	2.7	215	3.5
	Precipitation	93	1.4	97	1.6

3.3.3 McMahon Lake In-Lake Model

Both years 2007 and 2008 were similar for McMahon Lake in that internal phosphorus loading sources were the dominant fractions (Table 3-7). This can again be qualitatively inferred by looking at the historical seasonal data shown for the lake (Figure 3-8) where TP and Chl a increase throughout the summer while SD decreases. However, the timing of internal loading varied in each year and started later during the summer of 2008 (Figures 3-15 and 3-16). The onset of internal loading was determined by examining the in-lake water phosphorus concentrations and modeled external phosphorus loads. Increases in in-lake phosphorus concentrations were observed at levels well above what would be expected from the external phosphorus loads, clearly indicating the onset of substantial internal loading. Table 8 presents the existing water, external and internal TP budgets in McMahon Lake that were calculated using monitoring data, P8 and runoff coefficients, and in-lake models.

Table 3-7 Water, Total Phosphorus and Net Internal Load Budgets in McMahon Lake during 2007 and 2008

Calibration Year	Water Load Over the Growing Season (AF)	External Total Phosphorus Load Over the Water Year (lbs)	Internal Total Phosphorus Load Over the Water Year (lbs)
2007	146.8	172	298
2008	144.8	173	499

Figure 3-15 and 3-16 show the daily time step calibration models for McMahon Lake during 2007 and 2008. Both years show a similar pattern of somewhat elevated phosphorus concentrations in the spring subsequently followed by a decrease in late spring/early summer and then a steady increase in phosphorus concentrations towards the end of the summer. Although internal loading processes began earlier during 2007, the magnitude of phosphorus increase during the summer was greater during 2008. Variations in conditions that affect internal loading processes might explain the observed variations in the onset and intensity of internal loading. Aquatic plant growth (especially curlyleaf pondweed), climatic conditions, and carp behavior will all have influences on internal loading dynamics in the lake. Detailed data on these factors are difficult to obtain, and that level of detail was beyond the scope of the studies conducted on McMahon Lake.

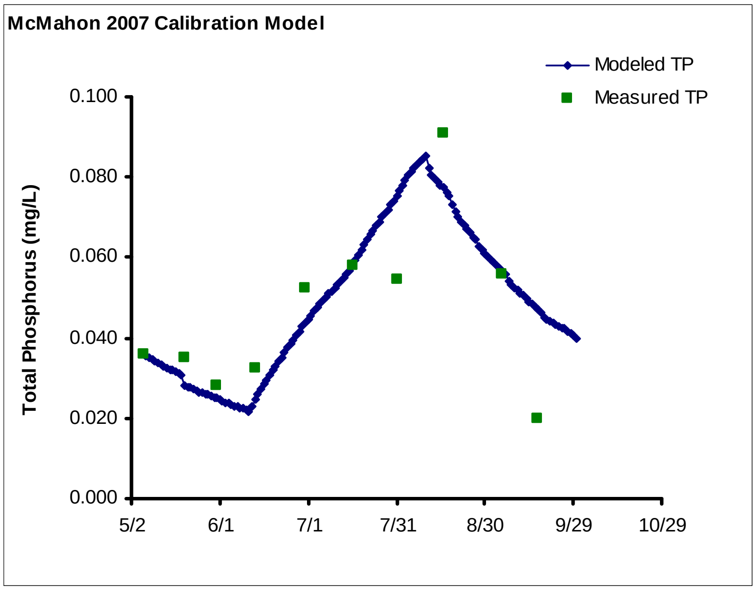


Figure 3-15 Total Phosphorus Calibration Model for McMahon Lake 2007

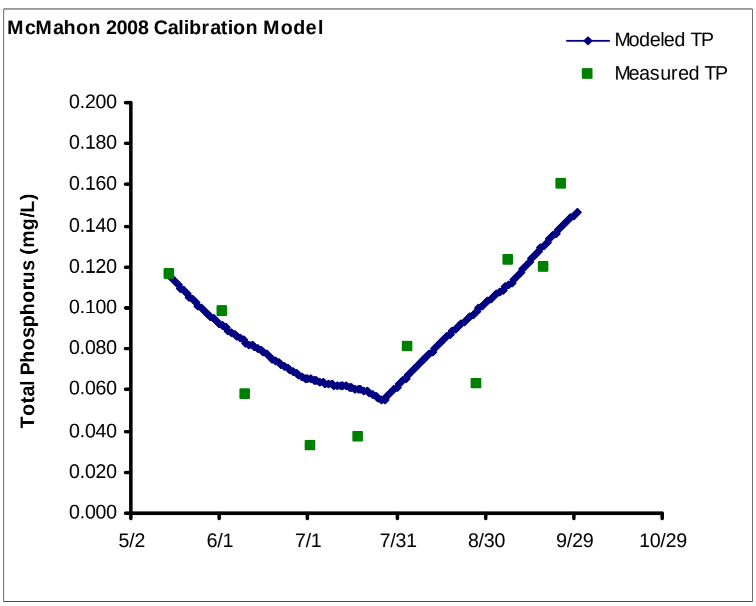


Figure 3-16 Total Phosphorus Calibration Model for McMahon Lake 2008

3.3.4 McMahon Lake Phosphorus Sources and Contributions

Figure 3-17 shows the relative contributions of phosphorus to McMahon Lake from different sources. Internal loading sources of phosphorus to McMahon Lake were 80% of the total phosphorus load to the water body. Sediment phosphorus release contributed 273 pounds while curlyleaf pondweed senescence added 19 pounds. External loading (the direct watershed and individual sewage treatment systems [ISTS]) accounted for 15% of the phosphorus load while precipitation was 5% of the phosphorus load via direct deposition on the lake surface.

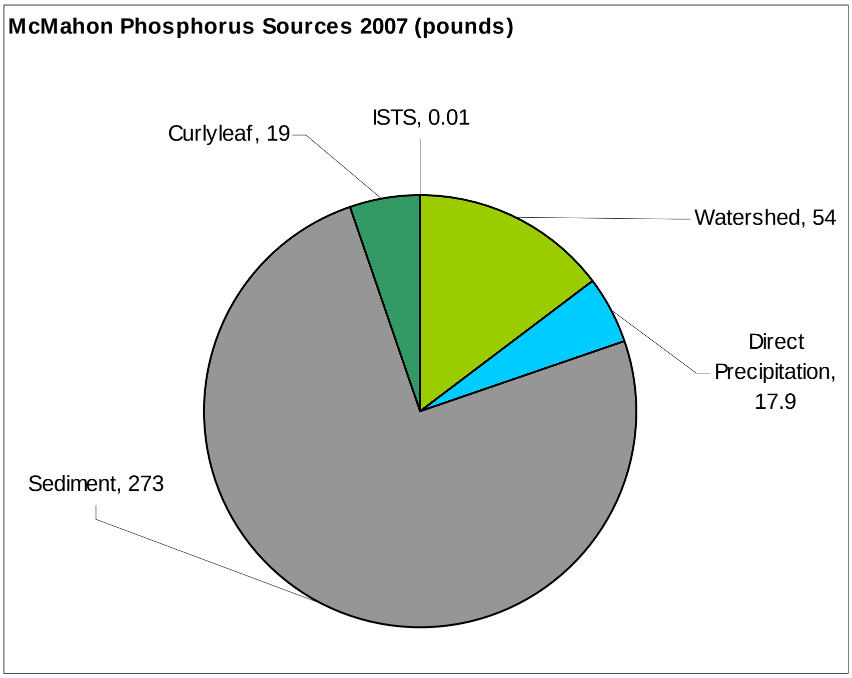


Figure 3-17 Phosphorus Sources to McMahon Lake during the 2007 Growing Season

Figure 3-18 shows the relative contributions of each phosphorus source to McMahon Lake during the 2008 water year. Internal loading was higher in 2008 (85%) of the total phosphorus load) due to elevated phosphorus loading from the sediment (474 pounds). External loading accounted for 12% of the phosphorus load while precipitation was 3% of the total phosphorus load to the lake via direct deposition on the lake surface, respectively. Table 3-8 lists the phosphorus loads to McMahon Lake for both 2007 and 2008.

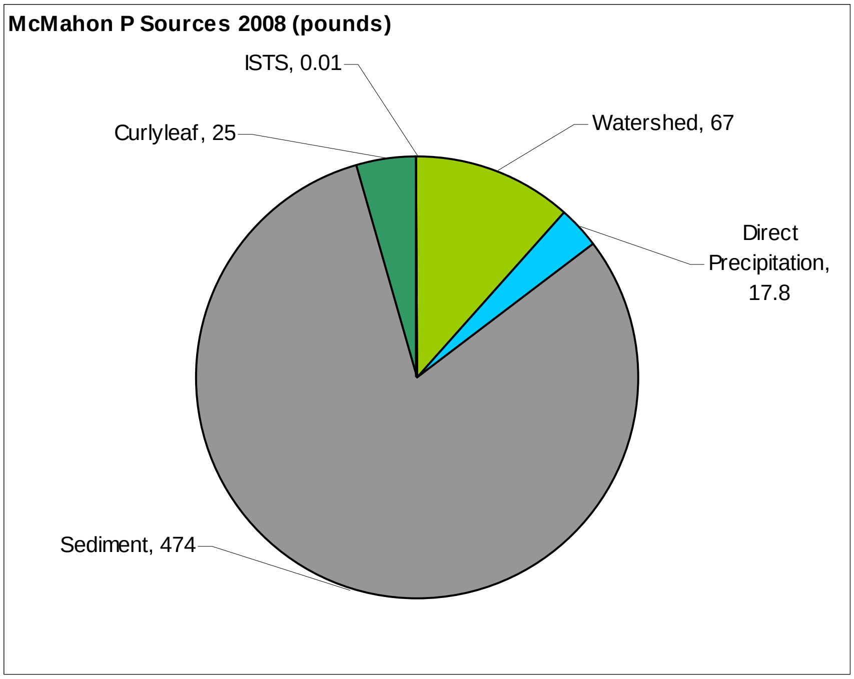


Figure 3-18 Phosphorus Sources to McMahon Lake during the 2008 Growing Season

Table 3-8 McMahon Lake Phosphorus Sources and Loads during 2007 and 2008 Growing Seasons

Phosphorus Source		2007 Pounds	2007 Percent	2008 Pounds	2008 Percent
Internal	Sediment	273	75	474	81
	Curlyleaf Pondweed	19	5.2	25	4.4
External	Direct Watershed	54	14.8	67	11.5
	ISTS	0.01	0.0	0.01	0.0
	Precipitation	18	4.9	18	3.1

3.4 Methodology for Load Allocations, Wasteload Allocations and Margin of Safety

A TMDL is defined as follows (EPA 1999):

TMDL = WLA + LA + MOS + Reserve Capacity

Where:

WLA	=	Wasteload Allocation to Point Sources
LA	=	Load Allocation to NonPoint Sources
MOS	=	Margin of Safety
Reserve Capacity	=	Load set aside for future allocations from growth or changes

This section will define each of the terms in this equation for Cedar and McMahon Lakes and will discuss seasonal variation and reasonable assurances for each TMDL.

Of the two scenarios evaluated in this study, the one resulting in the critical condition for water quality in each lake was the "average" precipitation scenario (the growing season of 2008). During the 2008 growing season, the watershed phosphorus load and the internal load of phosphorus combined to produce higher growing season, in-lake phosphorus concentrations in both lakes compared with 2007. The growing season, as opposed to the water year, was selected as the critical condition because this period is when water quality standards are generally in exceedance. For this reason, the allocations presented in this TMDL are based on the management scenarios required to bring the growing season average TP concentration to below either 90 µg/L (WCBP) or 60 µg/L (NCHF) in each lake during the climactic conditions observed during 2008. Also, because it is a year of average precipitation, it serves as a fair baseline to set allocations. It is reasonable to expect that, on average, phosphorus sources in the respective watersheds will have existing watershed TP loads on the order of those modeled during the growing season of 2008.

3.4.1 Wasteload Allocations

Cedar Lake and its watershed are located in unincorporated areas where there is neither an MS4 regulated community or regulated conveyance system. McMahon Lake and its subwatershed are located in an MS4 community (i.e., Spring Lake Township). However, the area is unincorporated and there are no regulated conveyance systems within the McMahon Lake subwatershed. Therefore, the only wasteload allocation in this TMDL is an allowance for construction or industrial activities, assuming that 1% of the watershed area (and external load) is subject to these activities for each lake.

There are no CAFOs in either watershed, and no known straight pipe septics. Scott County has an active Individual Sewage Treatment System (ISTS) program that meets all State requirements, and it is unlikely that any straight pipe systems exist. In addition, the area immediately around Cedar Lake was sewered in the early 2000s and is served by the Cedar Lake Sanitary District. Wastewater from the District is taken out of the Cedar Lake watershed by interceptor to the New Prague WWTP for treatment prior to discharge to Sand Creek.

3.4.2 Load Allocations to Nonpoint Sources

The load allocations for Cedar Lake and McMahon Lake are attributable to the internal, atmospheric, and non-point source (direct watershed) loads of phosphorus to each lake. Atmospheric phosphorus loads were estimated assuming 0.2615 kg/ha/yr (Barr 2004). The amount of internal phosphorus loading from sediment, curlyleaf pondweed, and carp were estimated using empirical relationships described in Section 3.2.

Export coefficients and phosphorus runoff relationships were used to develop phosphorus loads from each watershed and are listed in Table 3-3. The export coefficients in Table 3-3 are derived for average year precipitation in the Minnesota River Basin. Precipitation during the water year was slightly lower than average (28 inches) for the area during 2008 (25 inches).

Modeling results indicated that if the internal load observed during the average precipitation year was reduced by 72%, and non-point watershed contributions were reduced by 25%, as described above, the average growing season average TP in Cedar Lake would be less than 90 µg/L (the WCBP criteria). The reduction of internal and watershed loads for Cedar Lake results in an overall 68% load reduction. To meet the NCHF criteria, internal load observed during the average precipitation year was reduced by 90%, and non-point watershed contributions were reduced by 25%, resulting in an overall load reduction of 85%.

Because the 10-year average does not currently exceed the 10-year TP criterion for shallow lakes in the WCBP ecoregion and both modeled years were under the threshold, no reduction scenarios were modeled for McMahon Lake using the WCBP eutrophication standards. To meet the NCHF criteria, the internal load observed during the average precipitation year was reduced by 91%, and non-point watershed contributions were reduced by 25%, resulting in an overall load reduction of 81%.

3.4.3 Margin of Safety

The error involved in any modeling exercise can be significant. However, the calibration process used in this study minimized the errors associated with erroneous assumptions. Therefore, the margin of safety for this TMDL is largely provided implicitly through use of calibrated input parameters and conservative modeling assumptions in the development of allocations, which include:

- Export coefficients for watershed loading sources were used for an average year even though precipitation was slightly below that of an average year (i.e., precipitation was 2 and 3 inches below an average year in 2007 and 2008, respectively).

- A range of climatic conditions (dry and average precipitation years) were used to provide a range of water and TP loads, and their resulting effect on lake TP, that could be expected under different management scenarios. Load reduction strategies that allow the lake to meet the eutrophication criteria are based on the critical conditions that would produce the highest lake TP concentrations (2008).

The calibration of input parameters is discussed in Section 3.2 of this report. In addition to conservative modeling, the additional components below add to the margin of safety for these TMDLs:

- Modeled values were compared with derived, literature values for phosphorus loading components such as carp, sediment, and curlyleaf pondweed

- To offset errors implicit in the lake modeling for this study, the management scenario that is ultimately recommended in this TMDL report, if entirely successful, results in lake phosphorus concentrations that are 7% (Cedar) and 31% (McMahon) lower than the eutrophication standard for the WCBP ecoregion.

- Cedar and McMahon Lakes are shallow lakes that are in an impaired turbid-water state. Lake water quality models calibrated for shallows lakes in turbid-water state determine a loading capacity that also reflects a turbid-water state. A shallow lake will switch to from a turbid-water state to clear-water when its phosphorus load is reduced according to the reductions predicted by a model calibrated to the turbid-water state. Shallow lakes can tolerate larger phosphorus loads in a clear-water state while still meeting state standards for Chl a and secchi transparency, than they can in a turbid water state. Thus, the loading capacity of these shallow lakes as determined from the model calibrated to the turbid-water state is an underestimate thereby providing additional margin of safety.

3.4.4 Reserve Capacity

Because significant development is not expected in the watershed areas in this study through 2030, existing conditions can be considered ultimate land use conditions for the TMDL allocations for Cedar Lake and McMahon Lake.

3.5 Phosphorus TMDL Allocations for Cedar and McMahon Lakes

Both Cedar and McMahon Lakes are situated near the boundary between the WCBP and NCHF ecoregions. The allocations were developed to the meet the shallow lake standards for the NCHF ecoregion, while the WCBP information was developed to help guide local implementation decision making and future considerations.

3.5.1 Western Corn Belt Plains Ecoregion

Load allocations were set so that each lake met the total phosphorus criterion of 90 µg/L for the WCBP Ecoregion. Based on the regressions in Figures 3-4 and 3-9 the response factor Secchi disc depth will also meet the standard (0.7 m) for both lakes. The regressions for Chl *a* (Figures 3-5 and 3-10) do not appear to reliably predict Chl *a* levels due to scatter in the dataset, although for Cedar Lake the lower range shows less scatter and appears to show meeting the Chl *a* standard (30 µg/L). It is expected that McMahon Lake will meet the Chl *a* standard as well. This conclusion is based on information gathered in the development of the lake nutrient standards for Minnesota lakes (Minn. Rule 7050) in which the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (Heiskary and Wilson, 2005). Clear relationships were established between the causal factor total phosphorus and the response factors Chl *a* and Secchi disc, supporting the established standards for those parameters for the WCBP Ecoregion (30 µg/L and 0.7 m, respectively).

For both Cedar and McMahon Lakes, the 2008 growing season represented the critical condition with respect to phosphorus loading and concentration in the water column. The growing season duration of 138 days was used to determine the daily load and wasteload allocations of phosphorus for each lake (Tables 3-9 and 3-10).

Table 3-9 Suggested Cedar Lake Total Phosphorus Budgets and Wasteload and Load Allocations for the WCBP Ecoregion

Watershed TP Sources	Existing TP Load (Pounds)	TMDL Wasteload Allocation (WLA) (Pounds)	Daily TMDL Wasteload Allocation (WLA) (lbs/day) (Growing Season Pounds/138 days)	Percent Reduction of Existing TP Load (Percent)
Construction/Industrial	NA	2.4	0.017	0
Total Wasteload Sources	**NA**	**2.4**	**0.017**	**0**
Internal and Atmospheric Sources	**Existing TP Load (Pounds)**	**TMDL Load Allocation (LA) (Pounds)**	**TMDL Load Allocation (LA) (lbs/day) (Growing Season Pounds/138 Days)**	**Percent Reduction of Existing TP Load (Percent)**
Internal Sources (from sediment release, carp and curlyleaf pondweed)	5784.2	1645.5	11.924	72
Non-point watershed sources	316.3	234.8	1.701	25
Atmospheric Sources:	96.9	96.9	0.702	0
Total Load Sources	**6197.4**	**1977.2**	**14.327**	
Overall Source Total	**6197.4**	**1979.6**	**14.344**	**68**

Note: Wasteload and load allocations are based on the loads estimated by the 2008 model. During that growing season, the watershed phosphorus load and the internal and external loads of phosphorus combined to produce higher concentrations than in the other growing seasons modeled for this study. Both allocations were summed by growing season. The margin of safety is implicitly included in the way that modeling was conducted for Cedar Lake.

Table 3-10 Suggested McMahon Lake Total Phosphorus Budgets and Wasteload and Load Allocations for the WCBP Ecoregion

Watershed TP Sources	Existing TP Load (Pounds)	TMDL Wasteload Allocation (WLA) (Pounds)	Daily TMDL Wasteload Allocation (WLA) (lbs/day) (Growing Season Pounds/138 days)	Percent Reduction of Existing TP Load (Percent)
Construction/Industrial	NA	0.67	0.0049	0
Total Wasteload Sources	**NA**	**0.67**	**0.0049**	**0**
Internal and Atmospheric Sources	**Existing TP Load (Pounds)**	**TMDL Load Allocation (LA) (Pounds)**	**TMDL Load Allocation (LA) (lbs/day) (Growing Season Pounds/138 Days)**	**Percent Reduction of Existing TP Load (Percent)**
Internal Sources (from sediment release, carp and curlyleaf pondweed)	499.00	499.00	3.6159	0
Non-point watershed sources	67.40	66.73	0.4836	1
Atmospheric Sources:	17.80	17.80	0.1290	0
Total Load Sources	**584.20**	**583.53**	**4.2285**	
Overall Source Total	**584.20**	**584.20**	**4.2334**	**0**

Note: Wasteload and load allocations are based on the loads estimated by the 2008 model. During that growing season, the watershed phosphorus load and the internal and external loads of phosphorus combined to produce higher concentrations than in the other growing seasons modeled for this study. Both allocations were summed by growing season. The margin of safety is implicitly included in the way that modeling was conducted for McMahon Lake.

3.5.2 North Central Hardwood Forests Ecoregion

Load allocations were set so that each lake met the total phosphorus criterion of 60 µg/L for the NCHF Ecoregion. Based on the regressions in Figures 3-4 and 3-9 the response factor Secchi disc depth will also meet the standard (1.0 m) for both lakes. The regressions for Chl *a* (Figures 3-5 and 3-10) do not appear to reliably predict Chl *a* levels due to scatter in the dataset, although for Cedar Lake the lower range shows less scatter and appears to show meeting the Chl *a* standard (20 µg/L). It is expected that McMahon Lake will meet the Chl *a* standard as well. This conclusion is based on information gathered in the development of the lake nutrient standards for Minnesota lakes (Minn. Rule 7050) in which the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (Heiskary and Wilson, 2005). Clear relationships were established between the causal factor total phosphorus and the response factors Chl *a* and Secchi disc, supporting the established standards for those parameters for the NCHF Ecoregion (20 µg/L and 1.0 m, respectively).

For both Cedar and McMahon Lakes, the 2008 growing season represented the critical condition with respect to phosphorus loading and concentration in the water column. The growing season duration of 138 days was used to determine the daily load and wasteload allocations of phosphorus for each lake (Tables 3-11 and 3-12).

Table 3-11 Cedar Lake Total Phosphorus Budgets and Wasteload and Load Allocations for the NCHF Ecoregion

Watershed TP Sources	Existing TP Load (Pounds)	TMDL Wasteload Allocation (WLA) (Pounds)	Daily TMDL Wasteload Allocation (WLA) (lbs/day) (Growing Season Pounds/138 days)	Percent Reduction of Existing TP Load (Percent)
Construction/Industrial	NA	2.4	0.017	0
Total Wasteload Sources	**NA**	**2.4**	**0.017**	**0**
Internal and Atmospheric Sources	**Existing TP Load (Pounds)**	**TMDL Load Allocation (LA) (Pounds)**	**TMDL Load Allocation (LA) (lbs/day) (Growing Season Pounds/138 Days)**	**Percent Reduction of Existing TP Load (Percent)**
Internal Sources (from sediment release, carp and curlyleaf pondweed)	5784.2	587.7	4.259	90
Non-point watershed sources	316.3	234.8	1.701	25
Atmospheric Sources:	96.9	96.9	0.702	0
Total Load Sources	**6197.4**	**919.4**	**6.662**	**85**
Overall Source Total	**6197.4**	**921.8**	**6.679**	**85**

Table 3-12 McMahon Lake Total Phosphorus Budgets and Wasteload and Load Allocations for the NCHF Ecoregion

Watershed TP Sources	Existing TP Load (Pounds)	TMDL Wasteload Allocation (WLA) (Pounds)	Daily TMDL Wasteload Allocation (WLA) (lbs/day) (Growing Season Pounds/138 days)	Percent Reduction of Existing TP Load (Percent)
Construction/Industrial	NA	0.51	0.0037	0
Total Wasteload Sources	**NA**	**0.51**	**0.0037**	**0**
Internal and Atmospheric Sources	**Existing TP Load (Pounds)**	**TMDL Load Allocation (LA) (Pounds)**	**TMDL Load Allocation (LA) (lbs/day) (Growing Season Pounds/138 Days)**	**Percent Reduction of Existing TP Load (Percent)**
Internal Sources (from sediment release and curlyleaf pondweed)	499.0	43.80	0.3174	91
Non-point watershed sources	67.4	50.10	0.3630	25
Atmospheric Sources:	17.8	17.80	0.1290	0
Total Load Sources	**584.2**	**111.70**	**0.8094**	**81**
Overall Source Total	**584.2**	**112.21**	**0.8131**	**81**

3.6 Seasonal Variation

Phosphorus concentrations in the lake vary significantly during the growing season, generally peaking in August. The TMDL guideline for total phosphorus is defined as the growing season (mid-May or June through September) mean concentration (MPCA, 2007b). Accordingly, water quality scenarios (under different management options) were evaluated in terms of the mean growing season total phosphorus (mid-May through September), when the critical condition for each lake occurs.

4.0 Monitoring Plan to Track TMDL Effectiveness

The water quality in Cedar and McMahon Lakes has been monitored for over 30 years, and will continue to be monitored for the foreseeable future. The Scott WMO will continue to monitor the water quality in the lakes periodically through the Citizen Assisted Monitoring Program (CAMP) coordinated by the Metropolitan Council. The typical lake sampling protocol is to visit the lakes 8 to 10 times between April and September. The following water quality parameters are measured at each visit. All parameters except Secchi disc and chlorophyll *a* are measured at various depths in the water column (every 1 to 2 meters.)

- Secchi disc
- Dissolved Oxygen
- Temperature
- Total Phosphorus
- Chlorophyll *a*

It will also be important to monitor the long-term effectiveness of any water quality improvement projects being constructed in either the Cedar Lake or McMahon Lake watersheds. Documentation of installed BMPs and testing of removal efficiencies of representative phosphorus reduction BMPs should be conducted, where possible.

Comprehensive phytoplankton, zooplankton, macrophyte and fisheries surveys should be conducted in both lake basins during at least one of the years that surface water quality monitoring is being accomplished. Carp populations should be enumerated by size class using a catch-tag-release-recapture method or similar approach for producing reliable estimates of fish populations.

The comparison between future monitoring data and the modeling results in this study can be conducted as follows:

1. Using monitoring results (flow and water quality sampling data), calculate the annual load (or the load over some other time period) of phosphorus leaving the basins.
2. Run the in-lake models for same time period and calculate the load that the model predicts for pre-project conditions.
3. Compare the two loads, and calculate the percent reduction that was achieved over the time period of interest.

5.0 TMDL Implementation Strategies

5.1 Annual Load Reductions

Both lakes are situated within the NCHF ecoregion but are close to the boundary with the WCBP. Because of this, the TMDL implementation strategies for each lake were developed with dual endpoints serving as short-term (WCBP) and long-term (NCHF) goals. The TMDL implementation strategies focus on reducing both external, watershed sources of phosphorus and internal, in-lake sources of phosphorus.

Growing season reductions of 81 pounds (26%) from external loading and 4139 pounds (72%) from internal loading sources are required to achieve the required TMDL threshold of 90 µg/L for Cedar Lake under the WCBP criteria. Total phosphorus load (both external and internal) to Cedar Lake will decrease overall loading by 4,220 pounds, or 68% during the growing season in order to achieve the overall TMDL load allocation of 1980 pounds.

To meet the NCHF phosphorus threshold of 60 µg/L, growing season reductions of 81 pounds (26%) from external loading and 5,196 (90%) pounds from internal loading sources are required. A total phosphorus load reduction to Cedar Lake of 5,278 (85%) pounds during the growing season will be required to achieve to overall TMDL load allocation of 922 pounds.

Because the 10-year averages for water quality in McMahon Lake currently meet the MPCA standards for lakes in the WCBP Ecoregion, phosphorus reductions were not developed. To meet the standards under the NCHF ecoregion, reductions of 17 pounds (26%) from external loading and 455 (91%) from internal loading sources are required. The overall phosphorus load to McMahon Lake will need to be reduced by 473 (81%) pounds in order to achieve the TMDL load allocation of 112 pounds.

The phosphorus load reduction projects will be implemented in a stepwise manner, with some implementation of projects already having occurred prior to this report. It is anticipated that it will take up to 20 years to implement all of the projects required to achieve these annual load reductions.

5.2 Sector-Specific Recommendations

A number of recommendations are made below to detail implementation strategies associated with each of the significant phosphorus loading sources within the Cedar and McMahon Lake watersheds.

These recommendations are designed to reduce both external and internal phosphorus sources and are documented in greater detail in the TMDL Implementation Plan prepared by the Scott WMO. The process to develop the recommendations included analysis of options, discussions with the DNR, the Cedar Lake Improvement District, stakeholders (as part of the public meetings), and the New Market Sportsman's club.

Options assessed for external load reduction include:

- Shoreland improvements
- Conservation on Highly Erodible Lands (HEL)
- Filter strips
- Guiding the conversion of agricultural land to rural residential
- Development of Cedar Lake Farms Regional Park
- Wetland Restoration
- Septic system improvements
- Stream channel stabilization
- Floodplain Reconnection/Natural Channel Restoration
- Urban stormwater improvements/permitting

Based on analysis of these options it was decided to promote shoreland improvements, conservation on HEL, filters strips, and wetland restoration through the Scott WMO cost share program. Wetland restoration will be pursued jointly through the special Wetland Reserve Enhancement Program grant that the Scott Soil and Water Conservation District, in conjunction with the Scott WMO, has received from the Natural Resources Conservation Service. County land development and stormwater regulations to affect water quality runoff improvements as agricultural land is converted or developed into rural residential land are already in place. Restoration of native plant communities at Cedar Lake Farms Regional Park will be pursued as a means of improving runoff and water quality. Water quality practices may also be built on park property as it develops. Septic system improvements will not be actively pursued as a separate effort from the County program because little return is expected since the area around Cedar Lake is already sewered and there are only a few homes around McMahon Lake. Stream channel stabilization, floodplain reconnection and natural channel restoration practices in the diversion watershed were not selected because of high cost and low landowner interest.

Options assessed for controlling internal phosphorus loads included:

- Aquatic plant management
- Lake drawdown
- Dredging
- Fish management and rough fish control
- Inactivation of sediment phosphorus

Dredging was eliminated because of cost. There was significant discussion and input solicited regarding the acceptability and proper sequencing of the other actions. In particular:

- It is better to first pursue sediment phosphorus inactivation, thereby reducing algae and improving water clarity so that curlyleaf pondweed turions through the lakes sprout, making subsequent treatment of the curlyleaf more effective; or Should internal management start with macrophyte management to demonstrate whether or not effective curlyleaf pondweed control can be achieved before completing the capital-intensive sediment treatment?
- Is a lake drawdown acceptable or feasible?

These options along with a no action option were assessed, with input solicited from DNR and other stakeholders.

For Cedar Lake the option of:

1. Completion of an Aquatic Plant Management Plan
2. External Watershed Treatment
3. Curlyleaf pondweed control
4. Carp Management

5. Sediment Phosphorus Inactivation

Where items 1, 2, 3, and 4 are completed concurrently, with #5 completed in 5 to 10 years depending on the results of the other efforts, appears to have the broadest base of support. Carp management in item 4 refers to subsidizing commercial harvesting for a few years while waiting for some of the existing studies by others to be completed.

For McMahon Lake there was not a clear consensus. The do nothing options was not acceptable with local land owners and does not meet Clean Water Act objectives. Lake drawdown is not feasible. In the end a sequence similar to that selected for Cedar Lake is being advanced where watershed treatments and aquatic plant management are initially advanced, with sediment inactivation considered in 5 to 10 years depending on the results of the other efforts. Stakeholders have, however, been informed that this approach may not show much in the way of results until the sediment treatment since there is little left in the watershed to treat, and a variance would be needed to treat the curlyleaf pondweed and Eurasian watermilfoil that infests the lake.

5.2.1 External (Watershed) Source Loading Reduction

The Scott WMO cost share incentive program was established together with the Scott SWCD in 2005. The goal of the program is to help improve water quality. Through the cooperation of local, State, and Federal agencies, landowners, and municipalities are eligible for programs that provide educational, technical, and financial assistance to execute various conservation practices.

Load reductions for construction storm water activities are not specifically targeted in this TMDL. It should be noted that construction storm water activities are considered in compliance with provisions of this TMDL if they obtain a Construction General Permit under the NPDES program and properly select, install and maintain all BMPs required under the permit, including any applicable additional BMPs required in of the Construction General Permit for discharges to impaired waters, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

5.2.1.1 Completed Actions

Reduce Loading from Individual Septic Treatment Systems (ISTS)

A community sewage collection system was installed (Cedar Lake Sewer District, 2001) to reduce loading from ISTS.

5.2.1.2 Future Actions

Targeting the Scott WMO Cost Share Program to the Cedar Lake and McMahon Lake watershed.

Identify and implement BMP opportunities to reduce external loading of phosphorus to Cedar and McMahon Lakes through the Scott WMO Cost Share Program. The program, administered by the Scott WMO, provides approximately $240,000 to $270,000 annually for BMP implementation across the entire WMO. Cedar and McMahon watershed residents are eligible to apply for this program.

Restoration of Native Plant Communities at Cedar Lake Farms Regional Park.

Scott County recently acquired Cedar Lakes Farms Regional Park on the southwest side of Cedar Lake. Regional Parks operated by the County have a natural resource focus. While acquisition is relatively recent, and a Master Plan for the Park is not complete, in the future much of the Park will be converted to more natural landscapes. The Park is about 300 acres of which 119 acres are in the Cedar Lake direct watershed. Of this 23 acres are cropland, 74 acres are maple basswood forest, and 22 acres are grass/forest picnic area. It is expected that most of the cropland and about one-half of the grass/picnic area will be restored to native plant communities. Much of the shoreland will be stabilized and restored. Funding is in place to work with Great River Greening on the shoreland through a combination of Clean Water, LCCMR and Scott WMO funds. A design is scheduled for early fall of 2011 with implementation anticipated to be complete by the end of 2012.

Construction of Water Quality Practices at Cedar Lake Farms Regional Park.

The County and the Scott WMO are investigating the feasibility and benefits of constructing water quality practices on park property that would not only treat park land, but also runoff from surrounding lands. One feasibility study is complete; the other will start August 2011. The completed study looked at the feasibility and benefit of constructing a treatment wetland at the outlet of the diversion watershed at the south end of the park. Unfortunately the area is small and a feasible and beneficial project was not identified. The Scott WMO will continue to look at this area for locating a rough fish migration barrier. The second feasibility study area is the northwest corner of the park that has a small off-site drainage area of row crops.

5.2.2 Internal Source Loading Reduction

The reduction of internal sources of phosphorus will require a phased approach. Initially, macrophyte plans will be needed for both Cedar and McMahon Lakes to satisfy permit requirements for macrophyte management in these lakes. Once these are complete, a comprehensive plan to reduce internal loading in each lake can be developed. Completed and future action strategies designed to reduce internal phosphorus loading in each lake are detailed below.

5.2.2.1 Completed Actions

Internal Phosphorus Loading Study

Sediment phosphorus composition and potential internal phosphorus loading was assessed through sediment phosphorus analysis in 2007.

Macrophyte Surveys in Cedar and McMahon Lakes

The community composition and coverage of native and invasive aquatic plants in Cedar and McMahon Lakes through macrophyte surveys was conducted in 2007.

5.2.2.2 Future Actions

Macrophyte Management Plan Development

Before the MNDNR will issue a permit for large scale treatment of lakes for curlyleaf pondweed, aquatic plant management plans, developed in conjunction with DNR, are required. These plans detail the current status of the macrophyte community along with specific treatment objectives and activities. For both lakes, goals and actions will need to be established for improving the native plant community. DNR has expressed a willingness to consider herbicide treatment in McMahon Lake for curlyleaf pondweed and Eurasian watermilfoil control if completed according to an approved plan.

Macrophyte Management to Control Curlyleaf Pondweed

Manage the growth of curlyleaf pondweed to limit internal phosphorus loading from plant die back during the growing season. This will be accomplished through herbicide treatment since drawdown is not feasible or acceptable. However, because McMahon Lake is listed as a Natural Environment Lake, herbicide treatment may not be allowed. For Cedar Lake control efforts will start with a pilot effort targeting the northeast bay of the lake. A pilot effort was selected to assess whether or not native plants will reestablish.

Fisheries Management and Carp Control

Carp control efforts will consist of an interim effort to reduce carp populations by providing a small supplemental payment to the area fisherman to seine the lake for carp. Longer term efforts include implementing a preliminary study on carp populations in Cedar Lake and the potential effects on in-lake phosphorus dynamics. Provide information to the public on the status of the fishery, and in particular carp, in Cedar Lake. Results will be used to evaluate the need and methods for carp population reduction and the water quality and fisheries management benefits. Using the information gained in the feasibility study, implement a carp management plan to reduce both direct and indirect internal loading sources to Cedar Lake. There are a number of existing studies regarding carp control currently underway in the State. There is a strong desire to take advantage of the findings of these studies, and thus the study on Cedar Lake will not be initiated for several years. The Scott WMO will, however, assess the feasibility of a carp migration barrier at the outlet of the diversion watershed. If feasible, construction of such a structure will be considered when the park is developed.

Inactivation or Removal of Sediment Phosphorus

Based on current sediment phosphorus data for Cedar Lake and McMahon Lake gained in the Internal Phosphorus Loading Study, reducing sediment phosphorus levels that contribute to internal loading would need to be accomplished either through sediment inactivation (e.g. alum application) or dredging. However, because McMahon Lake is listed as a Natural Environment Lake, sediment nutrient inactivation may not be allowed, and dredging to achieve the standards has been shown to be cost prohibitive in the order of hundreds of millions of dollars.

5.3 Responsible Parties

The Scott WMO will initially take the lead role in implementing projects to achieve the LA defined in this TMDL. However, other entities are expected to fulfill their existing responsibilities in storm water management to help meet the goals of this TMDL. Particularly, because these are “waters of the state”, the Scott WMO, the County and other local units of government expect state and federal assistance.

Specifically, work in the Cedar Lake and McMahon Lake watersheds will:

- Continue to implement volume reduction BMPs on all County projects to comply with WMO standards.

- Look for opportunities to implement projects through the Scott WMO BMP cost share program to reduce runoff and nutrient export wherever possible, taking advantage of (cost-share or land acquisition) programs for water quality improvements.

- Continue to implement Storm Water Pollution Prevention Plans (SWPPPs) and to improve their public works maintenance practices wherever possible.

5.4 Estimated Costs

Estimated costs to achieve the TMDL vary by lake. For Cedar Lake the estimated cost is from $1,390,000 to $2,430,000. For McMahon the cost range is from $271,000 to $456,000. The range in cost is primarily due to the uncertainty of whether one or two sediment treatments will be needed, and for Cedar Lake the uncertainty of carp control.

6.0 Reasonable Assurances

Attaining either the WCBP or the NCHF standard for Cedar Lake will be challenging, as will attaining the NCHF standard in McMahon Lake without increasing problems from known exotic plants that currently infest McMahon Lake. The lakes are shallow and most of the existing load is from internal sources. Control of these internal sources is challenging, and the science is still evolving for some practices. There is better assurance of the watershed load reductions. Cedar Lake was also physically altered with its depth increased 5 feet in the 1950s when a new outlet was constructed, and its watershed was also altered in the 1930s with the construction of the diversion. Reasonable assurance for internal, external and other reductions are discussed separately below.

6.1 Internal Load Reasonable Assurance

As discussed above there are many challenges to reducing the internal loads of these lakes as follows:

- Sediment nutrient inactivation for reducing sediment phosphorus release in shallow lakes is uncertain and an emerging science. This is mainly due to under dosing of phosphorus binding metals (e.g. alum) but also the relatively large impact littoral interactions between sediment and water can have (e.g. bioturbation and diurnal changes). This means that the lakes may require multiple or periodic treatments.

- Carp control is an emerging science, and thus, internal load reduction through management of the fishery in Cedar Lake may be difficult to achieve. Instigating a fish kill by either a lake drawdown or with rotenone is not an option for Cedar Lake at this time due to a lack of public acceptance. Cedar Lake is recognized as a very good sport fishery and public support is not there for killing off and restarting the fishery. The same is true to a rotenone treatment. There is also some concern by lakeshore residents that with a lake drawdown that Cedar Lake might not fill back up again for years given the small watershed size and limited inflow from external sources (i.e. St. Patrick Wetland and the diversion weir).

- Control of curlyleaf pondweed is an emerging science, and thus, achieving required internal load reductions in Cedar and McMahon Lakes through herbicide treatment and/or lake water drawdown may be difficult. A lake draw down is not an option for

McMahon Lake as the lake internally drains and does not have an outlet. There is also some concern that natives plants may not come back in Cedar Lake given the results of the aquatic plant survey which showed almost complete dominance of the aquatic plant community by curlyleaf pondweed. Finally, with respect to McMahon Lake, where the presence of water milfoil is confirmed, there is concern that efforts to control curlyleaf pondweed and to improve water clarity will lead to the increase of the Eurasian watermilfoil and a different type of recreational impairment.

6.2 External Load Reasonable Assurance

Achieving the necessary load reductions for McMahon Lake may not be attainable because the McMahon Lake watershed is currently largely unaltered. There are only 66 acres of row crop in the watershed, a handful of rural residential homesteads, and no restorable wetlands. Most of the watershed is forest and unaltered wetland. The only real watershed treatment opportunity is the area in row crop. The following should be considered as reasonable assurance that implementation will occur and will result in external load reductions to Cedar and McMahon Lakes.

- The BMPs and other actions outlined in Section 5.0 have all been demonstrated to be effective in reducing transport of pollutants to surface water (Cooke et al., 1993 and USEPA Watershed Academy). Also, many of these actions are currently being promoted by local resource managers with some local efforts showing significant levels of adoption by land owners. Over 200 practices designed to reduce sediment, nutrient and hydrologic loading have been initiated via the Scott WMO Cost Share and Incentive Program in the past 4 years having a total phosphorus reduction benefit estimated at over 7,300 lbs. These are scattered across the Scott WMO, however, five of these were shore land restorations/stabilizations around Cedar Lake.

- The MPCA's Construction and Industrial Activities NPDES Permits require permittees to provide reasonable assurances that if an EPA-approved TMDL has been developed, they must review the adequacy of their Storm Water Pollution Prevention Plan to meet the TMDL's WLA set for stormwater sources. Current stormwater management efforts within the Scott WMO are fairly comprehensive, and exceed those of the NPDES General Permit for Construction. The WMO completed Rules and a plan amendment incorporating the Rules in May of 2005. A copy of the Rules and guidance is available on the WMO website www.co.scott.mn.us/wmo. These rules are expected to mitigate any phosphorus load increases from new development in the watershed particularly since the areas are largely converting from agriculture to very low density rural residential.

- Both Scott County and the Scott WMO have embraced a Natural Areas Corridor concept that promotes "green infrastructure." McMahon Lake and its watershed are located within the corridors; portions of the Cedar Lake watershed (i.e. the area of the Cedar Lake Farms Park) are also within the corridors. This green infrastructure approach is designed to buffer water bodies thereby reducing nutrient loading.

- Scott County recently acquired Cedar Lakes Farms Regional Park on the southwest side of Cedar Lake and Regional Parks operated by the County have a natural resource based focus. While acquisition is relatively recent, and a Master Plan for park development is not complete, in the future much of the park will be converted back to a more natural landscape as compared to the current active use (mowed lawn) park setting. It is expected that these natural landscapes will reduce nutrient loading by buffering and filtering, improving shoreline stability, increasing infiltration, decreasing surface runoff, and reducing the production and mobility of grass clippings.

6.3 Other Reasonable Assurances

Other things that contribute to reasonable assurance of reducing nutrient loads to the lakes include the following:

- Local water governance capacity is overlapping. Both Cedar and McMahon Lakes are located in the Scott WMO, which is part of Scott County government, but is set up as a separate taxing district. Cedar Lake and some of the surrounding area is also covered by the Cedar Lake Improvement District, also a local unit of government with taxing authority. This means that there are two local government organizations with capacity to help improve Cedar Lake, and one to help with McMahon Lake.

- The stakeholder group convened to provide feedback and input into the project had broad representation from government, citizens, and technical experts.

- Monitoring will be conducted to track progress and provide data needed to adjust the implementation approach, if necessary.

7.0 Public Participation

Public participation on the Cedar Lake and McMahon Lake TMDLs has occurred through meetings and updates on the TMDL project, including:

- A public information meeting regarding the lake TMDLs was held on December 6, 2007.

- On October 15, 2009 a TMDL meeting was conducted between Scott WMO staff, the public and representatives from the various stakeholder groups that are responsible for loads within the each watershed.

- The Technical Advisory Committee of the Scott WMO has been briefed on the TMDL study progress at each of the semi-annual meetings over the course of the project.

- The Watershed Planning Commission (a committee of citizens appointed to advise the Scott WMO Board) has been periodically briefed on the study through the duration.

- A 30-day public comment period on the draft TMDL was announced via a public notice in the State Register. The comment period ran from June 20 to July 20, 2011, and was extended for a period from August to August 15, 2011, due to the State government being shut down during part of the original comment period.

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Appendices

Appendix A

Historical Season Averages of Water Quality Parameters for Cedar and McMahon Lakes

Cedar Lake Water Quality Growing Season Means 1976-2008

	Secchi Disc Depth		Total Phosphorus		Chlorophyll a	
Year	(m)	Number of samples	(ug/L)	Number of samples	(ug/L)	Number of samples
2008	0.81	11	205	11	46	11
2007	0.88	10	197	10	52	10
2006	1.03	10	165	10	69	10
2005	1.36	10	129	10	39	9
2004		0		0		0
2003		0		0		0
2002	2.19	10		0		0
2001	0.67	19	154	10	151	4
2000	1.80	10		0		0
1999	1.52	11		0		0
1998	0.99	21	286	10		0
1997	1.57	12		0		0
1996	1.67	15		0		0
1995	1.63	14		0		0
1994	2.62	15		0		0
1993	1.87	18	215	10		0
1992	0.71	12		0		0
1991	0.70	14		0		0
1990	0.80	24	118	10		0
1989	0.60	13		0		0
1988		0		0		0
1987		0		0		0
1986		0		0		0
1985	1.19	16		0		0
1984	1.55	22	168	5		0
1983	1.79	17		0		0
1982	1.67	17		0		0
1981	1.57	20	346	7		0
1980	1.44	21	416	9		0
1979	1.42	17	439	0		0
1976	1.20	8		0		0
Historical (1976-2008) Growing Season Mean*	1.36	387	236	102	71	44
10-Year (1999-2008) Growing Season Mean*	1.28	91	170	51	71	44

Notes

Growing Season is Mid-May through September

* Long term means were calculated by first calculating the seasonal means of individual years, and then calculating the mean of those results.

McMahon Lake Water Quality Growing Season Means 1984-2008

	Secchi Disc Depth		Total Phosphorus		Chlorophyll a	
Year	(m)	Number of samples	(ug/L)	Number of samples	(ug/L)	Number of samples
2008	0.97	10	89	10	87	10
2007	0.89	8	46	10	41	8
2006	0.87	10	67	10	44	10
2005	0.85	10	112	10	85	10
2004		0		0		0
2003		0		0		0
2002		0		0		0
2001	0.82	9	112	11	92	4
2000		0		0		0
1999		0		0		0
1998	1.19	10	76	10		0
1997		0		0		0
1996		0		0		0
1995	1.72	10	104	10		0
1994		0		0		0
1993		0		0		0
1992		0		0		0
1991		0		0		0
1990		0		0		0
1989		0		0		0
1988		0		0		0
1987		0		0		0
1986		0		0		0
1985		0		0		0
1984	1.02	5	105	5		0
Historical (1984-2008) Growing Season Mean*	1.04	72	89	76	70	42
10-Year (1999-2008) Growing Season Mean*	0.88	47	85	51	70	42

<u>Notes</u>

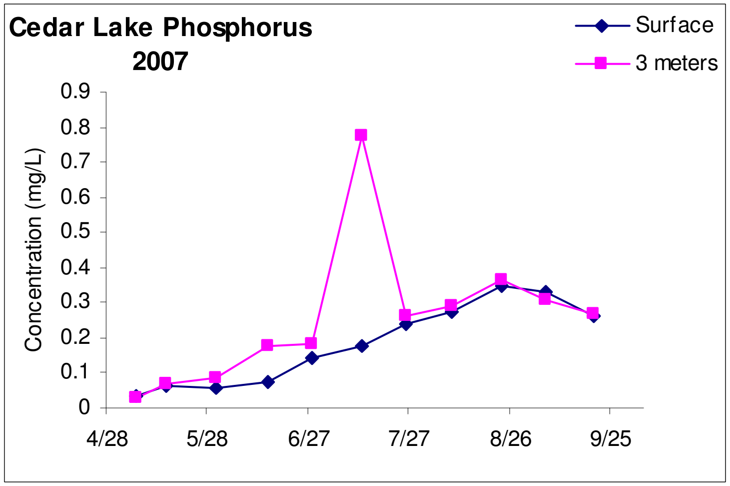
Growing Season is Mid-May through September

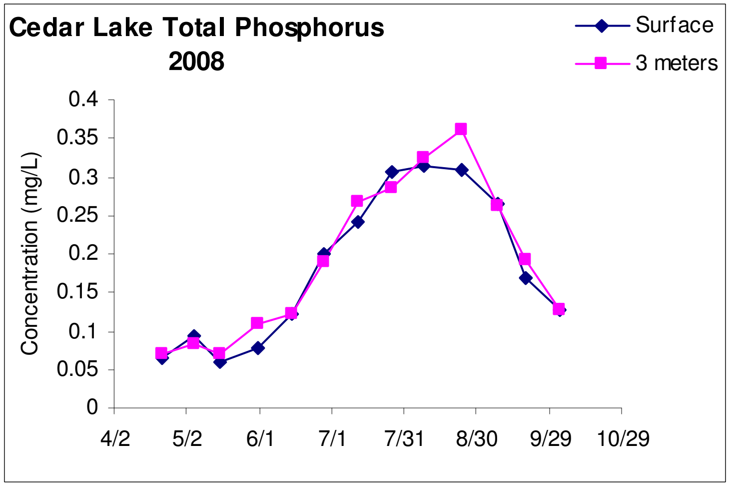
* Long term means were calculated by first calculating the seasonal means of individual years, and then calculating the mean of those results.

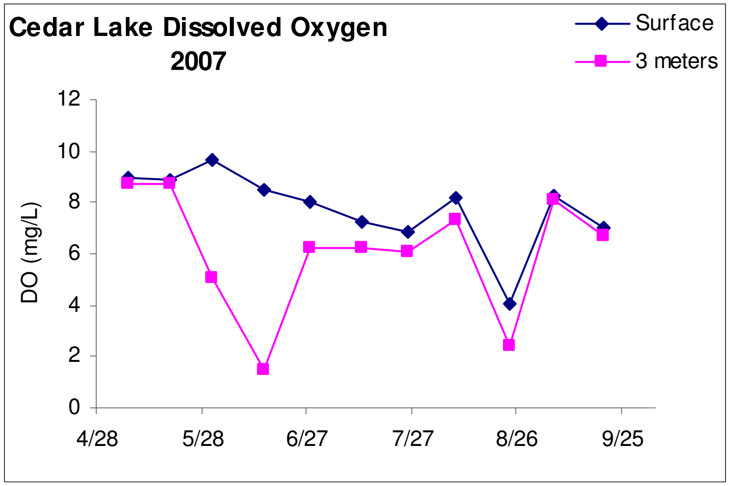
Appendix B

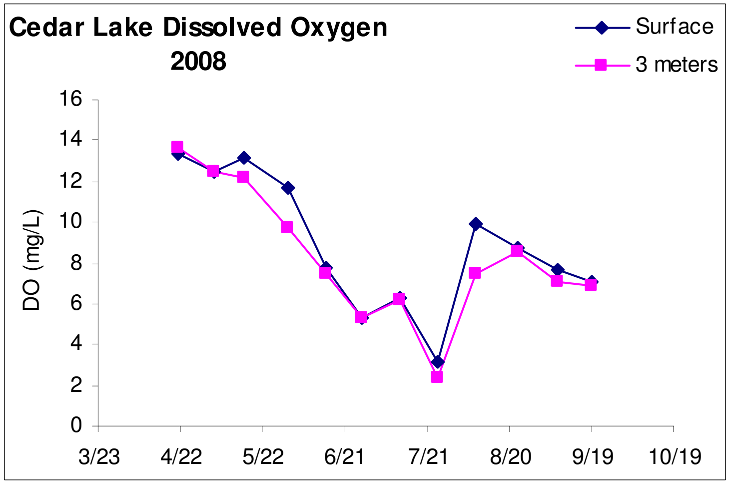
Additional Water Quality Data for Cedar and McMahon Lakes

Cedar Lake phosphorus and dissolved oxygen concentrations during 2007 and 2008 monitoring periods

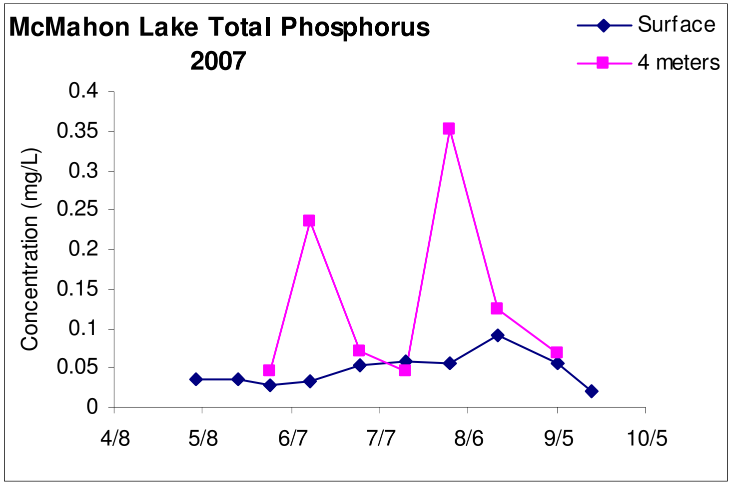


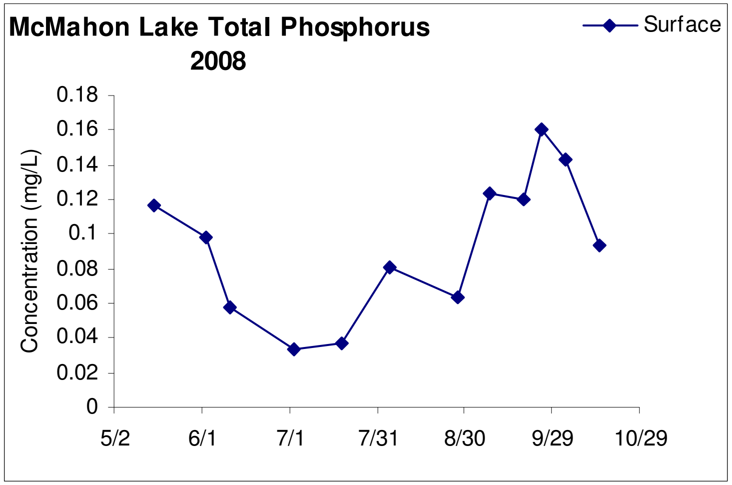


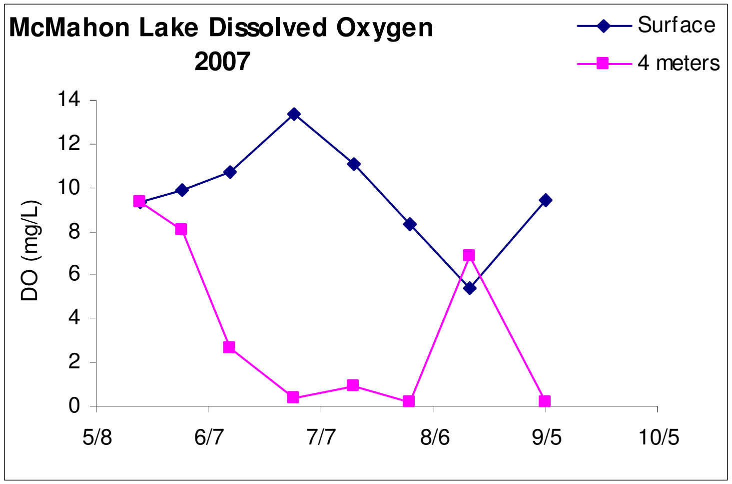




McMahon Lake phosphorus and dissolved oxygen concentrations during 2007 and 2008 monitoring periods







Appendix C

Sediment Phosphorus Internal Loading Study

Sediment Investigation of Cedar and McMahon Lakes

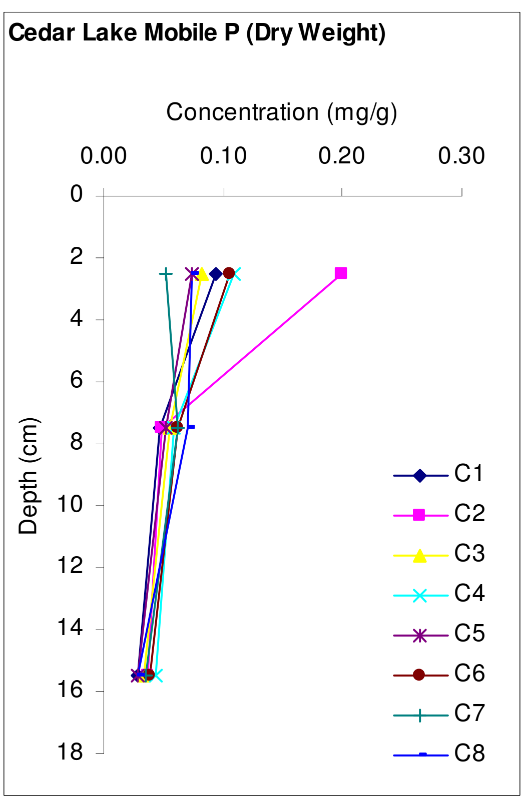
Sediment Cores were collected in May of 2007 to determine sediment phosphorus concentrations that can lead to internal phosphorus loading in Cedar and McMahon Lakes. Phosphorus fractions were determined according to a modified version of Psenner et al. (1988) and internal loading estimates were calculated according to the method developed by Pilgrim et al. (2007). After laboratory analysis, sediment phosphorus concentrations were modeled to determine lake wide internal phosphorus loading rates using Geostatistical Analyst within the ArcMap GIS program.

Cedar Lake

Eight cores were collected from Cedar Lake and analyzed for mobile and organically bound phosphorus (Figure 1). Both mobile and organic bound fractions were elevated in the surficial sediment and concentrations decreased with increasing depth.

Based on mobile phosphorus in the sediment, internal phosphorus loading estimates ranged from 0.18 to 2.37 mg/m^2/day in the eight cores collected from the lake. Lake wide internal loading rate averages (determined using core and modeled data) were between 0.52 (modeled average) and 0.97 (core average) mg/m^2/day across the lake. Modeled phosphorus data are shown in Figure 2.

Figure 1. Sediment phosphorus concentrations (dry weight) in Cedar Lake



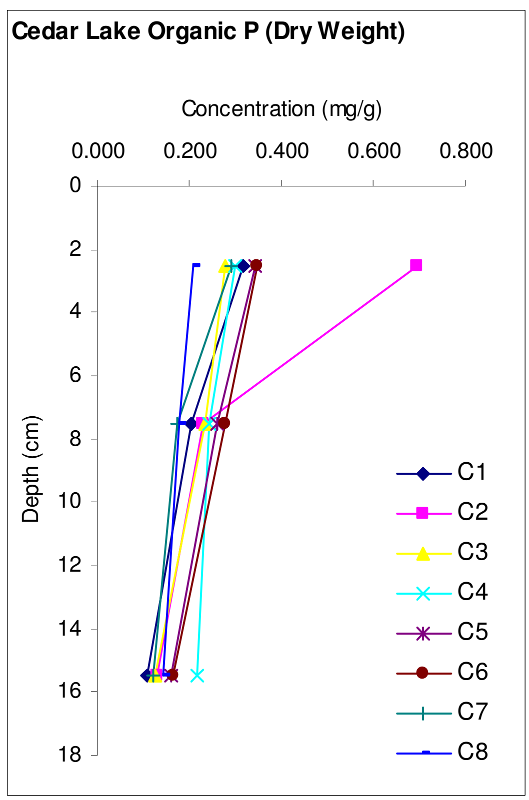
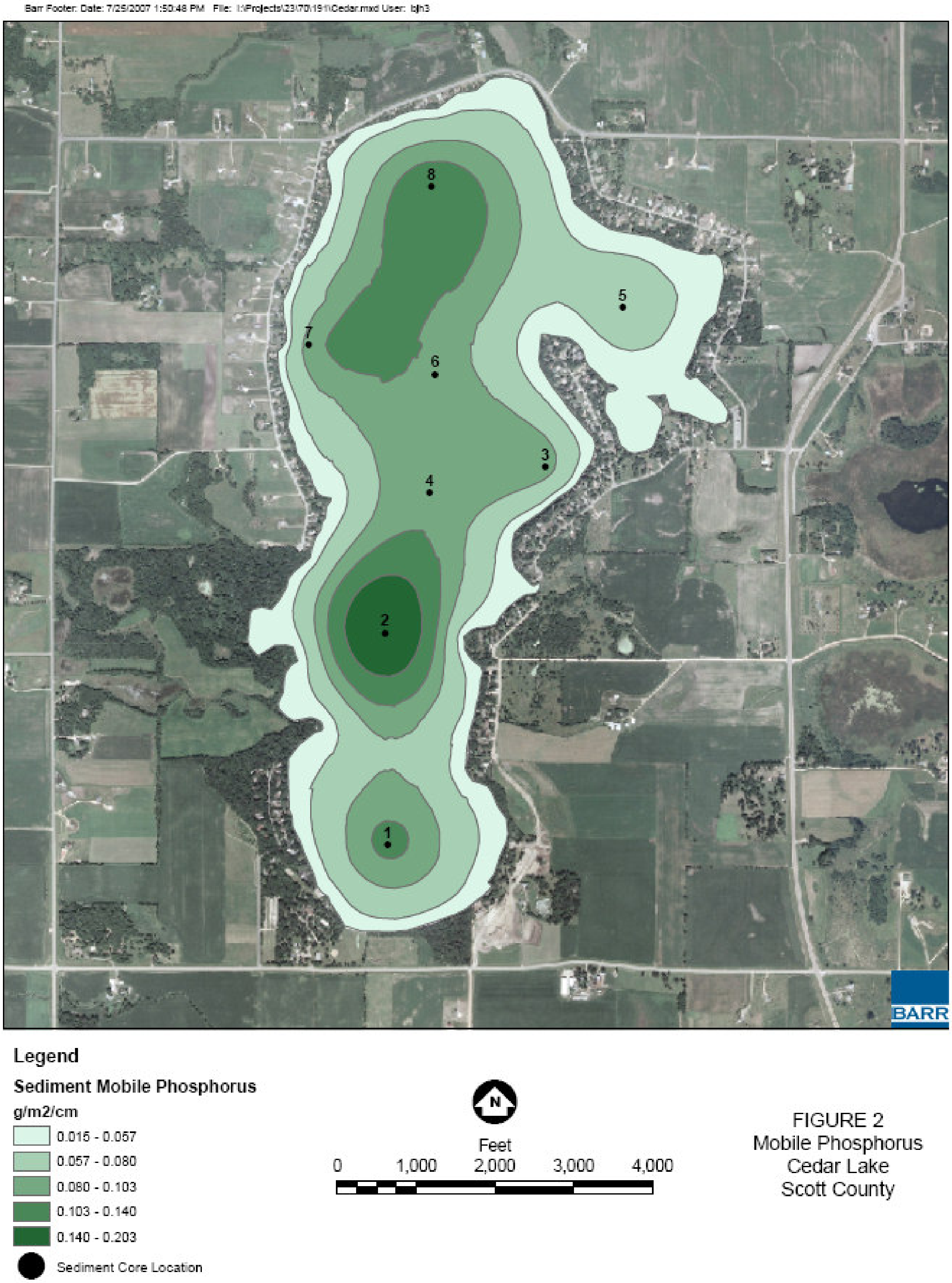


Figure 2. Modeled sediment mobile phosphorus concentrations in Cedar Lake

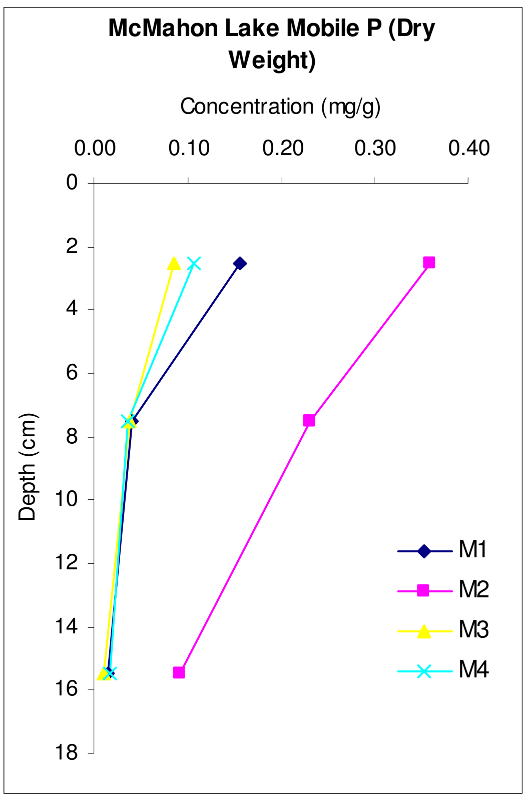


McMahon Lake

Four cores were collected from McMahon Lake and analyzed for mobile and organically bound phosphorus fractions (Figure 3). Both mobile and organic bound fractions were again elevated in the surficial sediment and concentrations decreased with increasing depth.

Based on mobile phosphorus in the sediment, internal phosphorus loading estimates ranged from 0.21 to 8.01 $mg/m^2/day$ in the eight cores collected from the lake. Lake wide internal loading averages were determined using core data and modeled data and were between 1.77 (modeled average) and 3.24 (core average) $mg/m^2/day$. Modeled phosphorus data are shown in Figure 4.

Figure 3. Sediment phosphorus concentrations (dry weight) in Cedar Lake



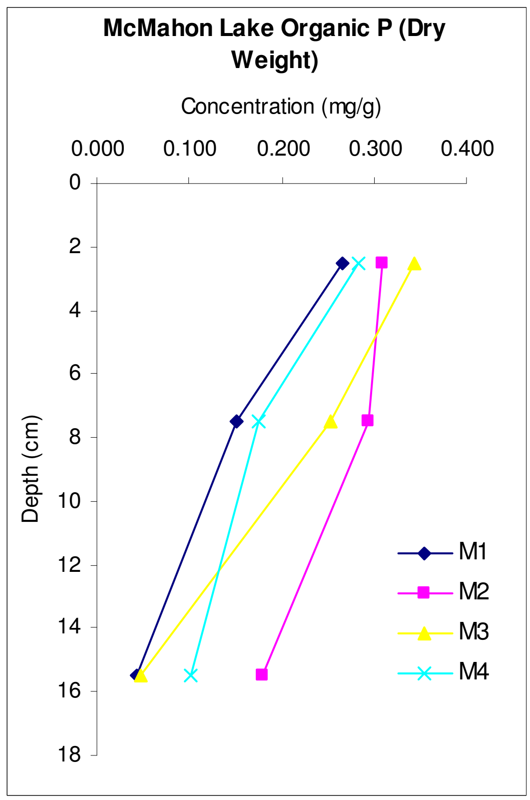
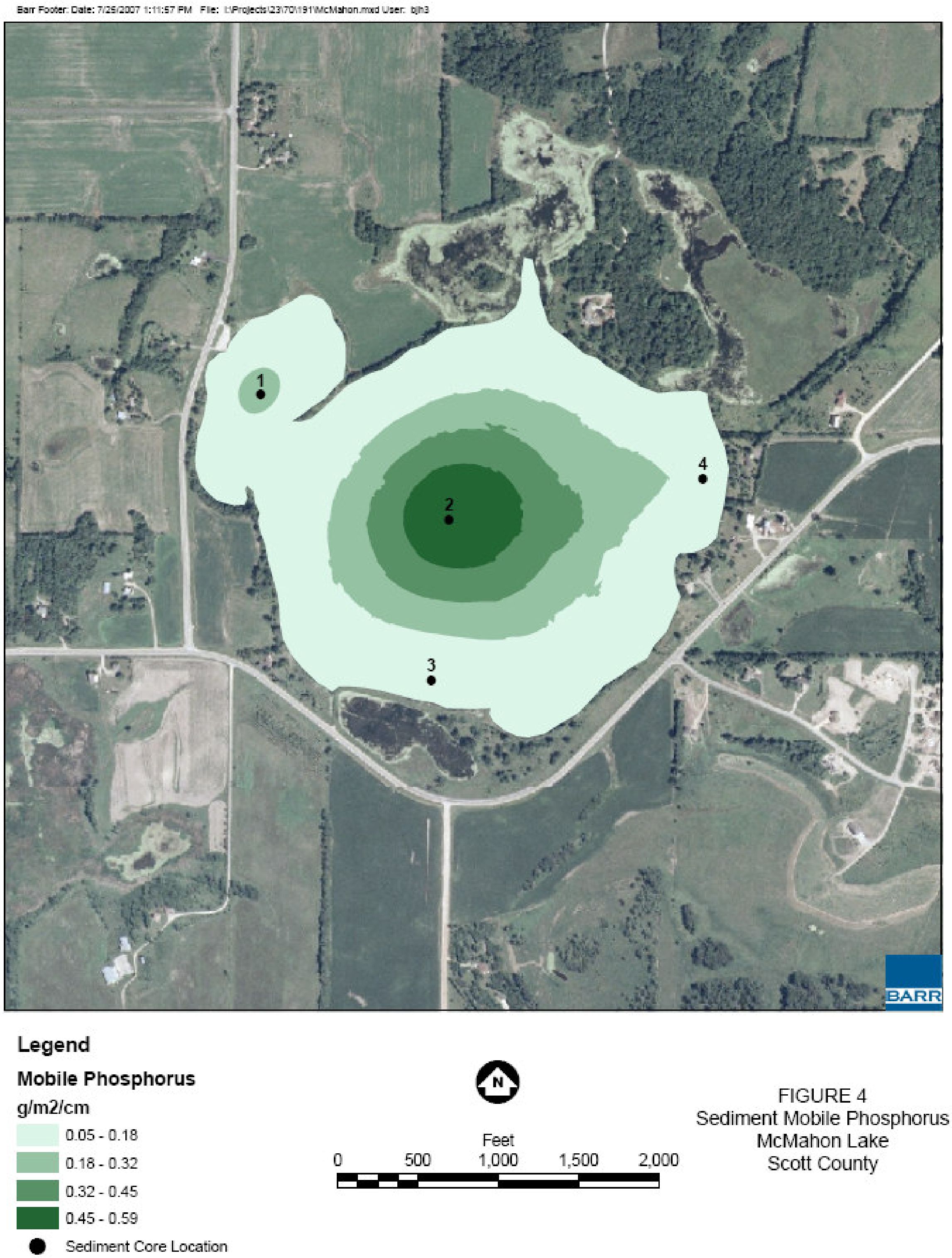


Figure 4. Modeled sediment mobile phosphorus concentrations in McMahon Lake



Estimated Phosphorus Mass Loading to the Water Column

Summer phosphorus loading to Cedar and McMahon Lakes was calculated based on the average internal loading estimates calculated in this study. The results are presented in Table 1.

Anoxic period was estimated at 90 days and lake areas were determined using ArcMap GIS software. Using these figures and sediment mobile phosphorus content, internal phosphorus loading contributes approximately 147 kg of phosphorus in Cedar Lake and 92 kg of phosphorus in McMahon Lake. These numbers are estimates and are dependent upon a number of factors including in-lake chemistry (pH and dissolved oxygen) and sediment mixing (e.g. benthiverous fish).

Organic bound Phosphorus

Because organic phosphorus is elevated in the surficial sediment of both lakes, it is likely that a portion of the organic phosphorus will degrade over time, contributing to the mobile phosphorus pool. Using the concentrations determined from deeper sediment collected from each core, an estimated background concentration can be calculated for organic phosphorus. Any excess above this background amount has the potential to degrade (labile) and add to the mobile phosphorus pool over time. When labile organic phosphorus is taken into account, potential internal loading rates increase to 3.7 and 5.6 $mg/m^2/d$ for Cedar and McMahon Lakes, respectively (Table 1). However, it should be noted that the estimates using both mobile and organic phosphorus assume all of the labile organic phosphorus will degrade and be released at a comparable rate to mobile phosphorus.

Table 1. Internal sediment loading rates and mass export for Cedar and McMahon Lakes

	Cedar		McMahon	
	Mobile P	Mobile + Organic P	Mobile P	Mobile + Organic P
Loading Rate ($mg/m^2/d$)	0.52	3.7	1.8	5.6
Phosphorus Mass (kg)	149	1069	92.3	292

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Appendix D

Macrophyte Surveys

Cedar Lake, Scott County, Minnesota (Google Earth)

Aquatic Plant Surveys for Cedar Lake, Scott Co, Minnesota, 2007

[Early Summer Survey Conducted on May 18 and 29, 2007]
[Late Summer Survey Conducted on August 24, 2007]

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Report Prepared: February 2008

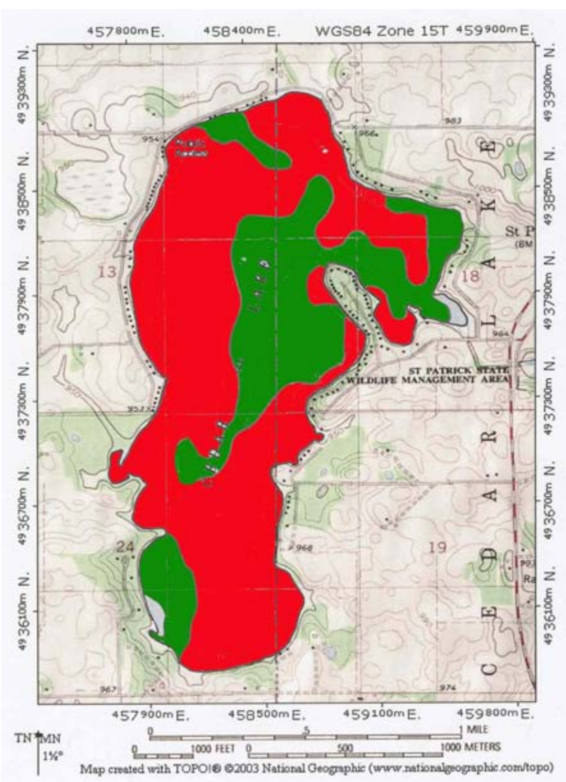
Aquatic Plant Surveys for
Cedar Lake, Scott Co, Minnesota, 2007

Summary

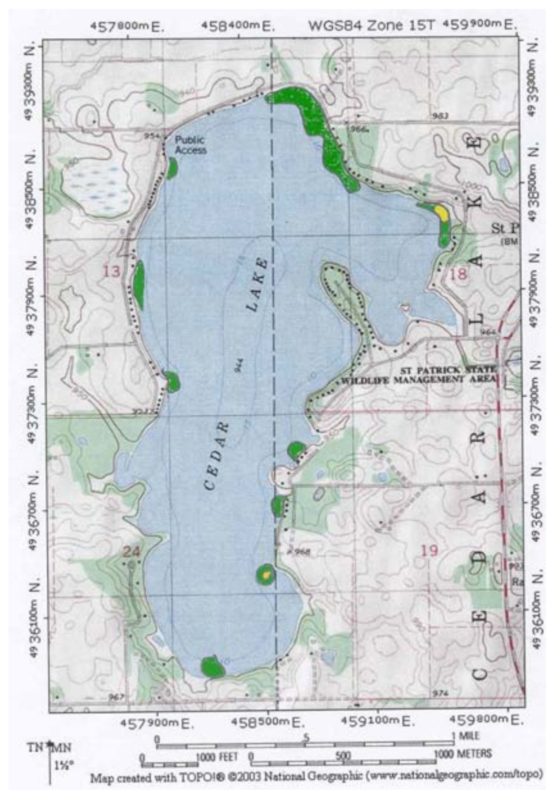
Cedar Lake (MnDNR ID: 70-0097) is a 780 acre lake located in Scott County. The coverage of aquatic plants for early summer and late summer conditions is shown below based on point-intercept plant surveys. Plants (primarily curlyleaf pondweed) grew out to 13 feet of water depth in early summer. In late summer, after curlyleaf died back, plants were found out to 5-feet of water depth.

Table 1. Summary of aquatic plant results from two plant surveys conducted in 2007.

	May 18, 2007 (Est. plant coverage: 771 ac)		August 24, 2007 (Est. plant coverage: 48 ac)	
	Occurrence (339 sites)	**Average Density**	**Occurrence (339 sites)**	**Average Density**
Coontail	--	--	1% (1)	2
Star duckweed	--	--	1% (1)	0.5
Curlyleaf pondweed	98% (333)	3.8	6% (20)	1.3
Sago pondweed	1% (1)	0.5	1% (1)	0.5



Early summer curlyleaf pondweed coverage. Nuisance growth is shown in red shading and light to moderate growth is shown in green shading.



Late summer aquatic plant coverage includes curlyleaf pondweed (green shading) and native plants (yellow shading).

Key to Curlyleaf Pondweed Growth Characteristics

(source: Steve McComas, Blue Water Science, unpublished)

Light Growth Conditions

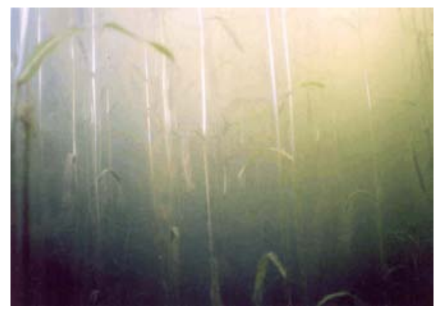
Plants rarely reach the surface.

Navigation and recreational activities are not generally hindered.

Stem density: 0 - 160 stems/m^2
Biomass: 0 - 50 g-dry wt/m^2
Estimated TP loading: <1.7 lbs/ac

MnDNR rake sample density equivalent for light growth conditions: 1, 2, or 3.

Moderate Growth Conditions



Broken surface canopy conditions.

Navigation and recreational activities may be hindered.

Lake users may opt for control.

Stem density: 100 - 280 stems/m^2
Biomass: 50 - 85 g-dry wt/m^2
Estimated TP loading: 2.2 - 3.8 lbs/ac

MnDNR rake sample density equivalent for moderate growth conditions: 3 or 4.

Heavy Growth Conditions

Solid or near solid surface canopy conditions.

Navigation and recreational activities are severely limited.

Control is necessary for navigation and/or recreation.

Stem density: 400+ stems/m^2
Biomass: >300 g-dry wt/m^2
Estimated TP loading: >6.7 lbs/ac

MnDNR rake sample density has a scale from 1 to 4. For heavy growth conditions where plants top out at the surface, the scale has been extended: 4.5 is equivalent to a near solid surface canopy and a 5 is equivalent to a solid surface canopy.

Cedar Lake, Scott County (ID:70-0091)

Lake Area: 779.5 acres (MnDNR)
Littoral Area: 779.5 acres (MnDNR)
Maximum depth: 13 ft (MnDNR)

Introduction

Cedar Lake is a large lake in Scott County and has had reports of non-native aquatic plant growth in the past with curlyleaf pondweed as the dominant non-native plant. The objective of the 2007 plant evaluation was to conduct two plant surveys to characterize the aquatic plant community of Cedar Lake in early summer and then to resample the plants in late summer.

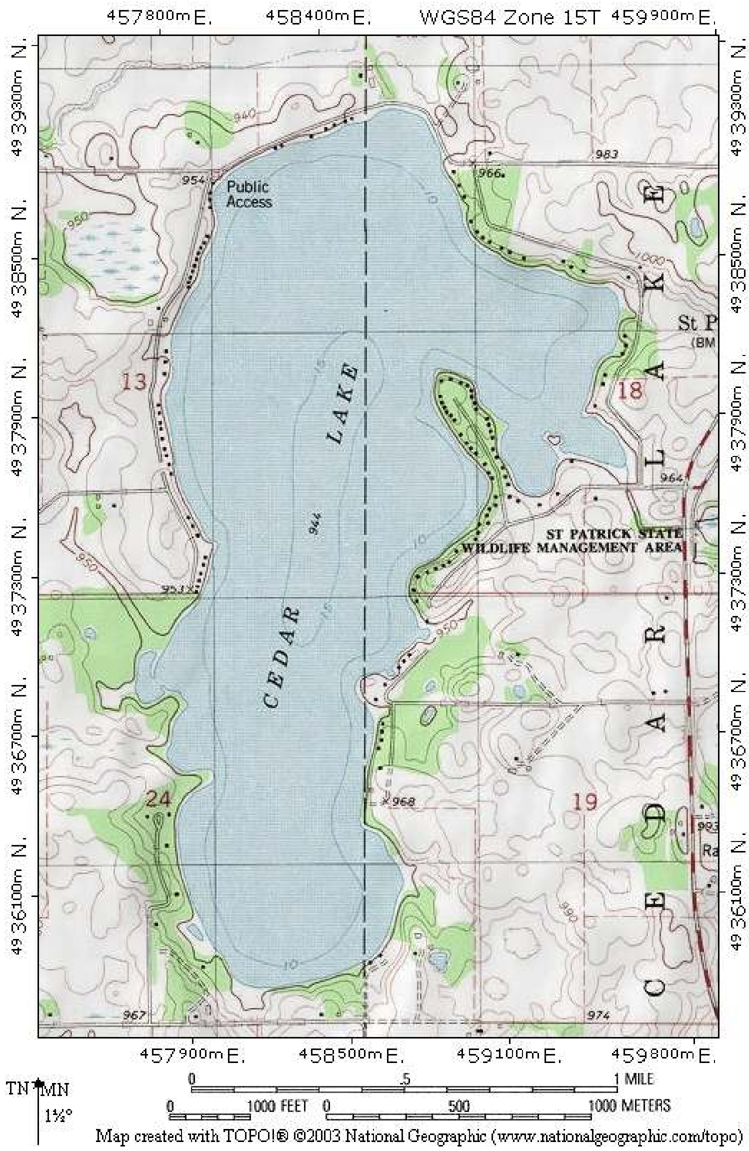


Figure 1. Contour map.

Methods

Two aquatic plant surveys of Cedar Lake were conducted by Blue Water Science in 2007. The early season survey was conducted on May 18 and 29, 2007. The late summer survey was conducted on August 24, 2007. Each survey used a point-intercept survey method. A map was prepared by Blue Water Science and a consisted of a total of 340 points that were distributed throughout the lake (Figure 2). Points were spaced 100 meters apart and each point represented an average of 2.3 acres of lake surface area (779 littoral acres ÷ 340 points = 2.3 ac/pt). GPS coordinates used a UTM WGS84 datum. For each survey, the maximum depth of plant growth was found in the course of sampling. Then one point deeper was checked as well. For the May survey, plants were found to 13 feet and all 340 sites were sampled. In the August survey, all sites were checked. At each sample point, plants were sampled with a rake sampler. A MnDNR plant density rating was assigned to each plant species on a scale from 1 to 4. A 4.5 or 5 rating indicated matting surface plant growth. Visual observations of surface growth were mapped in the field using a hand held GPS to verify locations.

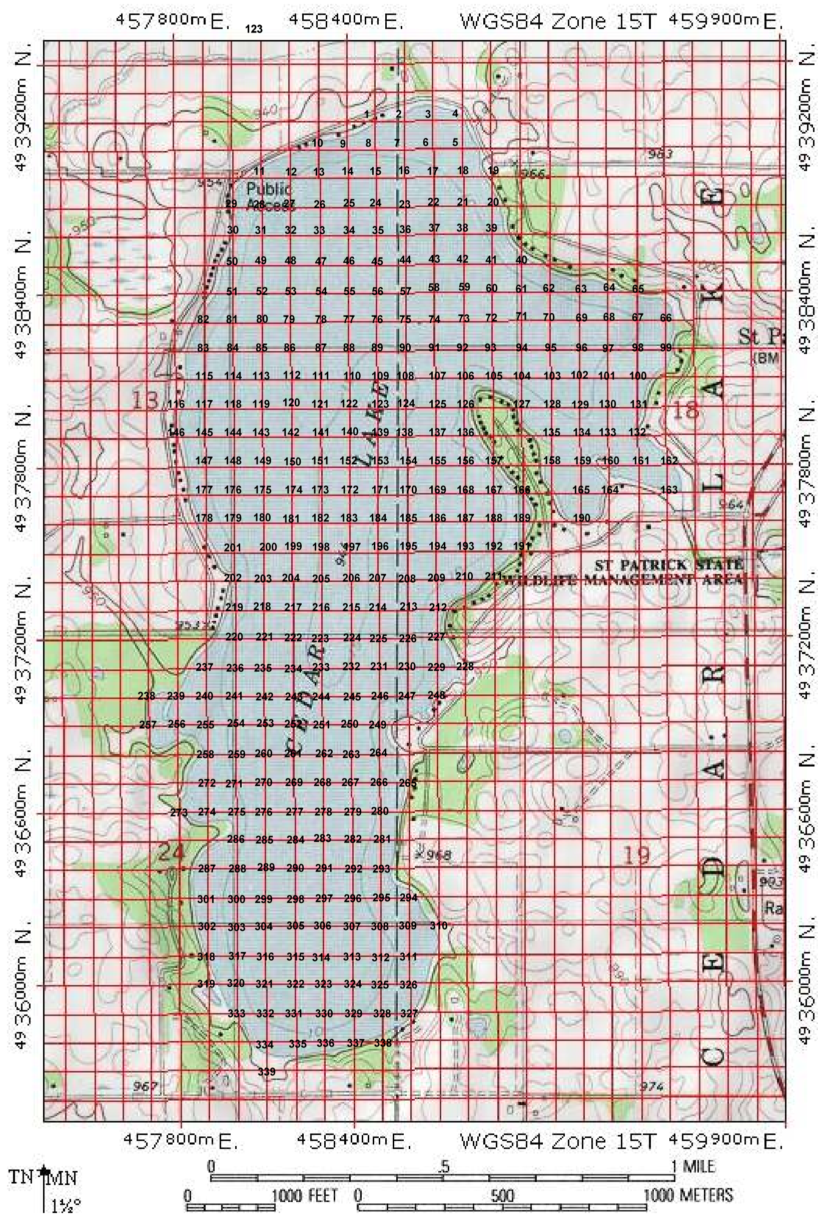


Figure 2. Point locations for the aquatic plant surveys. Lake map with UTM coordinates using the WGS84 datum.

Results of the May 18 & 29, 2007 Aquatic Plant Survey

Results of the early summer aquatic plant survey conducted on May 18, 2007 found that curlyleaf pondweed was the dominant plant in the lake (Table 1).

Results from the point-intercept plant survey found that plants grew out to depth of 13 feet (Table 2 and Figure 3). Curlyleaf was found in depths from 2 to 13 feet. Sago pondweed was found growing in one location in 2 feet of water.

The coverage of curlyleaf pondweed was estimated at 771 acres (Figure 3). The coverage of heavy growth of curlyleaf was estimated at 534 acres out of the 771 acres of curlyleaf.

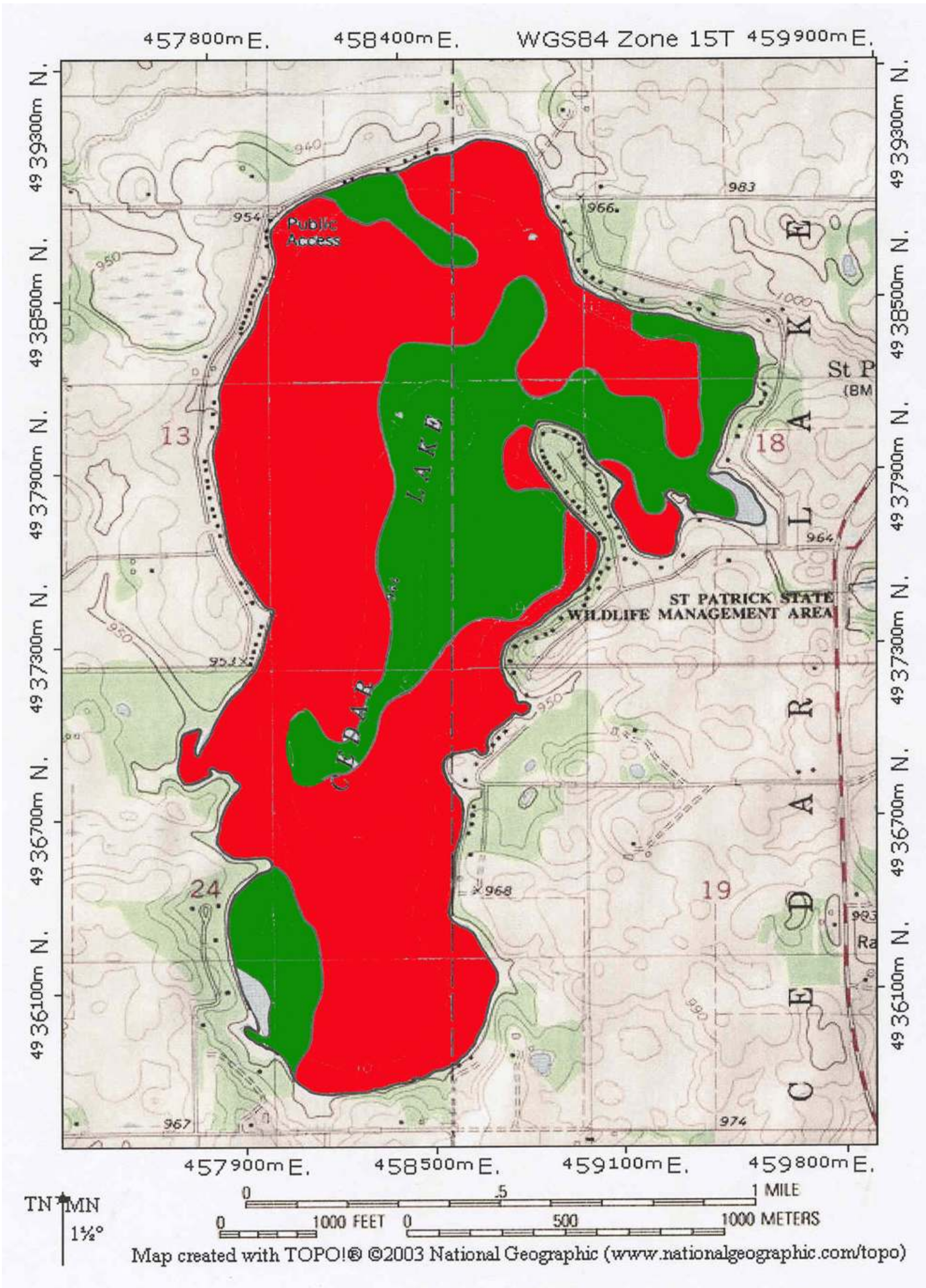
Table 1. Cedar Lake aquatic plant occurrences and densities for the May, 2007 survey based on 339 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

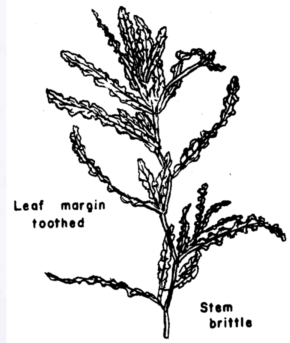
	All Stations (n=339)		
	Occur	% Occur	Density
Curlyleaf pondweed (*Potamogeton crispus*)	333	98	3.8
Sago pondweed (*Stuckenia pectinata*)	1	1	0.5

Table 2. Occurrence of plants by depth in Cedar Lake out to a depth of 11 feet.

Depth (feet)	Number of Sites	Curlyleaf Pondweed	Sago Pondweed	Average Number of Species per Site
1	0	0		0
2	3	1	1	0.7
3	11	10		0.9
4	10	10		1
5	36	36		1
6	17	17		1
7	18	16		0.9
8	47	47		1
9	65	64		1
10	72	72		1
11	40	40		1
12	18	18		1
13	2	2		1
All Depths	339	333	1	

Individual point intercept data for Cedar Lake plants are shown in the Appendix. Curlyleaf was the only plant found at a site. Heavy nuisance curlyleaf growth was typically found in water depths five to eight feet. Areas with nuisance growth, as defined with a density of a "4.5" or a "5" are shown with red shading in Figure 3. Heavy growth covered about 534 acres out of the 771 acres covered by curlyleaf.





Curlyleaf pondweed

Figure 3. Curlyleaf pondweed coverage map for May 18 & 29, 2007. Curlyleaf pondweed covered about 771 acres. Light to moderate growth of curlyleaf is shown in green and heavy growth is shown in red.

Figure 4. [top] On May 18, curlyleaf pondweed was sampled with rakes at a density of a 3. [middle] On May 18, curlyleaf pondweed was widespread and growing to the surface in many areas. [bottom] On May 29, surfacing curlyleaf pondweed.

Results of the August 24, 2007 Aquatic Plant Survey

Results of the late summer aquatic plant survey (August 24, 2007) found vegetation conditions changed considerably compared to the early summer survey. The biggest change was the collapse of curlyleaf pondweed community.

Four submerged vascular aquatic plant species were identified in the late summer survey (Table 3). The most common plants were curlyleaf pondweed which had resprouted at 20 sites, coontail, sago pondweed, and star duckweed. The curlyleaf that was dominant while native aquatic plant growth was sparse. Total aquatic plant coverage was estimated at 48 acres and native plant coverage was about 6 acres.

Table 3. Cedar Lake aquatic plant occurrences and densities for the August 24, 2007 survey based on 37 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	All Stations (n=339)		
	Occur	% Occur	Density
Coontail (*Ceratophyllum demersum*)	1	1%	2.0
Star duckweed (*Lemna trisulca*)	1	1%	0.5
Curlyleaf pondweed (*Potamogeton crispus*)	20	6%	1.3
Sago pondweed (*Stuckenia pectinata*)	1	1%	0.5

Table 4. Occurrence of plants by depth in Cedar Lake on August 24, 2007.

Depth (feet)	Number of Sites	Coontail	Star Duckweed	Curlyleaf Pondweed	Sago Pondweed
1	0				
2	3	1		1	1
3	11			1	
4	10		1	7	
5	38			6	
6	17				
7	18			5	
8	47				
9	65				
10	72				
11	40				
12	18				
13	2				
All Depths	339	1	1	20	1

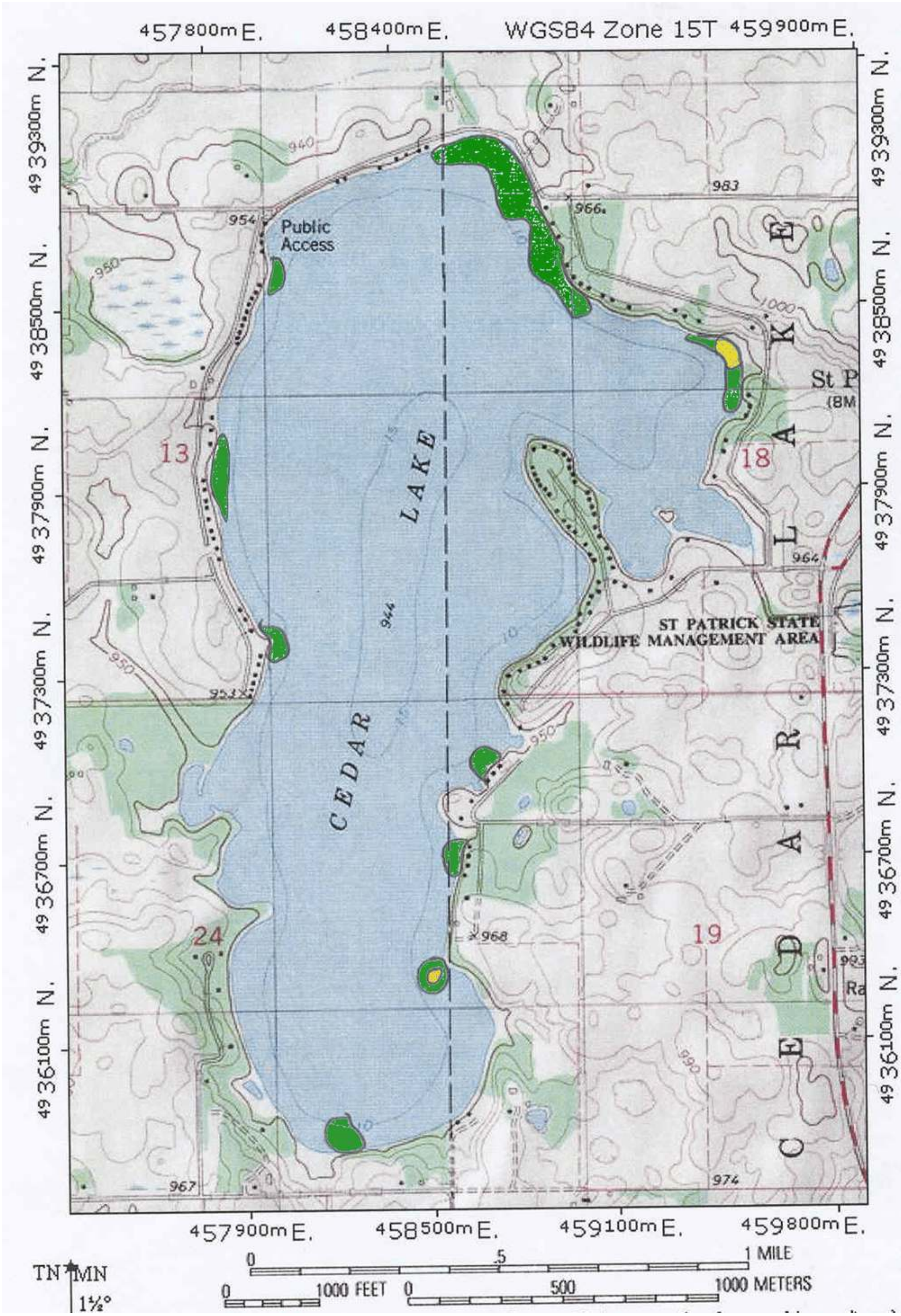


Figure 5. Aquatic plant distribution in Cedar Lake on August 24, 2007. Green shading represents curlyleaf pondweed and yellow shading represents native plants.

Figure 6. [top] Curlyleaf pondweed had resprouted at 20 sites in Cedar Lake. [middle] Curlyleaf pondweed was only 5 to 7 inches long where it was found. [bottom] Coontail was found at one site on August 24, 2007.

Summary

Cedar Lake (MnDNR ID: 70-0091) is a 780 acre lake located in Scott County. The coverage and occurrence of aquatic plants for early summer and late summer conditions were based on point-intercept plant surveys. A curlyleaf pondweed check was conducted on May 18. Plants (primarily curlyleaf pondweed) grew out to 11-feet of water depth in early summer. Curlyleaf pondweed is a plant of concern by lake residents in Cedar Lake. In 2007, there was an estimated total of 771 acres of curlyleaf with 534 acres of heavy growth.

In late summer, after curlyleaf died back, plants were found out to 5-feet of water depth. Curlyleaf pondweed was still the dominant plant in August, 2007 (Table 5).

Table 5. Summary of aquatic plant results from two plant surveys conducted in 2007.

	May 18, 2007 (Secchi disc: feet) (Est. plant coverage: 771 ac)		August 24, 2007 (Secchi disc: feet) (Est. plant coverage: 48 ac)	
	Occurrence (and Percent Occurrence) (339 sites)	Average Density	Occurrence (and Percent Occurrence) (339 sites)	Average Density
Coontail	–	--	1 (1%)	2
Star duckweed	–	--	1 (1%)	0.5
Curlyleaf pondweed	333 (98%)	3.8	20 (6%)	1.3
Sago pondweed	1 (1%)	0.5	1 (1%)	0.5

Cedar Lake, Scott County, May 18 and 29, 2007

Site	Depth ft	Curlyleaf Pondweed	Sago Pondweed
1	3	3	
2	5	5	
3	3	5	
4	4	4	
5	5	4	
6	6	4	
7	6	4	
8	7	4	
9	9	3.5	
10	9	3	
11	7	4	
12	8	4	
13	9	4	
14	9	4	
15	10	4	
16	10	4	
17	11	3	
18	9	4	
19	5	4	
20	6	4	
21	8	4	
22	9	4	
23	9	3.5	
24	8	3	
25	8	4	
26	8	4	
27	7	4	
28	7	4	
29	6	4	
30	5	5	
31	9	4	
32	9	4	
33	10	4	
34	10	4	
35	10	4	
36	11	4	
37	11	4	
38	8	4	
39	7	4	
40	5	4	
41	10	4	
42	8	3.5	
43	10	4	
44	11	4	
45	11	4	
46	11	4	
47	10	4	
48	10	4	
49	9	4	
50	6	4.5	
51	7	4	
52	9	4	
53	10	4	
54	10	4	
55	11	4	
56	10	4	
57	10	3.5	
58	9	3	
59	9	3.5	
60	9	4	
61	9	4	
62	9	4	
63	8	3.5	
64	7	3.5	
65	6	2	
66	5	1.5	
67	7	3	
68	8	4	
69	9	4	
70	10	4	
71	9	4	
72	10	4	
73	10	3	
74	10	3.5	
75	11	3	
76	10	3.5	
77	10	3	
78	9	4	
79	9	4	
80	10	4	
81	9	4	
82	6	4	
83	7	4	
84	9	4	
85	10	4	
86	10	4	
87	8	3	
88	9	3.5	
89	10	3	
90	10	2	
91	10	3.5	
92	9	3	
93	9	4	
94	9	3	
95	9	4	
96	8	4	
97	8	4	
98	6	1	
99	4	0.5	
100	5	0.5	
101	8	4	
102	9	3.5	
103	9	3.5	
104	9	3.5	
105	6	2.5	
106	9	2.5	
107	9	3	
108	9	3	
109	10	3	
110	12	3	
111	12	3.5	
112	11	4	
113	10	4	
114	9	4	
115	8	4	
116	5	5	
117	8	4.5	
118	9	4	
119	10	4	
120	11	4	
121	11	4	
122	11	3	
123	12	3	
124	11	3	
125	7	4	
126	4	4	
127	3	1	
128	8	3.5	
129	8	1.5	
130	6	4	
131	4	1.5	
132	2		0.5
133	5	1.5	
134	6	3.5	

Cedar Lake, Scott County, May 18 and 29, 2007

Site	Depth ft	Curlyleaf Pondweed	Sago Pondweed
135	5	4	
136	9	5	
137	8	4	
138	10	3	
139	11	3	
140	11	3	
141	12	4	
142	12	4	
143	11	4	
144	10	4	
145	8	4	
146	5	5	
147	5	5	
148	8	5	
149	10	4	
150	11	4	
151	10	4	
152	10	3	
153	11	3.5	
154	10	3.5	
155	9	3.5	
156	9	3	
157	9	3	
158	3	5	
159	4	1.2	
160	3	5	
161	3	1	
162	3		
163	2		
164	2	4	
165	3	5	
166	8	4	
167	10	2	
168	11	3	
169	12	3	
170	12	3	
171	11	2	
172	11	1	
173	13	3.5	
174	10	4	
175	9	4	
176	8	5	
177	5	5	
178	5	5	
179	8	5	
180	9	5	
181	10	4	
182	11	4	
183	10	3	
184	11	2	
185	12	3	
186	12	1	
187	11	2	
188	9	3	
189	8	3	
190	3	4	
191	8	4	
192	9	3	
193	10	3	
194	12	3.5	
195	12	3	
196	12	3	
197	12	3.5	
198	11	4	
199	11	4	
200	8	4	
201	5	5	
202	5	4.5	
203	8	4	
204	11	4.5	
205	11	4	
206	10	3	
207	11	3.5	
208	10	3	
209	10	3	
210	10	3.5	
211	9	4	
212	7	4	
213	10	4	
214	11	3	
215	12	3	
216	11	4	
217	10	4	
218	10	4	
219	6	4	
220	8	4	
221	9	4	
222	10	3.5	
223	12	3	
224	13	2	
225	12	4	
226	11	4	
227	7	4	
228	4	4	
229	5	4	
230	9	4	
231	11	4	
232	11	4	
233	10	3.5	
234	10	5	
235	10	4	
236	9	4	
237	5	4	
238	5	5	
239	5	5	
240	5	5	
241	9	3	
242	10	3	
243	10	3.5	
244	11	4	
245	12	4	
246	11	4	
247	8	4	
248	4	4	
249	7	4	
250	9	4	
251	10	4	
252	11	4	
253	9	3.5	
254	10	3.5	
255	5	5	
256	5	5	
257	5	5	
258	5	5	
259	8	4	
260	12	4	
261	11	4	
262	10	4	
263	10	4	
264	8	4	
265	3	4	
266	8	4	
267	9	4	
268	10	4	
269	11	4	
270	9	4	

Cedar Lake, Scott County, May 18 and 29, 2007

Site	Depth ft	Curlyleaf Pondweed	Sago Pondweed
271	8	4	
272	5	5	
273	3	5	
274	6	5	
275	8	5	
276	9	4	
277	10	4	
278	10	4	
279	9	4	
280	8	4	
281	7	4	
282	10	4	
283	10	4	
284	10	4	
285	10	4	
286	10	4	
287	6	3	
288	7	2	
289	9	4	
290	11	4	
291	10	4	
292	10	4	
293	6	4	
294	4	5	
295	5	5	
296	9	4	
297	10	4	
298	10	4	
299	9	4	
300	8	3	
301	5	3	
302	8	2.5	
303	8	1	
304	9	3	
305	10	4	
306	10	4	
307	10	4	
308	10	4	
309	8	4	
310	5	5	
311	5	5	
312	5	5	
313	8	5	
314	9	4	
315	9	4	
316	8	3	
317	7	3	
318	4	2	
319	7		
320	7		
321	6	0.5	
322	9	1	
323	9	1	
324	9	1	
325	9	1	
326	8	5	
327	5	5	
328	5	5	
329	8	5	
330	8	5	
331	9	4	
332	8	4	
333	6	3	
334	8	2	
335	5	5	
336	5	5	
337	5	5	
338	8	5	
339	4	5	

Cedar Lake, Scott County, August 24, 2007

Site	Depth (ft)	Coontail	Curlyleaf Pondweed	Sago Pondweed	Star Duckweed	FA
62	2			0.5		
295	2	2	0.5			
99	2.5		1			
2	3		2			
3	3		2			
4	3		3			
19	3		2			
65	3		1			
66	3		1.5		0.5	
163	3					0.5
265	3		1			
5	4		2			
40	4		1			
116	4		0.5			
146	4		0.5			
202	4		1			
248	4		0.5			
18	5		1			
20	5		2			
30	5		1			
39	5		2			
335	5		1			
Average		**2.0**	**1.3**	**0.5**	**0.5**	**0.5**
occurrence	339	1	20	1	1	1
% occurrence (all sites)		1	6	1	1	1
occurrence	21	1	20	1	1	1
% occurrence (with plants)		5	95	5	5	5

McMahon Lake, Scott County, Minnesota (Google Earth)

Aquatic Plant Surveys for McMahon Lake, Scott Co, Minnesota, 2007

[Early Summer Survey Conducted on May 18 and 29, 2007]
[Late Summer Survey Conducted on September 4, 2007]

Prepared for:
Scott County, Minnnesota

Prepared by:
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Report Prepared: March 2008

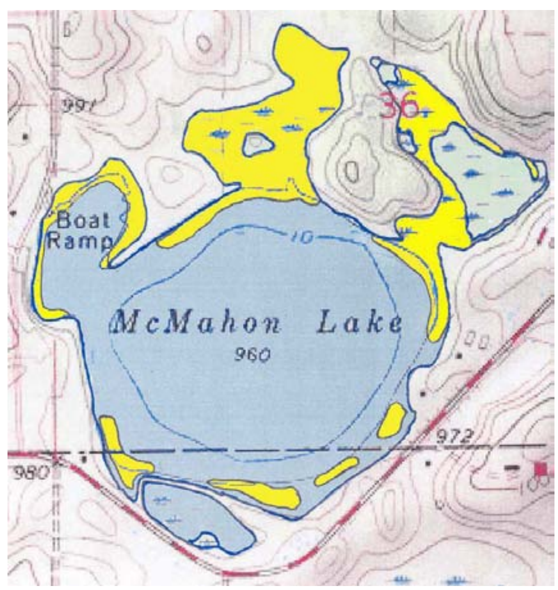
Aquatic Plant Surveys for McMahon Lake, Scott Co, Minnesota, 2007

Summary

McMahon Lake (MnDNR ID: 70-0050) is a 167 acre lake located in Scott County. The coverage of aquatic plants for early summer and late summer conditions is shown below based on point-intercept plant surveys. Plants (primarily curlyleaf pondweed) grew out to 12 feet of water depth in early summer. In late summer, after curlyleaf died back, plants were found out to 4-feet of water depth.

Table 1. Summary of aquatic plant results from two plant surveys conducted in 2007.

	May 18, 2007 (Secchi disc: 7.2 feet) (Est. plant coverage: 68 ac)			September 4, 2007 (Secchi disc: 2.0 feet) (Est. plant coverage: 52 ac)		
	Occurrence	Percent Occurrence (81 sites)	Average Density	Occurrence	Percent Occurrence (41 sites)	Average Density
White waterlily	--	--	--	18	44%	0.8
Coontail	--	--	--	10	24%	1.3
Elodea	--	--	--	4	10%	1.5
Eurasian watermilfoil	--	--	--	16	39%	1.5
Curlyleaf pondweed	72	89%	3.6	1	2%	0.5
Sago pondweed	--	--	--	3	7%	1.3
Filamentous algae	--	--	--	1	2%	1.0



[left] Early summer - curlyleaf pondweed coverage (red shading represents nuisance growth).
[right] Late summer aquatic plant coverage (includes curlyleaf pondweed and native plants).

Key to Curlyleaf Pondweed Growth Characteristics

(source: Steve McComas, Blue Water Science, unpublished)

Light Growth Conditions

Plants rarely reach the surface.

Navigation and recreational activities are not generally hindered.

Stem density: 0 - 160 stems/m^2
Biomass: 0 - 50 g-dry wt/m^2
Estimated TP loading: <1.7 lbs/ac

MnDNR rake sample density equivalent for light growth conditions: 1, 2, or 3.

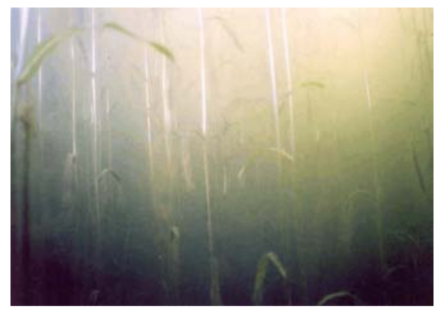
Moderate Growth Conditions

Broken surface canopy conditions.

Navigation and recreational activities may be hindered.

Lake users may opt for control.

Stem density: 100 - 280 stems/m^2
Biomass: 50 - 85 g-dry wt/m^2
Estimated TP loading: 2.2 - 3.8 lbs/ac



MnDNR rake sample density equivalent for moderate growth conditions: 3 or 4.

Heavy Growth Conditions

Solid or near solid surface canopy conditions.

Navigation and recreational activities are severely limited.

Control is necessary for navigation and/or recreation.

Stem density: 400+ stems/m^2
Biomass: >300 g-dry wt/m^2
Estimated TP loading: >6.7 lbs/ac

MnDNR rake sample density has a scale from 1 to 4. For heavy growth conditions where plants top out at the surface, the scale has been extended: 4.5 is equivalent to a near solid surface canopy and a 5 is equivalent to a solid surface canopy.

McMahon Lake, Scott County (ID:70-0050)

Lake Area: 167 acres (Blue Water Science)
Littoral Area: 167 acres (Blue Water Science)
Maximum depth: 14 ft (MnDNR)

Introduction

McMahon Lake is a recreational lake in Scott County. For overall lake management considerations, aquatic plants play an important role. There have not been recent plant surveys conducted in McMahon Lake. The objective of the 2007 plant evaluation was to conduct two plant surveys to characterize the aquatic plant community of McMahon Lake.

A USGS map for McMahon Lake is shown in Figure 1. The lake basin configuration has changed in recent years and the aerial photo with the present lake basin is shown on the right in Figure 1. For plant surveys conducted in 2007, the USGS map was revised to reflect the new lake basin configuration.

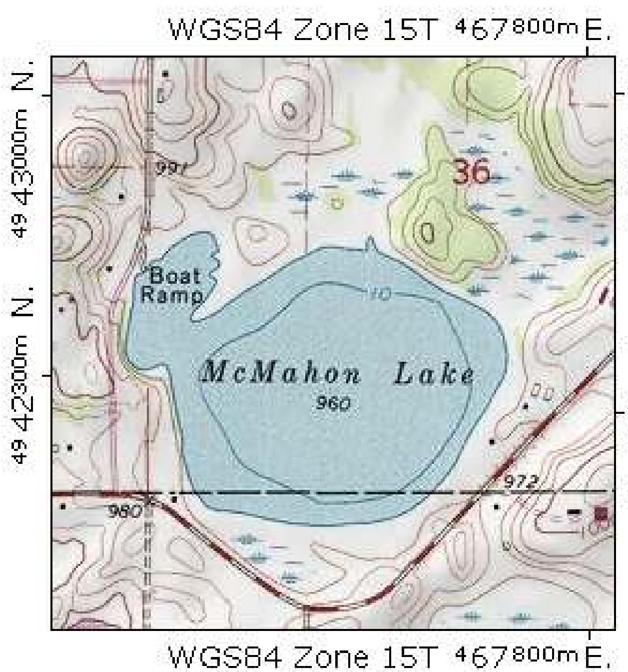


Figure 1. [left] U.S.G.S. topographic map of McMahon Lake, Scott County (1976).
[right] Aerial view of McMahon Lake, Scott County, Minnesota (source: Google Earth)(2007).

Methods

Two aquatic plant surveys of McMahon Lake were conducted by Blue Water Science in 2007. The early season survey was conducted on May 18 and 29, 2007. The late summer survey was conducted on September 4, 2007. Each survey used a point-intercept survey method. A map was prepared by Blue Water Science and a consisted of a total of 163 points that were distributed throughout the lake (Figure 2). Points were spaced 60 meters apart and each point represented an average of 1.0 acre of lake surface area (167 acres ÷ 163 points = 1.02 ac/pt). GPS coordinates used a UTM WGS84 datum. For each survey, the maximum depth of plant growth was found in the course of sampling. Then one point deeper was checked as well. For the May survey, plants were found to 12 feet and 81 sites were sampled at 12 feet or less. In the August survey, 81 sites were sampled again. At each sample point, plants were sampled with a rake sampler. A MnDNR plant density rating was assigned to each plant species on a scale from 1 to 4. A 4.5 or 5 rating indicated matting surface plant growth. Visual observations of surface growth were mapped in the field using a hand held GPS to verify locations.

Figure 2. Point locations for the aquatic plant surveys. Lake map with UTM coordinates using the WGS84 datum.

Results of the May 18 and 29, 2007 Aquatic Plant Survey

Results of the early summer aquatic plant survey conducted on May 18 and 29, 2007 found that curlyleaf pondweed was the only plant in the survey (Table 1). However Eurasian watermilfoil was observed at one location not on the grid. It's presence was confirmed by the MnDNR.

Results from the point-intercept plant survey found that plants grew out to depth of 12 feet (Table 2 and Figure 3). Curlyleaf was found in depths from 4 to 12 feet.

The coverage of curlyleaf pondweed was estimated at 68 acres (Figure 3). The coverage of heavy growth of curlyleaf was estimated at 39 acres out of the 68 acres of curlyleaf.

Table 1. McMahon Lake aquatic plant occurrences and densities for the May 18 and 29, 2007 survey based on 81 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	All Stations Sampled to Water Depth of 12 feet (n=81)		
	Occur	% Occur	Density
Curlyleaf pondweed (*Potamogeton crispus*)	72	89%	3.6

Table 2. Occurrence of plants by depth in McMahon Lake out to a depth of 12 feet. Number of sites sampled was 90 sites. Nine additional sites, shown in parenthesis, were inaccessible and not sampled in May 2007.

Depth (feet)	Number of Sites	Curlyleaf Pondweed	Average Number of Species per Site
1	0 (2)		
2	2 (3)	2	1
3	3 (1)	3	1
4	22 (3)	22	1
5	5	5	1
6	5	5	1
7	3	3	1
8	9	9	1
9	11	10	0.9
10	5	5	1
11	10	7	0.7
12	6	1	0.2
13	7	0	0
14	4	0	0
All Depths with plants	81	72	

Individual point intercept data for McMahon Lake plants are shown in the Appendix. Curlyleaf was the only plant found at a site. Nuisance curlyleaf growth was typically found in water depths out to five feet with abundant growth out to 8 feet. Individual sites with nuisance growth, as defined with a density of a "4.5" or a "5" are shown with red shading in Figure 3. Curlyleaf pondweed covered an estimated 68 acres and heavy growth of curlyleaf was estimated at 39 acres.

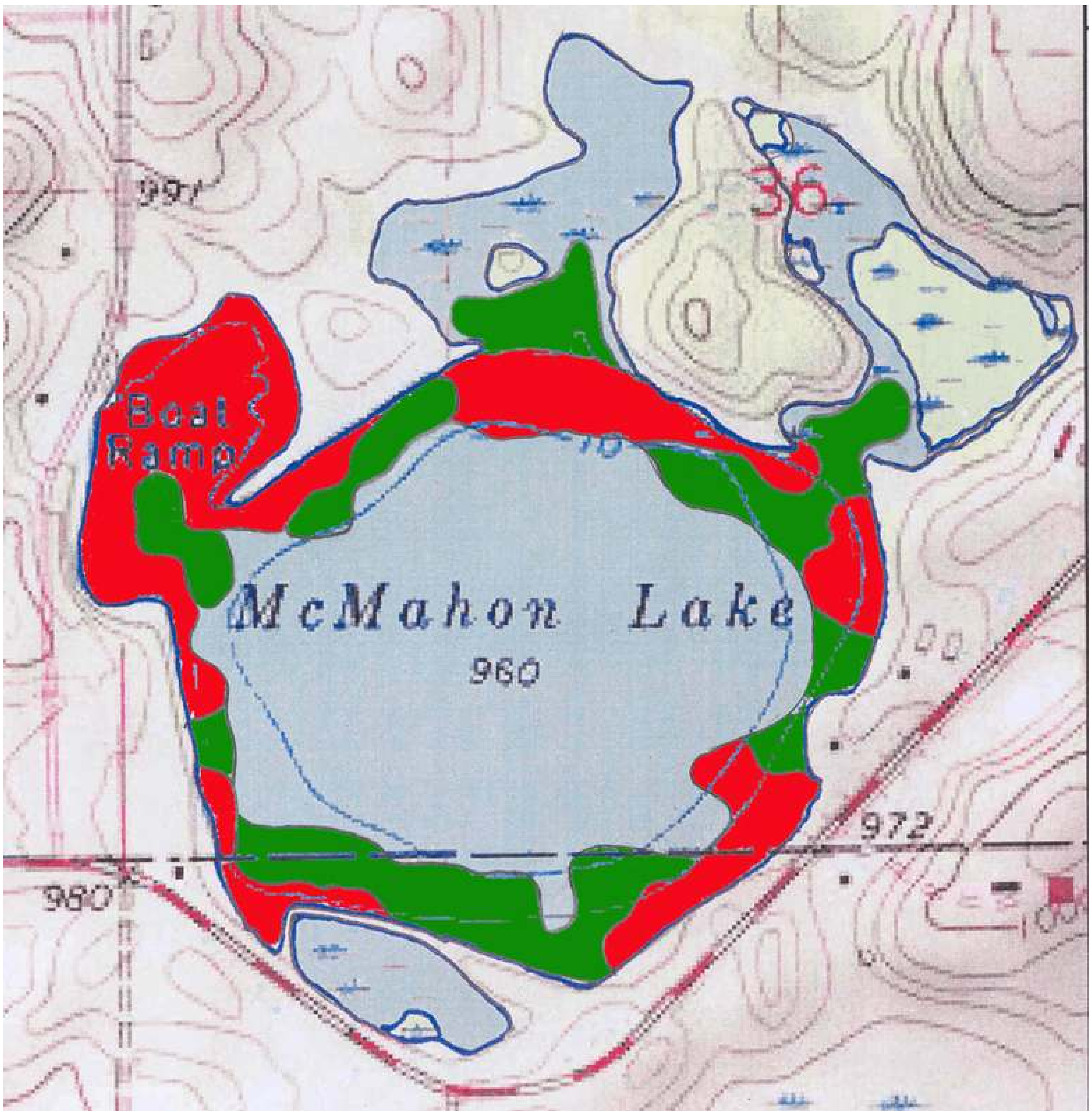


Figure 3. Curlyleaf pondweed coverage map for May 18 and 29, 2007. Curlyleaf pondweed coverage is shown in green with nuisance coverage shown in red. Curlyleaf pondweed covered about 68 acres.

Figure 4. [top] On May 18, 2007 curlyleaf pondweed was widespread and dense in some areas.
[middle] Curlyleaf topping out on May 18, 2007.
[bottom] May 29, 2007 conditions, looking north into the "new" lake area. This was not shown on the MnDNR lake map from 1971.

Results of the September 4, 2007 Aquatic Plant Survey

Results of the late summer aquatic plant survey (September 4, 2007) found vegetation conditions changed considerably compared to the early summer survey. The biggest change was the collapse of curlyleaf pondweed community and the increase in Eurasian watermilfoil.

Five submerged vascular aquatic plant species were identified in the late summer survey (Table 3). The most common plants were Eurasian watermilfoil and coontail. The curlyleaf that was found was sparse and had recently sprouted. It represented the new growth that will be present in 2008.

Overall, plant density was low and diversity was modest. The maximum depth of aquatic plant growth in McMahon Lake at the time of the survey was 7 feet. The bottom coverage of aquatic plants was estimated at 52 acres.

Table 3. McMahon Lake aquatic plant occurrences and densities for the September 4, 2007 survey based on 90 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	All Stations sampled to Water Depth of 4 feet (n=41)		
	Occur	**% Occur**	**Density**
White waterlily (*Nymphaea tuberosa*)	18	44%	0.8
Coontail (*Ceratophyllum demersum*)	10	24%	1.3
Elodea (*Elodea canadensis*)	4	10%	1.5
Eurasian watermilfoil (*Myriophyllum spicatum*)	16	39%	1.5
Curlyleaf pondweed (*Potamogeton crispus*)	1	2%	0.5
Sago pondweed (*Stuckenia pectinata*)	3	7%	1.3
Filamentous algae	1	2%	1.0

Table 4. Occurrence of plants by depth in McMahon Lake on September 4, 2007.

Depth (feet)	Number of Sites	White waterlily	Coontail	Elodea	Eurasian watermilfoil	Curlyleaf pondweed	Sago Pondweed	Average Number of Species per Site
1	2	2						0
2	7	4	2		3			1.5
3	15	4	3	2	8	1	2	1.5
4	17	8	5	2	5		1	0.7
5	5							0
6	5							0
7	3							0
8	9							0
All Depths with Plants	41	18	10	4	16	1	3	

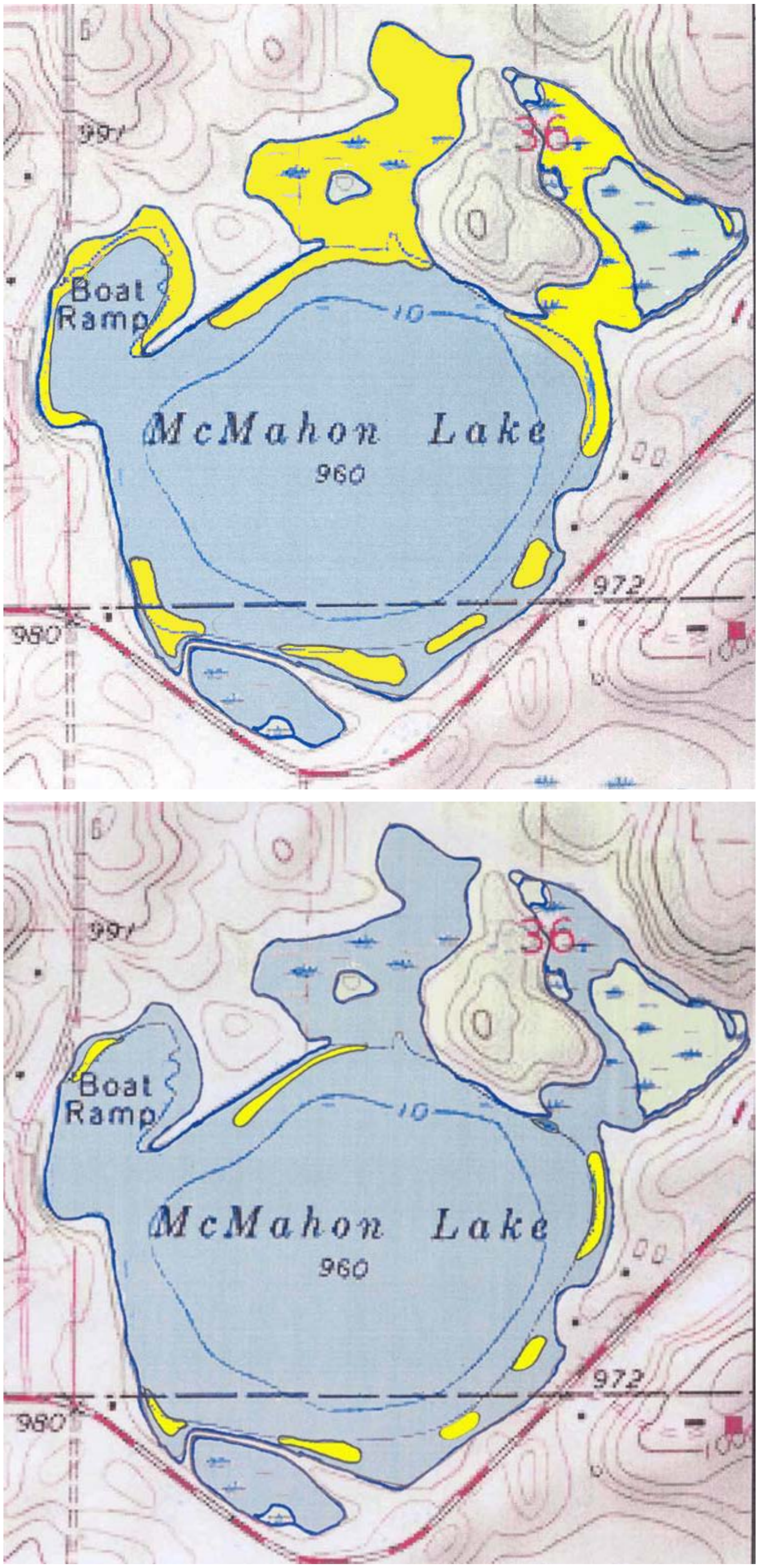


Figure 5. [top] Total aquatic plant coverage in the late summer survey of August 29, 2007 was estimated at 52 acres.
[bottom] Eurasian watermilfoil coverage on September 29, 2007.

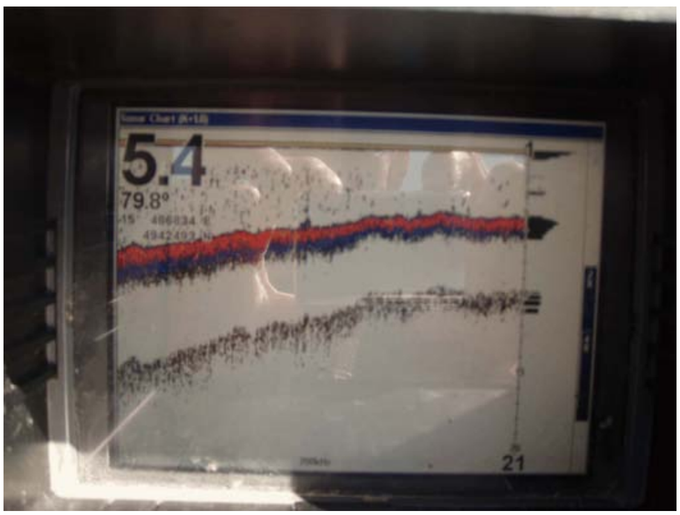


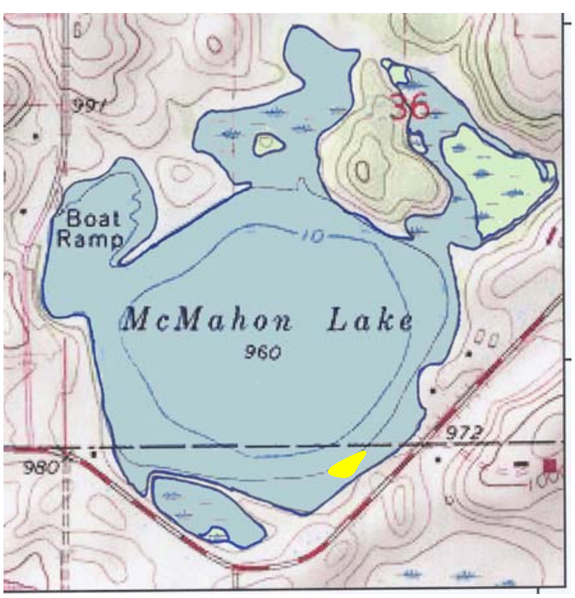
Figure 6. [top] Eurasian watermilfoil and coontail were the most common aquatic plants on September 4, 2007. [middle] Aquatic plants were not found in water deeper than 5-feet. The sonar picture shows no plants at 5.4 feet. [bottom] Sample of Eurasian watermilfoil from McMahon Lake. Eurasian watermilfoil was found in McMahon Lake in 2007.

Summary

McMahon Lake (MnDNR ID: 70-0050) is a 167 acre lake located in Scott County. The coverage and occurrence of aquatic plants for early summer and late summer conditions were based on point-intercept plant surveys. Plants (primarily curlyleaf pondweed) grew out to 12-feet of water depth in early summer. In late summer, after curlyleaf died back, Eurasian watermilfoil, which was first found in 2007, was the dominant plant. Plants were found out to 4-feet of water depth.

Table 5. Summary of aquatic plant results from two plant surveys conducted in 2007.

	May 18, 2007 (Secchi disc: 7.2 feet) (Est. plant coverage: 68 ac)			September 4, 2007 (Secchi disc: 2.0 feet) (Est. plant coverage: 52 ac)		
	Occurrence	Percent Occurrence (81 sites)	Average Density	Occurrence	Percent Occurrence (41 sites)	Average Density
White waterlily	--	--	--	18	44%	0.8
Coontail	--	--	--	10	24%	1.3
Elodea	--	--	--	4	10%	1.5
Eurasian watermilfoil	--	--	--	16	39%	1.5
Curlyleaf pondweed	72	89%	3.6	1	2%	0.5
Sago pondweed	--	--	--	3	7%	1.3
Filamentous algae	--	--	--	1	2%	1.0



Eurasian watermilfoil locations on May 29, 2007.

Eurasian watermilfoil locations on September 29, 2007.

May 18 and 29, 2007

Site	Depth (ft)	Curlyleaf Pondweed	No Plants	Number species	Species per site
1	2	4			
1.5	4	5		1	1.0
2	8	4		1	1.0
3	8	4.5		1	1.0
4	4	5		1	1.0
5	4	5		1	1.0
6	10	2		1	1.0
7	10	1.5		1	1.0
8	8	4		1	1.0
9	8	5		1	1.0
10	4	5		1	1.0
10.5	4	5		1	1.0
11	8	5		1	1.0
12	7	4.5		1	1.0
13	5	5		1	1.0
14	11	1		1	1.0
15	11	1.5		1	1.0
16	12		1		
17	11	4		1	1.0
18	11	3		1	1.0
19	9	4		1	1.0
20	6	4		1	1.0
21	6	4		1	1.0
22	11	1.5		1	1.0
23	12		1		
24	13		1		
25	13		1		
26	13		1		
27	13		1		
28	12		1		
29	4	4		1	1.0
30	2	5			
31	5	5			
32	4	5			
33	4	4		1	1.0
34	10	1		1	1.0
35	13		1		
36	13		1		
41	12	0.5		1	1.0
42	4	5		1	1.0
43	7	4		1	1.0
44	10	2			
49	14		1		
50	14		1		
51	9	4		1	1.0
52	6	3.5		1	1.0
53	4		X		
54	1		X		
55	4	3.5		1	1.0
56	12		1		
65	10	3		1	1.0
66	11	2		1	1.0
76	9	4		1	1.0
77	4		X		
78	4		X		
79	2		X		
80	3	2			
81	4	2			
82	8	4		1	1.0
83	14		1		
92	11	2		1	1.0
93	5	2			
94	11		1		
95	12		1		
104	6	4			
105	4	3			
106	4	2			
107	3		X		

May 18 and 29, 2007

Site	Depth (ft)	Curlyleaf Pondweed	No Plants	Number species	Species per site
108	2		X		
109	2		X		
110	1		X		
111	3	4			
112	8	4		1	1.0
122	9	3.5		1	1.0
123	5	3.5			
124	4	5		1	1.0
125	9	3.5		1	1.0
133	9	3.5		1	1.0
134	7	4		1	1.0
135	8	3.5		1	1.0
140	13		1		
141	8	4		1	1.0
142	14		1		
143	6	4			
145	4	4		1	1.0
146	9		1		
147	11		1		
148	11		1		
151	9	3.5		1	1.0
152	3	4			
154	4	4			
155	9	4		1	1.0
156	9	4			
157	5	3			
158	9	2		1	1.0
159	4	5		1	1.0
160	4	5		1	1.0
161	4	3			
162	4	3			
163	4	3			
Average Density		**3.6**			
Total sites (91)		72	20		
% occurrence (all sites)		72			
% occurrence (with plants)		89			

September 4, 2007

Site	Depth (ft)	White Waterlily	Coontail	Elodea	Eurasian Watermilfoil	Curlyleaf Pondweed	Sago Pondweed	No Plants	FA
1	2		2		2				1
1.5	6							1	
2	8							1	
3	8							1	
4	5							1	
10	4		1		1				
11	7							1	
12	7							1	
16	4							1	
17	4							1	
18	4							1	
19	3	0.5							
20	2		2		2				
21	3				2	0.5	2		
42	3				2				
43	4			1	1		1		
52	4				2				
53	4	3							
54	1	3							
55	4				2				
65	7							1	
66	9							1	
77	4	3	3						
78	4	3							
79	2	3							
80	3	3	3						
81	3		0.5						
92	7							1	
93	3			1	1		1		
94	2	1							
105	4	2	1	1					
106	4	4							
107	3	4							
108	2	4							
109	2	2							
110	1	2							
111	3	2							
122	2.5							1	
124	2				1				
134	4.5							1	
143	6							1	
145	3				1				
146	9							1	
152	3		1		1				
153	4		2						
154	3.5				2				
157	3			2	1				
158	3							1	
159	3				2				
160	3				2				
161	4	3							
162	4	3	2						
163	4	2							
Average		**2.6**	**1.8**	**1.3**	**1.6**	**0.5**	**1.3**		**1.0**
Occurrence (53 sites)		18	10	4	16	1	3	17	1
% occurrence (all sites)		34	19	8	30	2	6		2
Occurrence (36 sites)		18	10	4	16	1	3		1
% occurrence (sites with plants)		50	28	11	44	3	8		3