Middle St. Croix Watershed Management Organization 2015 Water Monitoring Report

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

BCWD	Brown's Creek Watershed District
Benthic	Lake bottom
biweekly	Every other week
BMP	Best Management Practice
cf	cubic feet
cfs	cubic feet per second
Chl-*a*	Chlorophyll-*a*
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
Littoral	The area of a body of water where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow
MCES	Metropolitan Council Environmental Services
mg/L	milligram per liter
MN DNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MSCWMO	Middle St. Croix Watershed Management Organization
NCHFE	North Central Hardwood Forest Ecoregion
OHW	Ordinary High Water level
SOP	Standard Operating Procedure
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSI	Trophic State Index
TSMP	Trout Stream Mitigation Project
TSS	Total Suspended Solids
µg/L	microgram per liter
µmhos/cm	micromhos per centimeter
VSS	Volatile Suspended Solids
WCD	Washington Conservation District

EXECUTIVE SUMMARY

This report focuses on the summary and comparison of lake water quality data collected by the Washington Conservation District (WCD) in 2015 as well as previous years. In 2015 the Middle St. Croix Watershed Management Organization (MSCWMO) monitored both water quality and water surface elevation on McKusick Lake and Lily Lake. Seven inlets to Lily Lake were monitored to investigate the source of the majority of the nutrient load, findings will be presented in a separate report. Information from the Brown's Creek Diversion Structure stream monitoring site is also included in this report as this affects the water quality of McKusick Lake. The purpose of this monitoring is to assess and document current water quality conditions of the lakes, as well as continuing a long-term monitoring program that will enable the MSCWMO to identify trends associated with best management practices (BMPs) and land use changes in the watershed.

Lily Lake was classified as eutrophic (Table 2) and received a C+ grade in 2015 (Table 3). Lily Lake was above the North Central Hardwood Forest Ecoregion (NCHFE) range for chlorophyll-*a* (chl-*a*) and total Kjeldahl nitrogen (TKN), and within the NCHFE range for total phosphorous (TP) and Secchi disk transparency readings for the 2015 monitoring season. One of the twelve samples collected exceeded the MPCA threshold for TP, and six of the twelve samples collected exceeded the MPCA threshold for chl-*a*. Three of the Secchi disk transparency readings exceeded the MPCA threshold.

In 2015 McKusick Lake was classified as eutrophic (Table 2) and received a grade of C (Table 3). McKusick Lake was above the NCHFE range for chl-*a* and within the NCHFE range for TP, TKN, and Secchi disk transparency. Three of the fourteen water quality samples exceeded the MPCA shallow lake threshold for TP, and five samples exceeded the MPCA threshold for chl-*a*. Two Secchi disk transparency measurements exceeded the MPCA shallow lake threshold.

The Brown's Creek Diversion Structure site showed a decrease in discharge in 2015 to 46,276,327 cf from 53,519,017 cf in 2014. The phosphorus load increased from 392 lbs. in 2014 to 1,837 lbs. in 2015. TSS also showed an increased export to McKusick Lake, from 99,532 lbs.

in 2014 to 1,008,346 lbs. in 2015 (Table 6). The total discharge was the fifth highest recorded value since monitoring the Brown's Creek Diversion Structure began. The phosphorous load and TSS export in 2015 were the second highest recorded values in the last 10 years, in part due to a head cut identified on the South Branch of the diversion drainage.

In 2014 the MSCWMO discontinued monitoring of Brick Pond, Perro Creek and Perro Pond. The MSCWMO instead focused on problem investigation monitoring strategies for Lily Lake and Brick Pond that began in 2015 and will continue in 2016. This approach will enable the MSCWMO to better determine sources of pollutants and more effectively implement management strategies and practices to address those sources.

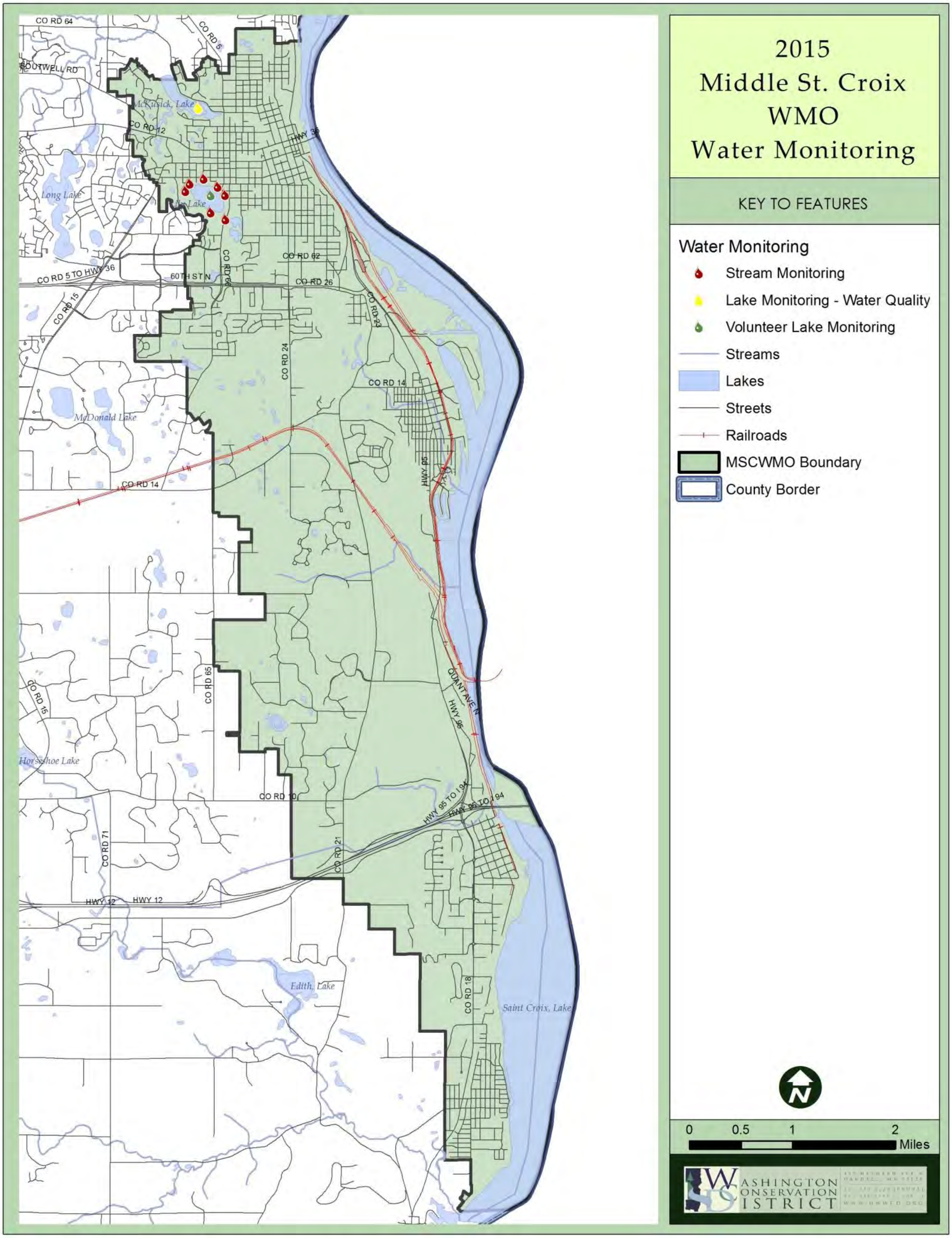

Figure 1. MSCWMO 2015 Water Monitoring Locations

LAKE MONITORING

A. METHODS, RESULTS AND DISCUSSION

In 2015 water quality data was collected biweekly on Lily and McKusick Lakes, over six consecutive months (May–October). Measurements obtained during the summer sampling season (June 1-September 30) are averaged for a comparison of individual lake dynamics from year to year between lakes within the watershed, and to the average NCHFE values. Average values for all parameters, as well as typical ranges for lakes in the NCHFE are presented in Appendix A, Figure 4, Figure 5, Figure 6, and Figure 7, which show the current and historic summer averages for each parameter. Water quality samples were collected with a two-meter (6.56 feet) integrated surface water column sampler. The MCES Laboratory analyzed the surface water samples for TP, chl-*a*, and total Kjeldahl nitrogen (TKN) on all MSCWMO lakes. A full description of WCD Standard Operating Procedures is available on the Washington Conservation District website at http://www.mnwcd.org/water-quality-water-monitoring/.

Total phosphorus is analyzed as it is a major nutrient involved in the eutrophication of lakes and is generally associated with the growth of aquatic plants and/or algal blooms. Common sources of phosphorus include runoff from agricultural fields, livestock areas, urban areas, lakeshore lawns, and improperly operating septic systems. With most lakes in this region, phosphorus is the least available nutrient; therefore, its abundance, or scarcity, controls the extent of algal growth. Algal growth, in turn, affects the clarity, or transparency, and ability of light to penetrate the water. The typical range of the NCHFE for TP is 0.023 – 0.050 mg/L. The MPCA sets lake eutrophication standards for aquatic recreation use. The standard for TP is 0.040 mg/L for deep lakes and 0.060 mg/L for shallow lakes. In general, shallow lakes are defined as <15 feet deep, with >80% littoral area, and >10 acres. The 2015 summer average of TP values of MSCWMO lakes can be found Figure 4.

Chlorophyll-*a* is measured as it is the photosynthetic component found in algae and aquatic plants and is an indication of algal productivity. The typical range of the NCHFE for chl-*a* is 5 – 22 µg/L. The MPCA standard for chl-*a* is 14 µg/L for deep lakes and 20 µg/L for shallow lakes. The 2015 summer average chl-*a* concentrations of MSCWMO lakes can be found in Figure 5.

Several forms of nitrogen exist in lakes; the form that is analyzed in MSCWMO lakes is TKN, which is the sum of organic nitrogen and ammonia. TKN is analyzed as it can increase the rate of lake eutrophication and can cause many health problems in the young and elderly. The NCHFE typical range for TKN is 0.60-1.20 mg/L. There is no impairment standard for TKN set by the MPCA because TP is the parameter used in their assessments. The 2015 summer average TKN concentrations of MSCWMO lakes can be found in Figure 6.

Table 1. North Central Hardwood Forest Ecoregion Values and Average 2015 Parameters

2015 MSCWMO Lakes Summer Averages (June-September)					
Lake/Units	**Total Phosphorus (mg/L)**	**Chlorophyll-*a* (µg/L)**	**Total Kjeldahl Nitrogen (mg/L)**	**Secchi Disk (meters)**	**Deep Or Shallow**
Eco-Region Value	*0.023-0.050*	*5.0-22.0*	*0.60-1.20*	*1.5-3.2*	
MPCA Deep Lake Impairment Threshold	*0.040*	*14.0*		*1.40*	
MPCA Shallow Lake Impairment Threshold	*0.060*	*20.0*		*1.00*	
Lily	*0.026*	*23.8*	*1.23*	*1.60*	Deep
McKusick	*0.051*	*37.3*	*0.92*	*1.37*	Shallow

No heavy metal testing was performed on samples collected on Mckusick Lake in 2015. Heavy metal samples were collected in 2012-2014 because many heavy metals are known to be chronically toxic to aquatic organisms. None of the samples collected exceeded the standards.

Field measurements are also recorded while collecting lake samples. Measurements include Secchi disk transparency, dissolved oxygen (DO) and temperature profiles, and lake elevation.

The measurement of light penetration using a Secchi disk gives a simple measure of water transparency, or clarity. It is an indication of turbidity in the water and an indication of the trophic state of the lake. A reduction in water transparency is typically the result of turbidity composed of suspended sediments, organic matter and/or phytoplankton (algae). Typical ranges for transparency in the NCHFE are between 1.5 – 3.2 meters. The MPCA standard for Secchi disk readings is 1.4 meters for deep lakes and 1.0 meters for shallow lakes.

User perception and physical/recreational suitability of lakes were recorded, along with temperature and dissolved oxygen profile measurements taken by the WCD during each sampling event. Profiles are recorded at one meter increments from the water surface to the lake bottom. The data show the extent of summer stratification and are useful in identifying the development of a thermocline (the layer of water in which the temperature rapidly declines). As a lake stratifies, the water column becomes more stable and mixing is less likely to occur. If mixing occurs during the growing season, nutrients from the bottom become available and can result in increased algal production. Lake DO profile data is useful in determining excessive production (algae/plants) in a lake. Increased production creates more DO, for a time, but as plants and algae die off and decay, they turn from producers of DO into consumers through the process of decomposition. Data collected from the rankings and profiles are contained in a database at the WCD, and can be obtained by request, as well as on the MPCA website at http://cf.pca.state.mn.us/water/watershedweb/wdip/index.cfm.

The Carlson Trophic State Index (TSI) is used to quantify the relationship between water quality data and trophic status. Many water quality scientists classify lakes according to their trophic state. Average summer values of TP, chl-*a*, and Secchi disk transparency are the parameters most often used to determine a lake's trophic state. Oligotrophic lakes, such as lakes common in the northeastern part of Minnesota, have low biological activity as a result of low phosphorus concentrations, low chl-*a* concentrations, and high Secchi disk transparency readings. Mesotrophic lakes have slightly more biological production, and are characteristic of the majority of the lakes found in the NCHFE of Minnesota. On the other end of the spectrum, lakes with high biological productivity characterized by high phosphorus concentrations, high chl-*a* concentrations, and low Secchi disk transparencies are classified as eutrophic or even hypereutrophic. Lakes classified as eutrophic or hypereutrophic typically receive excess nutrient loading from sources within their watersheds and receive large amounts of runoff from the surrounding drainage area. A percentage of these nutrients, however, can also be attributed to internal loading within the lake itself, which is typical of shallow, sediment-rich lakes (Table 2).

Table 2. Trophic State Index and Ranges

	Trophic State Index	TP (µg/L)	Chl-*a* (µg/L)	Secchi (m)
Oligotrophic	<40	<12	<2.6	>4.0
Mesotrophic	40-50	12 - 24	2.6 - 6.4	4.0 - 2.0
Eutrophic	50-70	24 - 96	6.4 - 56	2.0 – 0.5
Hypereutrophic	>70	>96	>56	<0.5

A Lake Grading System is also used in this report, to allow for a better understanding of lake water quality data and to aid in the comparison of lakes. The lake water quality grading system was developed following the 1989 sampling season by Dick Osgood, formerly of the Metropolitan Council. The concept of the lake grading system is a ranking of water quality characteristics by comparing measured values to those of other metro area lakes. The grading system represents percentile ranges for three water quality indicators: the June through September average values of TP, chl-*a*, and Secchi disk transparency. These percentiles use ranked data from 119 lakes sampled from 1980-1988 and are shown in Table 3. The variables used in the grading system strongly correlate to open-water nuisance aspects of a lake (i.e. algal blooms), which can indicate accelerated aging (cultural eutrophication). There is a good correlation when comparing the Lake Trophic Status and the Lake Grading System. Summaries of all lake results are presented in Appendix A.

Table 3. Lake Grade Ranges

Grade	Percentile	TP (ug/l)	CLA (ug/l)	SD (m)
A	<10	<23	<10	>3.00
B	10-29	23-31	10-19	2.20-3.00
C	30-69	32-67	20-47	1.20-2.19
D	70-90	68-152	48-77	0.70-1.19
F	>90	>152	>77	<0.70

A lake elevation gage, is located on two MSCWMO lakes, McKusick and Lily, and is compared to the lake's Ordinary High Water level (OHW)[1]. Both water bodies reflected significant decreases in elevation towards the end of the 2015 monitoring season, despite precipitation being above normal (Figure 8). Complete lake elevation data for 2015 can be found in Figure 2 and Figure 3. For historical lake elevations, visit the MN DNR Lake Finder webpage at http://www.dnr.state.mn.us/lakefind/index.html.

1. MCKUSICK LAKE

The McKusick Lake summertime average TP concentration in 2015 was 0.051 mg/L, lower than the 0.057 mg/L observed in 2014, with one of the nine summertime water quality samples collected exceeding the MPCA TP impairment standard for shallow lakes (Figure 4). McKusick Lake had a summertime average chl-*a* concentration of 37.3 μg/L, much higher than the chl-*a* average of 20.5 μg/L from 2014 and outside of the NCHFE range (Figure 5). Of the nine summertime samples collected in 2015, two exceeded the MPCA shallow lakes standard for chl-*a*. The average summertime TKN concentration for 2015 was 0.92 mg/L, slightly lower from the 0.94 mg/L measured in 2014 (Figure 6). There is no MPCA lake impairment standard for TKN. The 2015 summertime average water transparency measured by Secchi disk was 1.37 meters. All but one of the Secchi disk readings in 2015 was better than the MPCA lake impairment standard. Temperature and DO profiles indicate that McKusick Lake exhibited thermal stratification during the summer months of 2015 with the thermocline around 3 meters; therefore the lake was less likely to completely mix throughout the summer. The elevation of McKusick Lake remained above the OHW for the entire 2015 monitoring season, reaching its highest recorded level on 7/8/2015 with a level of 855.14 ft. and falling to its lowest recorded level on

[1] Minnesota State Statutes defines the ordinary high water level (OHW) as follows: Minnesota Statutes 103G.005 Subd. 14. Ordinary High Water Level. "Ordinary high water level" means the boundary of water basins, watercourses, public waters and public waters wetlands, and: The ordinary high water level is an elevation delineating the highest water level that has been maintained for a sufficient period of time to leave evidence upon the landscape, commonly the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial;

1) For watercourses, the ordinary high water level is the elevation of the top of the bank of the channel; and
2) For reservoirs and flowages, the ordinary high water level is the operating elevation of the normal summer pool.
3) For reservoirs and flowages, the ordinary high water level is the operating elevation of the normal summer pool.

8/18/2015 with an elevation of 853.99 ft. (Figure 2). Summaries of all lake results are presented in Appendix A.

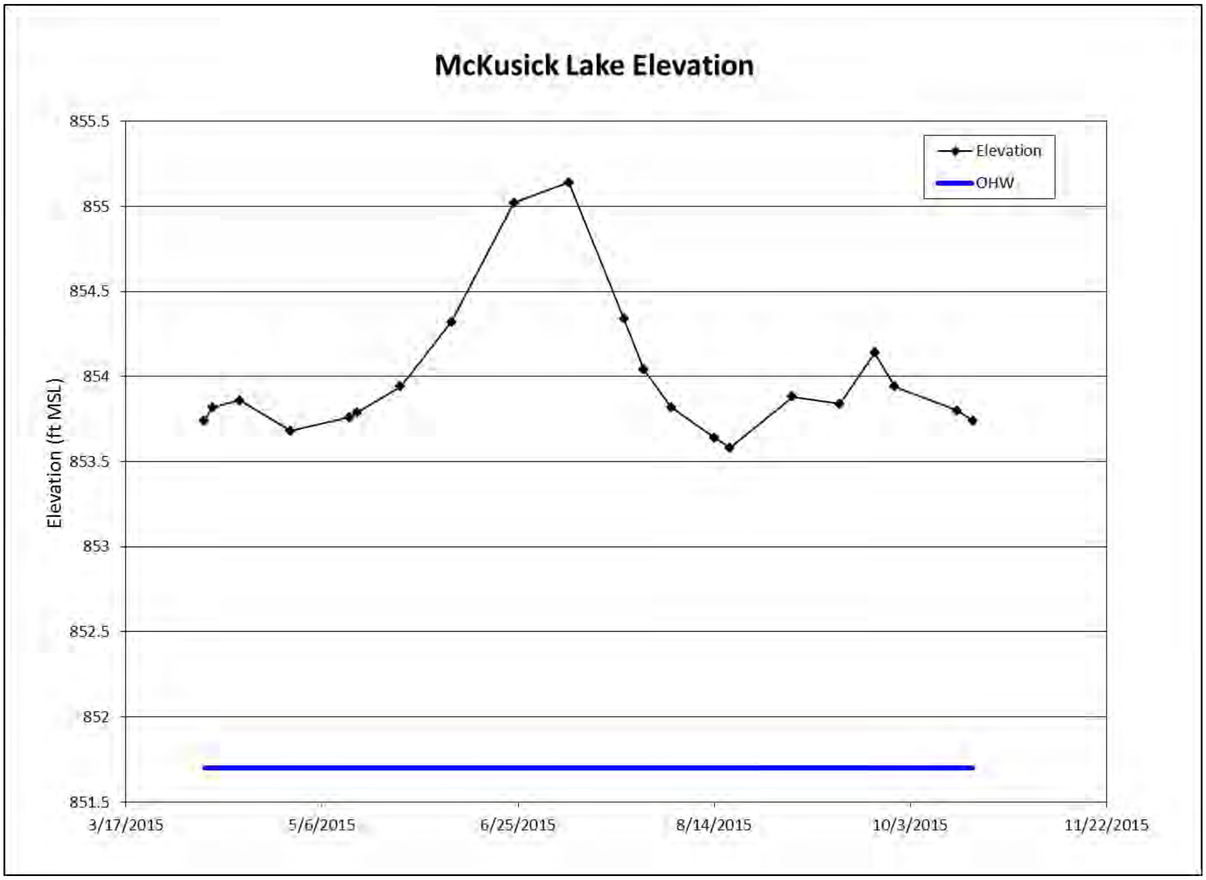

Figure 2. McKusick Lake 2015 Elevations

2. LILY LAKE

Lily Lake had an average summertime TP concentration of 0.026 mg/L, higher than the 2014 average summertime TP concentration of 0.021 mg/L, well below the MPCA lake nutrient impairment threshold for TP (Figure 4). One of the eight summertime results was greater than the MPCA lake nutrient impairment standard for TP. The 2015 average summertime concentration of chl-*a* was 23.8 µg/L, much higher than the 10.6 µg/L measured in 2014, with five of the eight water quality results exceeding the MPCA lake standard for chl-*a* impairment (Figure 5). Lily Lake had an average summertime TKN concentration of 1.23 mg/L in 2015, higher than the 0.81 mg/L seen in 2014 (Figure 6). There is no MPCA lake impairment standard for TKN. Secchi disk readings were measured in 2015 with a summertime average of 1.6

meters, with three of the eight water quality readings exceeding the MPCA lake standard for Secchi disk transparency impairment (Figure 7). Temperature and DO profiles were not collected for 2015 therefore, the thermocline cannot be determined. At the start of the monitoring season the water level of Lily Lake was below the OHW, falling to its lowest recorded level on 5/2/2015 with an elevation of 844.5 ft. The elevation then climbed above the OHW, reaching its highest recorded level on 7/11/2015 with a level of 845.9 ft. (Figure 3). Summaries of all lake results are presented in Appendix A.

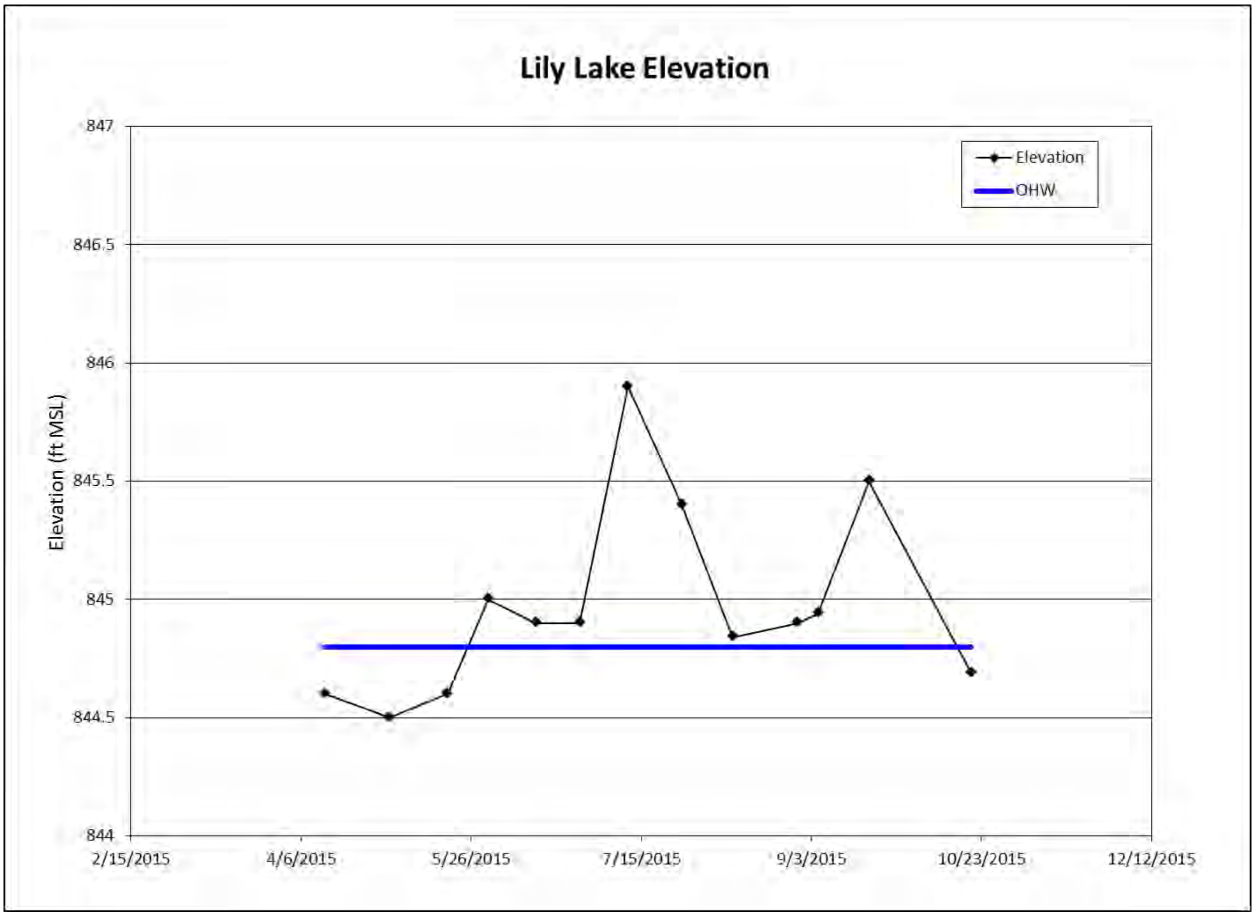

Figure 3. Lily Lake 2015 Elevations

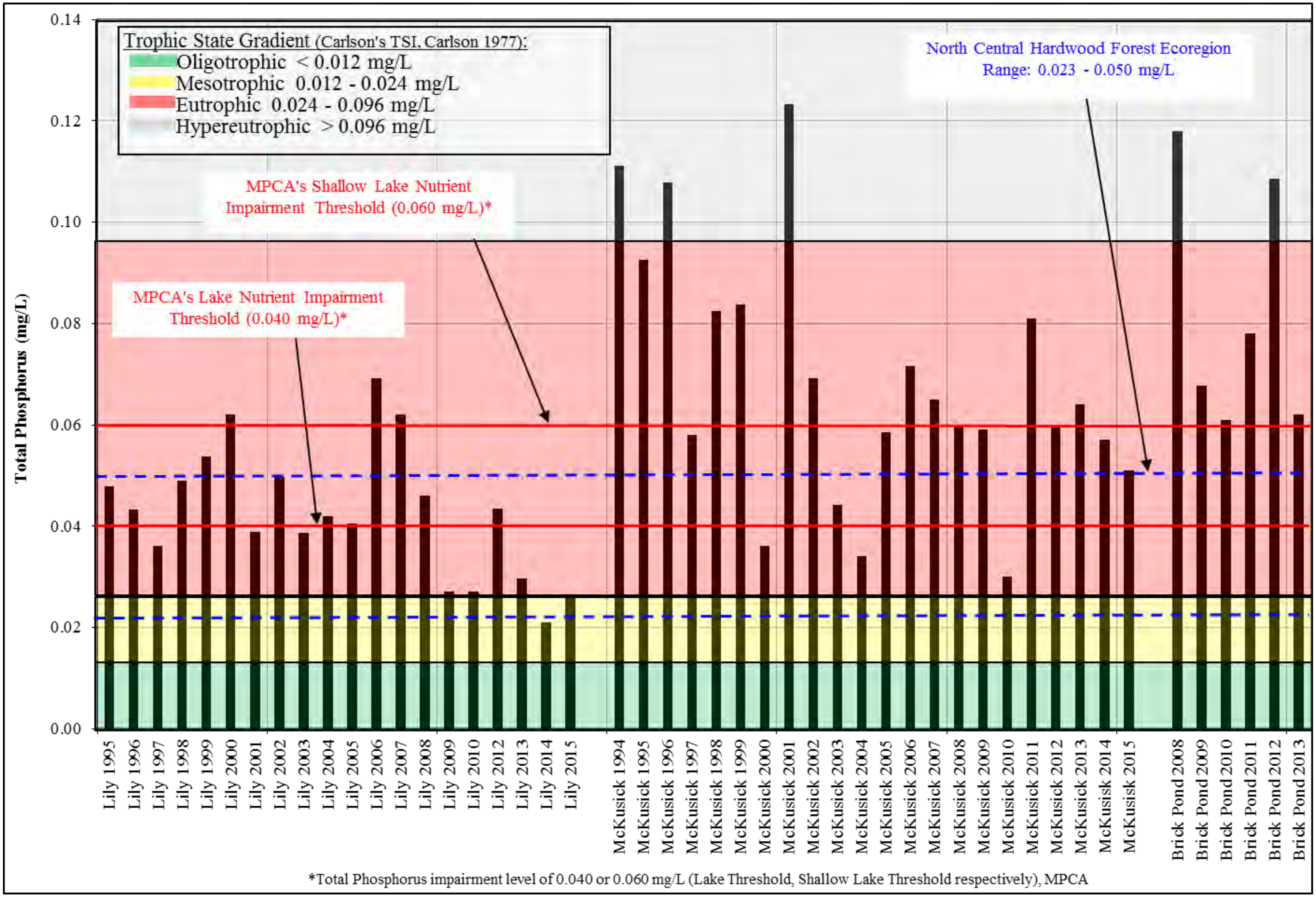

Figure 4. MSCWMO Historic Summer Average Total Phosphorus Data

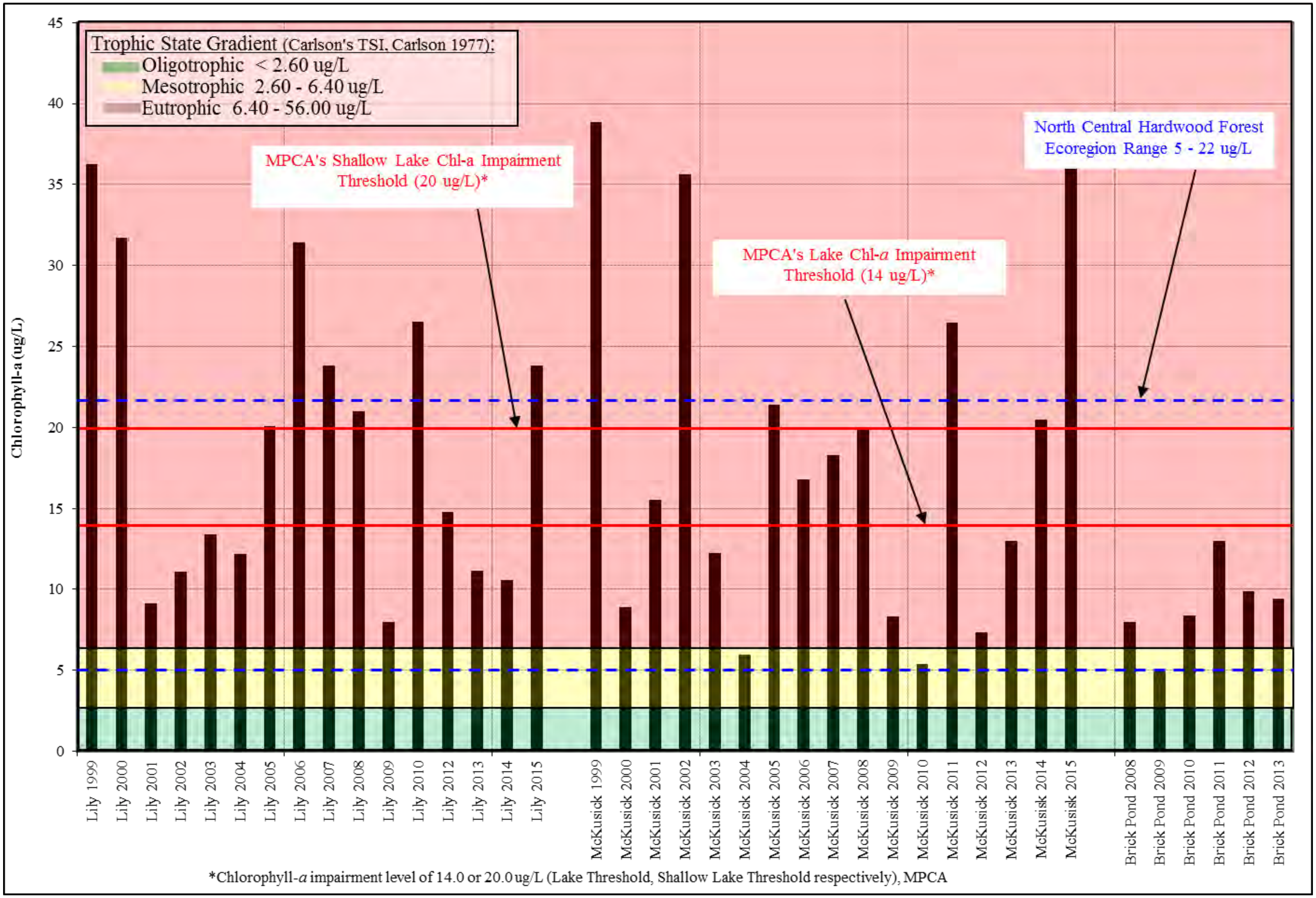

Figure 5. MSCWMO Historic Summer Average Chlorophyll-*a* Data

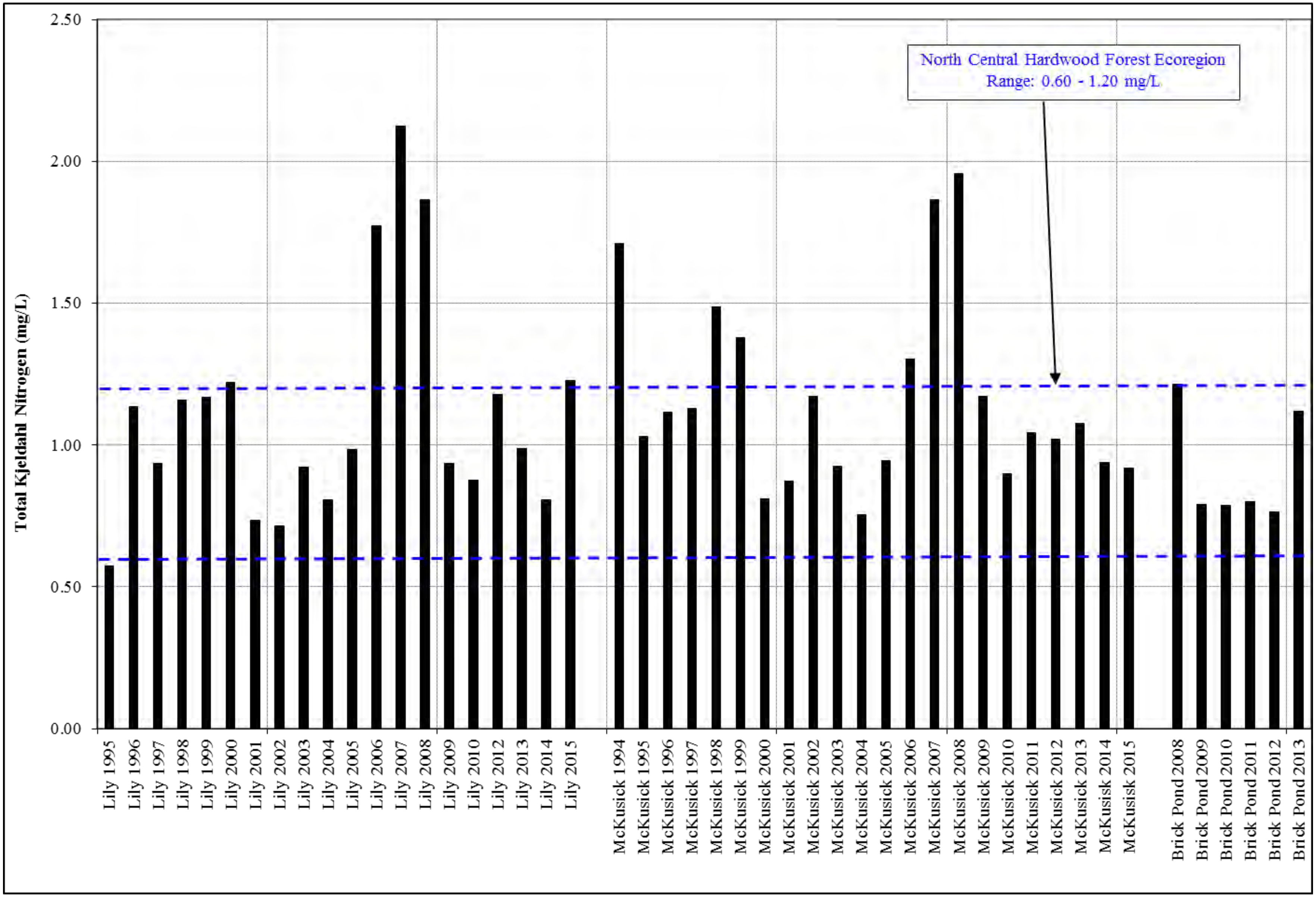

Figure 6. MSCWMO Historic Summer Average Total Kjeldahl Nitrogen Data

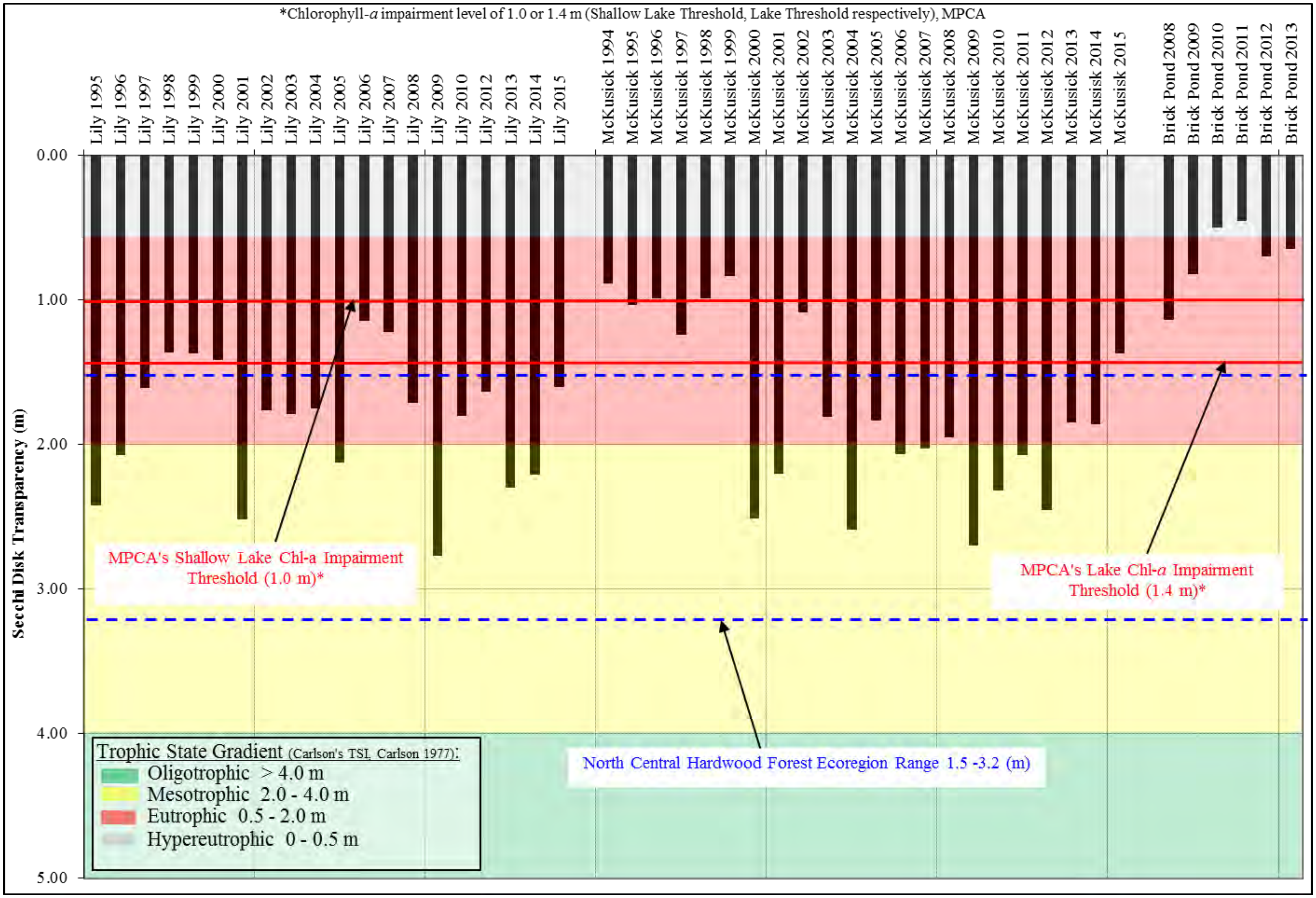

Figure 7. MSCWMO Historic Summer Average Secchi Data

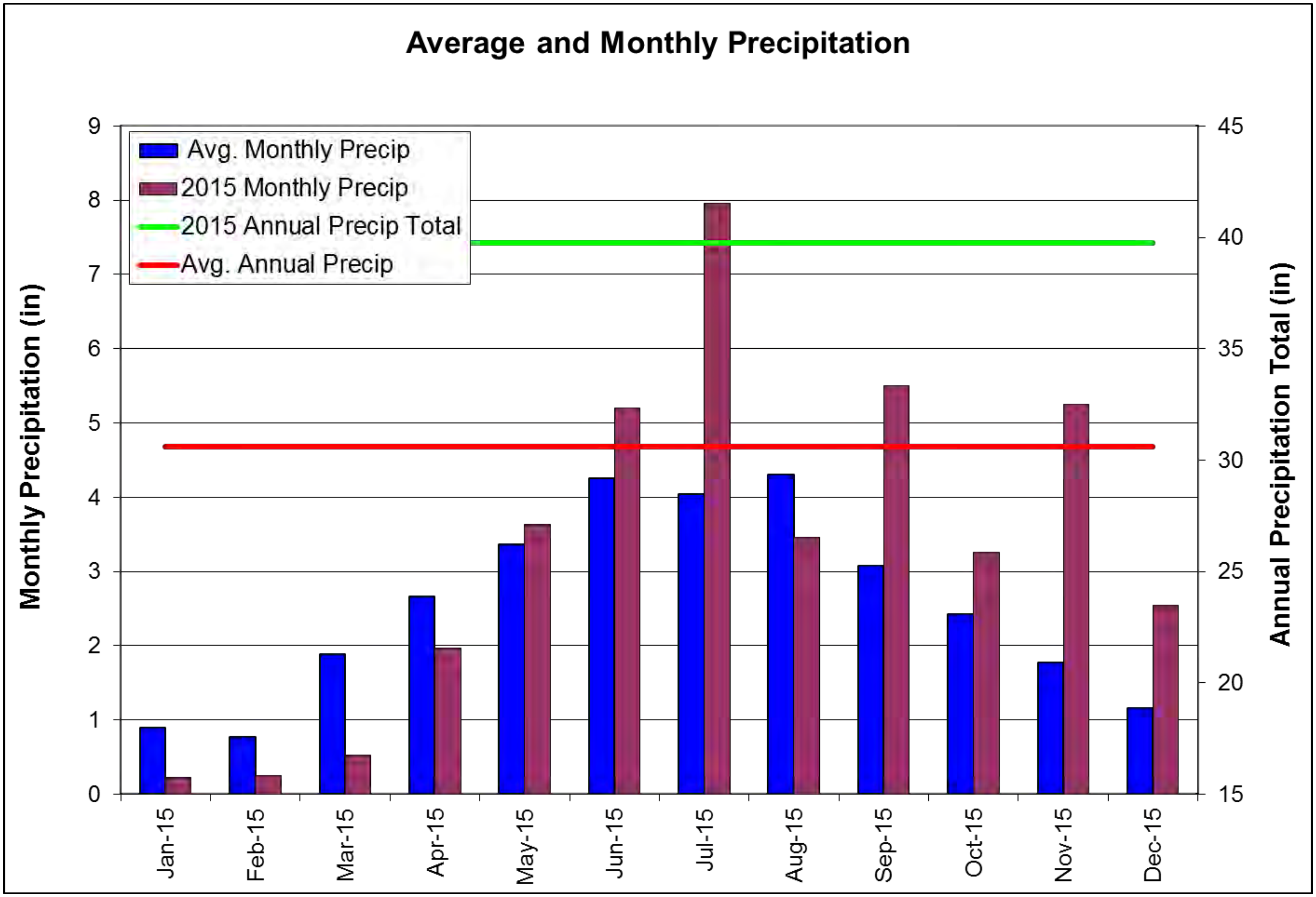

Figure 8. 2015 Annual Precipitation; Historical 30-Year* Average Annual Precipitation; Historical 30-Year* Average Monthly Precipitation; and 2015 Monthly Precipitation

2015 Data from Stillwater NWS gauge T 30N R 20W Sec 31

*Average monthly precipitation totals derived from historical 30-year (1986-2015) average for this region

B. MSCWMO LAKES: CONCLUSIONS AND RECOMMENDATIONS

Lake monitoring in MSCWMO continues to provide valuable baseline water quality information. To determine the health of the lakes in MSCWMO, physical and chemical parameters are compared on a year-to-year basis and to other lakes in the region. Water quality in a lake depends on a number of different variables such as: size of the contributing watershed, external nutrient sources, depth of the lake, and the current amount of nutrients available to be periodically released from the lake bottom. Some low water quality ratings of MSCWMO lakes are most likely due to long-term periods of urban runoff (Lily Lake) or from the shallowness of the lake (McKusick Lake). Shallow lakes typically exist in a low algal production, clear-water state or a high-algal production, turbid water state. Shallow lakes may not completely stratify in the summer, and therefore have the capability to continually mix throughout the summer. That mixing causes phosphorus to be distributed throughout the water column, causing more frequent and thick algal blooms. This is unlike deeper, stratified lakes where phosphorus below the thermocline is not available for primary production.

The MPCA had listed both Lily and McKusick Lake on the 303(d) Impaired Waters list for nutrient/eutrophication impairment, with McKusick Lake now officially delisted. If a water body is listed, it indicates that it does not currently meet water quality criteria. In order to meet those criteria, a total maximum daily load (TMDL) must be implemented. A TMDL outlines what pollutants are degrading the water quality and what will need to be done in order to meet current water quality standards. The MPCA had tentatively scheduled a three lake TMDL for Long Lake (Brown's Creek Watershed District), Lily Lake, and McKusick Lake in 2010, but because of improving water quality trends in those lakes over recent years, the MPCA, along with the MSCWMO, BCWD, and City of Stillwater, decided to postpone the TMDL. The MSCWMO, BCWD, and the City of Stillwater will utilize the City of Stillwater's existing Lake Management Plan, as well as the completed Lily and McKusick Lake subwatershed assessments, and Lily Lake inlet monitoring data to further guide project implementation in an effort to continue to improve the water quality of the lakes. The MPCA will consider the need for a TMDL again in the future.

2015 data shows that Lily Lake's summertime average for TP was higher than the 2014 values, and within the NCHFE range (Figure 4). In 2015 the WCD staff conducted two-tailed Kendall Tau statistical trend analysis on both lakes monitored within MSCWMO to determine any changes in long-term water quality trends, Lily Lake had a statistically significant improving trend found in the historical summer TP data ($p<0.05$). Average summertime value for chl-*a* in 2015 was much higher than what was measured in 2014, and outside the NCHFE range (Figure 5). There is no MPCA lake impairment standard for TKN, but the average 2015 summertime TKN result for Lily Lake was higher than what was seen in 2014, and outside the NCHFE range (Figure 6). The Secchi disk transparency for Lily Lake was shallower in 2015 than what was observed in 2014, but still was within the NCHFE range. No statistically significant trend in Secchi disk transparency could be determined ($p<0.05$). Lily Lake received a grade of C+ in 2015, down from the B+ it received for 2014. Summertime TP, chl-*a*, and Secchi disk transparency averages have remained relatively consistent over the last ten years in Lily Lake with the exceptions of 2001, 2009 and 2013, where overall water quality dramatically improved (Figure 4, Figure 5, and Figure 7). Summaries of all lake results are presented in Appendix A. In 2001 phosphorus and chl-*a* levels dropped and the lake grade improved significantly. There have been copper sulfate treatments on Lily Lake in the past, but the dates are unknown to the WCD. In 2006 and 2007, summer average TP, chl-*a*, and Secchi disk transparency deteriorated when compared to the averages seen from 2001 to 2005. In 2009 Lily Lake improved over previously recorded years and received a B+ lake grade, 2010 and 2012 sample results deteriorated, indicating that Lily Lake may have returned back to the long term normal, receiving a grade of a C+ this year. The cause of these one-year increases (2013, 2009, 2001, and 1995) in water quality is presently unknown, and there may be many possible explanations which could be investigated further in the future. Lake water quality best management practices on Lily Lake known to WCD staff are the completion of a native buffer planting at the public access in mid-2010, and copper sulfate treatments. The Lily Lake watershed underwent a subwatershed assessment in 2010. As a result, fifteen raingardens were constructed in the Lily Lake watershed in 2011, and more residential raingardens were completed in 2012. With a new round of funding, there were seven raingardens planned for installation in the spring of 2013, but due to complications with utilities the raingarden installation was postponed until summer 2014. Instead of seven smaller raingardens, six larger raingardens were installed. The first effects of these BMPs may have been seen from 2013 to 2015 monitoring seasons, but future monitoring is needed to see if the long term trends improve the longer the BMPs are installed. For more information about the Lily Lake subwatershed assessment refer to the Lily Lake Stormwater Retrofit Assessment found at http://mscwmo.org/wp-content/subwatershed/LILY-Assessment-Report-FINAL.pdf.

TP summertime average for McKusick Lake in 2015 was lower than what was seen in 2014, and was within the NCHFE range for 2015. Overall, McKusick Lake has seen statistically significant improvements ($p<0.05$) for TP from 1994 to the present (Figure 4). The 2015 summertime average for chl-*a* was higher than the average from 2014, and falls outside of the NCHFE value range for chl-*a*. The average 2015 summertime TKN value was within the NCHFE range for TKN, and slightly lower than what was measured in 2014 (Figure 6). Secchi disk transparency for 2015 is worse than what was observed in 2014, declining by 0.49 meters, and is outside the NCHFE range Secchi disk transparency. Overall there has been statistically significant improvements ($p<0.05$) seen in Secchi transparency from 1994 through the present (Figure 7). The overall water quality of McKusick Lake is comparable to last year, receiving a grade of C for 2015, the same as in 2014. Summaries of all lake results are presented in Appendix A. In June 2003 the City of Stillwater completed the Trout Stream Mitigation Project (TSMP) that has been functioning to divert stormwater from the 1,800-acre annexation area, away from Brown's Creek, through McKusick Lake, and ultimately to the St. Croix River. This diversion structure is designed to keep the warmer, urban stormwater from the southern tributary of Brown's Creek out of the temperature and nutrient sensitive Brown's Creek Ravine. Local residents' concerns about the amount of water and nutrients entering McKusick Lake are being investigated by the Brown's Creek Watershed District (BCWD) and the City of Stillwater. In 2006 the BCWD initiated stream flow monitoring and water quality sampling on the diversion structure drainage to assist in answering some of the water quality and quantity concerns. All associated data can be found in Table 4 through Table 10. There was a subwatershed assessment conducted on the McKusick Lake watershed in 2010. In 2011 six raingardens were constructed as a result of the sub-watershed assessment. With renewed funding, seven additional raingardens were to be installed in the McKusick Lake watershed in 2013 but because of issues with utilities, 5 larger raingardens were installed in 2014. The impacts of previously installed raingardens were not seen in the 2015 lake monitoring results, but the MSCWMO remain hopeful results will be seen in the future. For more information on the McKusick Lake subwatershed assessment refer to the McKusick Lake Stormwater Retrofit Assessment found at http://mscwmo.org/wp-content/subwatershed/McKUSICK-Assessment-Report-FINAL.pdf.

Water elevation monitoring was conducted on two lakes, McKusisk and Lily, from May to October 2015 (Figure 2 and Figure 3). Changes in lake water level elevation are mostly attributed to the changes in monthly precipitation. Precipitation was above average from May through December, with the exception of August. From early summer until the end of the year, precipitation was well above average, except August, and all MSCWMO lake elevations peaked in early summer and dropped towards the end of the monitoring season. Total annual precipitation for 2015 was 39.77 inches, with the majority of that occurring in the early in the summer and throughout the fall. That total is 9.16 inches above the 30 year (1981-2010) historical annual average of 30.61 inches (Figure 8). The highest recorded elevations in 2015 occurred in the earlier part of the summer. McKusick Lake recorded a high reading on 7/8/2015 and Lily Lake recorded a high reading on 7/11/2015.

The following are WCD recommendations to the MSCWMO:

- Continue to monitor water levels of MSCWMO lakes.
- Continue to monitor the water quality of MSCWMO lakes.
- Continue to monitor inlets to Lily Lake to determine where the majority of the nutrient load is coming from.

1. LILY LAKE INLET MONITORING

In 2015 seven inlets to Lily Lake were monitored to investigate the source of the majority of the nutrient load. This was a preliminary study and the results will be presented in a separate report. Continued investigatory monitoring is anticipated through 2017.

2. BROWN'S CREEK DIVERSION STRUCTURE

As additional data provided to the MSCWMO, the WCD took grab samples and automated flow-weighted samples during both base flow and storm event conditions at the Brown's Creek Diversion Structure for BCWD in 2015. The City of Stillwater constructed the diversion structure in June of 2003, as part of the completion of the Trout Stream Mitigation Project (TSMP). It has been functioning to divert water from the 1,800-acre annexation area, away from Brown's Creek through McKusick Lake, and ultimately to the St. Croix River. While this diversion structure will keep the warmer urban stormwater runoff from the southern tributary out of the temperature and nutrient sensitive Brown's Creek Ravine, it means that this water will be entering McKusick Lake, and could affect the lake water quality. Data collected at this site by the WCD includes total discharge and water quality sample analysis. All stream flow and chemistry data from 2015 can be found in Table 4 through Table 10.

Monitoring was conducted at five sites along the diversion drainage from April through October; South Branch, North Branch, West Branch 1, West Branch 2 and at the Diversion Structure. South Branch, North Branch and West Branch 1 were monitored with stage, discharge and manual grab sampling, West Branch 2 with manual grab sampling only, and the Diversion Structure with stage, discharge and automated storm composite sampling. Groundwater inflow accounts for the majority of the flow observed. Stormwater does contribute as well, with the bulk of it coming from sources not identified in this study. There are many storm water pond outlets present in this system and only flow when the ponds are at capacity. These pond outlet sites do not seem to be contributing to the values seen in the main channels. Discharge and loading data for the Diversion Drainage branches should be viewed with caution as the estimates are based on a coarse method of load calculation due to equipment limitations. The discharge and loading estimates are based only upon the period of monitoring as opposed to the entire year, and as a result gaps in the record, the number and timing of grab samples, and length of monitoring in a given season can significantly influence the estimated values. In 2015, the water level loggers at South Branch, North Branch and West Branch 1 experienced equipment failures, and gaps in the record exist from 6/22/2015-8/13/2015, 7/16/2015-8/13/2015 and 5/13/2015-8/07/2015, respectively.

High loads of TSS and TP have been observed at the Diversion monitoring station. By comparing the results of samples collected at the contributing sites, it appeared that the majority of this load was coming from the North and West Branches of the diversion drainage area, while loading from South Branch was much lower. In 2013, the annual TSS and TP loads at the South Branch departed from previous years and no longer displayed the lowest annual load. This pattern continued in 2014, as the estimated TSS load increased more than tenfold, and the estimated annual TP load was higher than either of the other two branches while total discharge remained nearly the same as 2013 at all sites. In 2015, discharge and loading was much lower at all sites than previous years, although this is an artifact of data gaps. However, even with limited data, the pattern of South Branch contributing the highest TSS and TP loads continued into 2015, despite having the lowest average storm concentrations (Table 4 and Table 5).

This shift in the South Branch can be explained in part by an erosional head cut identified near Boutwell Road. The eroding stream bed in this reach has been identified as a major contributor of sediment and nutrients in a study completed by Emmons & Olivier Resources, Inc. The study estimates 22 cubic yards of soil have been eroded between June 2013 and November 2014, based on surveys of the stream. It is expected much of this sediment will be deposited within the stream and wetlands upstream of McKusick Lake, although there may be an elevated nutrient load to the lake. Options to address the head cut are being considered by the Brown's Creek Watershed District. Also, several stormwater ponds draining to South Branch were flushed by the City of Stillwater throughout September and October, which may influence sample results. When comparing West Branch 1 to West Branch 2, make note that the TSS and TP concentrations observed generally increase when moving downstream, and are rather low at West Branch 2. This suggests that the majority of the sediment in the reach is being contributed between the two sites, which is consistent with prior monitoring (Table 4). Composite sampling at the Diversion site found extremely high concentrations of TSS, TP, and metals during two events on August 22nd and September 17th, likely due in part to the erosion occurring on the South Branch. The final acute standard for copper was exceeded on August 22nd, and the final acute standards for copper and zinc were exceeded on September 17th, meaning the water became acutely toxic to sensitive aquatic species (Table 7 and Table 8). This also illustrates the limitations of grab sampling, as the grab samples collected at the branches and the Diversion site did not capture peak inputs of TP, TSS or metals due to timing of collection.

Using a combination of composite and grab samples, phosphorus and TSS loads were calculated at the Brown's Creek Diversion Structure site. Phosphorus exported from the Brown's Creek Diversion Structure increased to 1,837 lbs. in 2015 from 292 lbs. in 2014. TSS also showed a large increase between 2014 and 2015, with 1,008,346 lbs. exported to McKusisk Lake in 2015 and 99,532 lbs. exported to McKusick Lake in 2014 (Table 6 and Table 10).

Water quality results showed seven out of the ten event flow samples exceeded the standard for TSS. Out of the five *E. coli* samples four exceeded the water quality standard (Table 7). There were ten event flow samples and eleven base flow samples that were tested for metals in 2015. There were no exceedances of metal standard thresholds for base flow samples. Three event flow samples exceeded the chronic standard for copper and two exceeded the final acute standard for copper. Six event flow samples exceeded the chronic standard for lead, with one sample that exceeded the max standard. One event flow sample exceeded the max standard for zinc and one exceeded the final acute standard for zinc. Two event flow samples exceeded the chronic standard for cadmium. There were no other exceedances of metals (Table 8). Water quality results showed one out of nine field data measurements exceeded the standard threshold for pH, and no field data measurements exceeded the standard threshold for dissolved oxygen (mg/L) (Table 9).

Continued monitoring will further refine the trends that have been observed in this drainage. Also, additional monitoring at the inlet and outlet of the iron enhanced sand filter (IESF) on the West Branch will help to further characterize loading to McKusick Lake via the Diversion Structure drainage. The IESF should help mitigate some of that load. The results from the 2014 and 2015 monitoring of the IESF are not discussed in this report, but will be available in a separate report prepared by Emmons & Olivier Resources, Inc.

Table 4. Long Lake-Brown’s Creek Diversion Drainage 2015 Water Quality Results

Site	Date	Sample Type	TSS (mg/L)	TP (mg/L)	TKN (mg/L)	TOC (mg/L)	Iron (mg/L)	Copper (mg/L)	Nickel (mg/L)	Lead (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Hardness (mg/L _CaCO3)
South Branch	5/14/2015 14:39	Total	4	0.086	0.73		~0.24	0.00093	0.00130	~0.00018	~0.0014	<0.0002	0.00072	236
		Dissolved		0.061		5.9	~0.05	0.00090	0.00096	<0.0001	0.0023	<0.0002	0.00097	
South Branch	6/22/2015 11:14	Total	44	0.147	1.20		~0.98	0.00110	0.00140	0.00064	0.0102	<0.0002	0.00081	54
		Dissolved		~0.038		6.8	~0.21	<0.00100	0.00065	~0.00017	~0.0015	<0.0002	0.00019	
South Branch	8/7/2015 9:24	Total	4	0.080	0.71		~0.33	0.00067	0.00098	~0.00023	0.0102	<0.0002	0.00068	166
		Dissolved		0.059		5.1	~0.08	0.00060	0.00086	~0.00015	0.0021	<0.0002	0.00065	
South Branch	8/18/2015 15:02	Total	42	0.154	1.30		1.10	<0.00500	0.00170	0.00082	0.0132	<0.0002	0.00150	114
		Dissolved		0.059		7.4	~0.04	<0.00500	0.00074	~0.00016	0.0035	<0.0002	0.00039	
South Branch	9/8/2015 8:43	Total	11	0.106	1.00		~0.63	<0.00500	0.00140	~0.00031	0.0069	<0.0002	0.00037	50
		Dissolved		~0.032		7.0	~0.14	<0.00500	~0.00044	~0.00017	0.0093	<0.0002	0.00023	
South Branch	9/17/2015 9:27	Total	18	0.131	1.20		~0.66	0.00130	0.00110	0.00067	0.0098	<0.0002	0.00084	40
		Dissolved		<0.020		7.0	~0.21	<0.00100	0.00064	~0.00024	0.0098	<0.0002	0.00047	
West Branch 1	5/14/2015 14:36	Total	10	0.064	0.51		~0.52	0.00087	0.00120	~0.00025	0.0034	<0.0002	0.00049	234
		Dissolved		~0.035		6.4	~0.03	0.00075	0.00082	<0.0001	0.0100	<0.0002	0.00025	
West Branch 1	6/22/2015 11:04	Total	57	0.232	1.10		2.70	0.00170	0.00360	0.00110	0.0040	<0.0002	0.00170	202
		Dissolved		~0.036		7.3	~0.07	<0.00500	0.00220	~0.00013	0.0026	<0.0002	0.00022	
West Branch 1	7/6/2015 9:20	Total	34	0.307	1.20		1.90	<0.00500	0.00150	0.00056	0.0037	<0.0002	0.00092	76
		Dissolved		0.161		10.4	~0.56	0.00150	0.00100	~0.00016	0.0018	<0.0002	0.00048	
West Branch 1	8/7/2015 8:48	Total	20	0.157	0.71		1.40	0.00081	0.00110	0.00054	0.0117	<0.0002	0.00097	234
		Dissolved		~0.035		4.7	~0.02	~0.00034	~0.00058	~0.00016	~0.0015	<0.0002	0.00024	
West Branch 1	818/2015 14:53	Total	94	0.414	1.80		3.00	<0.00500	~0.00059	~0.00015	0.0022	<0.0002	0.00034	216
		Dissolved		0.074		6.3	~0.05	<0.00500	0.00230	0.00170	0.0117	<0.0002	0.00240	
West Branch 1	9/8/2015 8:31	Total	15	0.159	0.75		1.40	<0.00500	0.00120	~0.00042	0.0067	<0.0002	0.00070	212
		Dissolved		~0.049		6.7	~0.09	<0.00500	0.00080	~0.00014	0.0094	<0.0002	0.00018	
West Branch 1	9/17/2015 9:18	Total	69	0.350	1.60		3.20	0.00280	0.00210	0.00120	0.0116	<0.0002	0.00210	104
		Dissolved		0.102		10.3	~0.17	0.00130	0.00092	~0.00017	0.0118	<0.0002	0.00053	
West Branch 2	5/14/2015 15:22	Total	~2	0.053	0.50		~0.50	0.00068	0.00110	~0.00013	0.0022	<0.0002	0.00049	248
		Dissolved		~0.024		7.3	~0.05	0.00062	0.00075	<0.0001	0.0017	<0.0002	~0.00015	
West Branch 2	6/22/2015 11:42	Total	30	0.496	0.93		6.20	<0.00100	0.00150	~0.00043	0.0021	<0.0002	0.00071	230
		Dissolved		~0.032		8.9	~0.21	<0.00100	0.00100	~0.00018	0.0025	<0.0002	0.00024	
West Branch 2	7/6/2015 9:42	Total	8	0.303	1.10									76
		Dissolved		0.160		10.9	~0.80	0.00130	0.00100	~0.00015	0.0028	<0.0002	0.00049	
West Branch 2	8/7/2015 9:47	Total	10	0.146	0.61		1.60	~0.00037	0.00078	~0.00043	0.0102	<0.0002	0.00054	238
		Dissolved		<0.020		9.0	~0.06	0.00690	0.00063	~0.00020	0.0542	<0.0002	0.00031	
West Branch 2	8/18/2015 15:31	Total	43	0.440	1.10		5.70	<0.00500	0.00130	0.00085	0.0102	<0.0002	0.00170	220
		Dissolved		0.054		7.1	~0.02	<0.00500	0.00072	~0.00015	0.0024	<0.0002	0.00040	
West Branch 2	9/8/2015 9:08	Total	8	0.179	0.66		1.80	<0.00500	0.00100	~0.00025	0.0047	<0.0002	0.00044	222
		Dissolved		~0.043		7.8	~0.05	<0.00500	0.00089	~0.00013	0.0040	<0.0002	0.00020	
West Branch 2	9/17/2015 9:55	Total	131	0.750	1.90		9.00	0.00320	0.00240	0.00200	0.0137	<0.0002	0.00370	64
		Dissolved		0.149		8.6	~0.24	0.00140	0.00080	~0.00015	0.0087	<0.0002	0.00053	
North Branch	5/14/2015 14:01	Total	22	0.103	0.55		~0.73	0.00110	0.00094	~0.00049	0.0023	<0.0002	0.00120	270
		Dissolved		0.054		3.2	~0.02	~0.00058	~0.00037	<0.0001	<0.0008	<0.0002	0.00035	
North Branch	6/22/2015 10:47	Total	157	0.349	1.60		3.20	0.00450	0.00450	0.00300	0.0130	<0.0002	0.00490	222
		Dissolved		0.065		6.9	~0.05	<0.00100	0.00110	~0.00013	0.0021	<0.0002	0.00032	
North Branch	7/6/2015 8:43	Total	67	0.252	1.40		2.00	0.00920	0.00270	0.00130	0.0072	<0.0002	0.00230	50
		Dissolved		0.118		9.8	~0.23	<0.00500	0.00100	~0.00019	0.0023	<0.0002	0.00041	
North Branch	8/7/2015 9:11	Total	57	0.189	0.75		2.00	0.00180	0.00180	0.00120	0.0216	<0.0002	0.00210	270
		Dissolved		0.061		5.7	~0.03	0.00070	0.00069	~0.00017	0.0019	<0.0002	0.00033	
North Branch	8/18/2015 14:44	Total	294	0.786	2.70		4.50	0.00680	0.00720	0.00540	0.0267	<0.0002	0.00890	218
		Dissolved		0.121		10.0	~0.09	<0.00500	0.00120	~0.00016	0.0018	<0.0002	0.00069	
North Branch	9/8/2015 8:08	Total	37	0.197	0.84		1.70	<0.00500	0.00180	0.00091	0.0077	<0.0002	0.00170	250
		Dissolved		0.084		6.4	~0.18	<0.00500	0.00089	~0.00015	0.0038	<0.0002	0.00043	
North Branch	9/17/2015 8:57	Total	422	0.596	3.00		4.60	0.00540	0.00500	0.00320	0.0206	<0.0002	0.00610	56
		Dissolved		~0.046		8.8	~0.15	0.00240	0.00110	~0.00021	0.0113	<0.0002	0.00049	
Browns Creek Diversion	5/14/2015 15:06	Total	8	0.061	0.49		~0.38	0.00075	0.00110	~0.00020	0.0027	<0.0002	0.00045	244
		Dissolved		~0.035			~0.03							
Browns Creek Diversion	6/22/2015 10:23	Total	22	0.359	2.10		4.70	0.00280	0.00370	0.00240	0.0102	<0.0002	0.00310	142
		Dissolved		~0.046		7.2	~0.06	<0.00100	0.00099	~0.00012	0.0016	<0.0002	0.00021	
Browns Creek Diversion	7/6/2015 8:34	Total	11	0.233	1.20		1.20	<0.00500	0.00150	0.00057	0.0040	<0.0002	0.00096	54
		Dissolved		0.133			~0.32							
Browns Creek Diversion	8/7/2015 8:53	Total	8	0.121	0.59		~0.94	~0.00058	0.00085	~0.00038	0.0091	<0.0002	0.00058	226
		Dissolved		~0.045			~0.03							
Browns Creek Diversion	8/18/2015 14:36	Total	53	0.337	1.00		2.90	<0.0050	0.00170	0.00110	0.0109	<0.0002	0.00180	222
		Dissolved		0.106			~0.08							
Browns Creek Diversion	9/8/2015 7:46	Total	15	0.136	0.87		~0.97	<0.00100	0.00110	0.00052	0.0024	<0.0002	0.00071	118
		Dissolved		<0.020			~0.14							
Browns Creek Diversion	9/17/2015 8:35	Total	396	0.533	2.70		4.30	0.00440	0.00420	0.00290	0.0208	<0.0002	0.00460	88
		Dissolved		0.090		9.8	~0.15	0.00100	0.00091	~0.00018	0.0081	<0.0002	0.00063	

- Exceeds Water Quality Standard for Turbidity(TSS Value used to calculate)
- Exceeds Chronic Standard
- Exceeds Max Standard
- Exceeds Final Acute Standard
- Exceedance not determined

Table 5. Long Lake-Brown’s Creek Diversion Drainage 2015 Estimated Discharge and Loading

Site	Average TSS (mg/L)	Average TP (mg/L)	Logged Discharge (cf)	Estimated Sediment Load (lbs)	Estimated Phosphorus Load (lbs)
North Branch	151	0.353	796,036	7,504	18
West Branch 1	43	0.240	4,550,572	12,215	68
South Branch	21	0.117	9,977,820	13,080	73

Table 6. Brown's Creek Diversion Structure Drainage 2015 Total Suspended Solids (TSS) and Total Phosphorus (TP) Loading

	Sample Collection Time				Loading Interval					
Sample Type	Start	End	TSS (mg/L)	TP (mg/L)	Start	End	Interval Volume (cf)	Interval Volume (ac-ft)	Interval TSS (lb)	Interval TP (lb)
*Base**			*9*	*0.108*	*1/1/2015 0:00*	*3/9/2015 8:00*	*58,176*	*1.34*	*33*	*0.39*
Snowmelt Grab*	3/9/2015 14:46	3/9/2015 14:46	110	0.341	3/9/2015 8:00	3/9/2015 20:00	367,200	8.43	2,522	7.82
*Base**			*9*	*0.108*	*3/9/2015 20:00*	*4/7/2015 10:15*	*5,558,625*	*127.68*	*3,123*	*37.48*
Base			*9*	*0.108*	*4/7/2015 10:15*	*4/9/2015 8:15*	*112,004*	*2.57*	*63*	*0.76*
Storm			*2,296*	*3.599*	*4/9/2015 8:15*	*4/10/2015 3:15*	*108,524*	*2.49*	*15,555*	*24.38*
Base			*9*	*0.108*	*4/10/2015 3:15*	*4/12/2015 21:15*	*249,558*	*5.73*	*140*	*1.68*
Storm			*2,296*	*3.599*	*4/12/2015 21:15*	*4/13/2015 16:15*	*104,027*	*2.39*	*14,910*	*23.37*
Base Grab	4/28/2015 9:25	4/28/2015 9:25	4	0.053	4/13/2015 16:15	5/3/2015 17:15	1,272,590	29.23	318	4.21
Storm			*2,296*	*3.599*	*5/3/2015 17:15*	*5/4/2015 6:15*	*66,859*	*1.54*	*9,583*	*15.02*
Base			*9*	*0.108*	*5/4/2015 6:15*	*5/10/2015 19:15*	*556,641*	*12.79*	*313*	*3.75*
Storm			*2,296*	*3.599*	*5/10/2015 19:15*	*5/11/2015 19:15*	*108,095*	*2.48*	*15,493*	*24.29*
Base Grab	5/14/2015 15:06	5/14/2015 15:06	8	0.061	5/11/2015 19:15	5/14/2015 16:15	188,928	4.34	94	0.72
Storm			*2,296*	*3.599*	*5/14/2015 16:15*	*5/15/2015 9:15*	*81,524*	*1.87*	*11,685*	*18.32*
Base			*9*	*0.108*	*5/15/2015 9:15*	*5/17/2015 10:15*	*166,803*	*3.83*	*94*	*1.12*
Storm			*2,296*	*3.599*	*5/17/2015 10:15*	*5/18/2015 14:15*	*120,916*	*2.78*	*17,331*	*27.17*
Base			*9*	*0.108*	*5/18/2015 14:15*	*5/24/2015 13:15*	*332,845*	*7.65*	*187*	*2.24*
Storm			*2,296*	*3.599*	*5/24/2015 13:15*	*5/25/2015 17:15*	*101,566*	*2.33*	*14,557*	*22.82*
Base			*9*	*0.108*	*5/25/2015 17:15*	*5/26/2015 13:15*	*60,068*	*1.38*	*34*	*0.40*
Storm			*2,296*	*3.599*	*5/26/2015 13:15*	*5/27/2015 3:15*	*58,534*	*1.34*	*8,390*	*13.15*
Base Grab	5/27/2015 9:24	5/27/2015 9:24	13	0.084	5/27/2015 3:15	5/29/2015 5:15	148,723	3.42	121	0.78
Storm			*2,296*	*3.599*	*5/29/2015 5:15*	*5/30/2015 3:15*	*107,457*	*2.47*	*15,402*	*24.14*
Base			*9*	*0.108*	*5/30/2015 3:15*	*6/3/2015 13:15*	*306,093*	*7.03*	*172*	*2.06*
Storm			*2,296*	*3.599*	*6/3/2015 13:15*	*6/4/2015 13:15*	*135,652*	*3.12*	*19,443*	*30.48*
Base			*9*	*0.108*	*6/4/2015 13:15*	*6/5/2015 14:15*	*112,994*	*2.60*	*63*	*0.76*
Storm			*2,296*	*3.599*	*6/5/2015 14:15*	*6/6/2015 3:15*	*127,922*	*2.94*	*18,335*	*28.74*
Base			*9*	*0.108*	*6/6/2015 3:15*	*6/7/2015 0:15*	*143,780*	*3.30*	*81*	*0.97*
Storm Composite	6/7/2015 1:27	6/7/2015 10:57	552	0.924	6/7/2015 0:15	6/7/2015 11:15	163,668	3.76	5,640	9.44
Base			*9*	*0.108*	*6/7/2015 11:15*	*6/17/2015 14:15*	*1,624,570*	*37.31*	*913*	*10.95*
Storm			*2,296*	*3.599*	*6/17/2015 14:15*	*6/17/2015 20:15*	*39,768*	*0.91*	*5,700*	*8.93*
Base			*9*	*0.108*	*6/17/2015 20:15*	*6/20/2015 6:15*	*258,277*	*5.93*	*145*	*1.74*
Storm			*2,296*	*3.599*	*6/20/2015 6:15*	*6/20/2015 14:15*	*49,310*	*1.13*	*7,068*	*11.08*
Base			*9*	*0.108*	*6/20/2015 14:15*	*6/22/2015 8:15*	*190,514*	*4.38*	*107*	*1.28*
Storm Grab**	6/22/2015 10:23	6/22/2015 10:23	22	0.359	6/22/2015 8:15	6/22/2015 18:15	57,413	1.32	79	1.29
Base Grab	6/25/2015 8:48	6/25/2015 8:48	13	0.175	6/22/2015 18:15	6/30/2015 12:15	424,487	9.75	344	4.64
Storm			*2,296*	*3.599*	*6/30/2015 12:15*	*7/1/2015 22:15*	*484,247*	*11.12*	*69,407*	*108.80*
Base			*9*	*0.108*	*7/1/2015 22:15*	*7/6/2015 2:15*	*750,883*	*17.25*	*422*	*5.06*
Storm Grab**	7/6/2015 8:34	7/6/2015 8:34	11	0.233	7/6/2015 2:15	7/7/2015 3:15	2,996,720	68.83	2,058	43.59
Base			*9*	*0.108*	*7/7/2015 3:15*	*7/12/2015 23:15*	*5,717,900*	*131.33*	*3,213*	*38.55*
Storm			*2,296*	*3.599*	*7/12/2015 23:15*	*7/13/2015 23:15*	*1,183,690*	*27.19*	*169,659*	*265.94*
Base			*9*	*0.108*	*7/13/2015 23:15*	*7/18/2015 1:15*	*3,331,720*	*76.53*	*1,872*	*22.46*
Storm Composite	7/18/2015 3:20	7/18/2015 5:09	782	0.453	7/18/2015 1:15	7/18/2015 13:15	476,571	10.95	23,265	13.48
Base			*9*	*0.108*	*7/18/2015 13:15*	*7/21/2015 13:15*	*1,537,910*	*35.32*	*864*	*10.37*
Base Grab	7/22/2015 9:32	7/22/2015 9:32	11	0.155	7/21/2015 13:15	7/23/2015 13:15	232,793	5.35	160	2.25
Base			*9*	*0.108*	*7/23/2015 13:15*	*7/28/2015 12:15*	*231,459*	*5.32*	*130*	*1.56*
Storm			*2,296*	*3.599*	*7/28/2015 12:15*	*7/29/2015 6:15*	*271,892*	*6.25*	*38,970*	*61.09*
Base			*9*	*0.108*	*7/29/2015 6:15*	*8/6/2015 6:15*	*366,037*	*8.41*	*206*	*2.47*
Base Grab	8/7/2015 8:53	8/7/2015 8:53	8	0.121	8/6/2015 6:15	8/8/2015 6:15	67,399	1.55	34	0.51
Base			*9*	*0.108*	*8/8/2015 6:15*	*8/18/2015 12:15*	*230,229*	*5.29*	*129*	*1.55*
Storm Grab**	8/18/2015 14:36	8/18/2015 14:36	53	0.337	8/18/2015 12:15	8/19/2015 1:15	61,005	1.40	202	1.28
Base			*9*	*0.108*	*8/19/2015 1:15*	*8/22/2015 21:15*	*212,975*	*4.89*	*120*	*1.44*
Storm Composite	8/22/2015 21:34	8/23/2015 0:33	3,450	5.210	8/22/2015 21:15	8/23/2015 7:15	342,769	7.87	73,822	111.48
Base Grab	8/26/2015 8:46	8/26/2015 8:46	7	0.108	8/23/2015 7:15	8/27/2015 7:15	572,404	13.15	250	3.86
Base			*9*	*0.108*	*8/27/2015 7:15*	*9/3/2015 15:15*	*279,774*	*6.43*	*157*	*1.89*
Unexplained Event Composite	9/3/2015 16:14	9/5/2015 2:30	646	0.806	9/3/2015 15:15	9/5/2015 7:15	515,013	11.83	20,769	25.91
Base			*9*	*0.108*	*9/5/2015 7:15*	*9/6/2015 7:15*	*85,750*	*1.97*	*48*	*0.58*
Storm			*2,296*	*3.599*	*9/6/2015 7:15*	*9/7/2015 3:15*	*154,416*	*3.55*	*22,133*	*34.69*
Base Grab	9/8/2015 7:46	9/8/2015 7:46	15	0.136	9/7/2015 3:15	9/11/2015 15:15	398,879	9.16	374	3.39
Unexplained Event			*585*	*0.669*	*9/11/2015 15:15*	*9/12/2015 8:15*	*225,327*	*5.18*	*8,229*	*9.41*
Base			*9*	*0.108*	*9/12/2015 8:15*	*9/14/2015 15:15*	*190,206*	*4.37*	*107*	*1.28*
Unexplained Event Composite	9/14/2015 15:57	9/15/2015 12:54	524	0.532	9/14/2015 15:15	9/15/2015 10:15	206,464	4.74	6,754	6.86
Base			*9*	*0.108*	*9/15/2015 10:15*	*9/17/2015 6:15*	*305,887*	*7.03*	*172*	*2.06*
Storm Composite	9/17/2015 7:23	9/17/2015 16:22	4,400	7.810	9/17/2015 6:15	9/18/2015 3:15	845,676	19.42	232,286	412.31
Base			*9*	*0.108*	*9/18/2015 3:15*	*9/28/2015 3:15*	*3,966,820*	*91.11*	*2,229*	*26.74*
Base Grab	9/29/2015 9:52	9/29/2015 9:52	4	0.078	9/28/2015 3:15	9/30/2015 3:15	176,651	4.06	44	0.86
Base			*9*	*0.108*	*9/30/2015 3:15*	*10/2/2015 16:15*	*90,025*	*2.07*	*51*	*0.61*
Unexplained Event			*585*	*0.669*	*10/2/2015 16:15*	*10/4/2015 9:15*	*262,218*	*6.02*	*9,576*	*10.95*
Base			*9*	*0.108*	*10/4/2015 9:15*	*10/8/2015 4:15*	*198,955*	*4.57*	*112*	*1.34*
Storm			*2,296*	*3.599*	*10/8/2015 4:15*	*10/9/2015 2:15*	*312,374*	*7.17*	*44,773*	*70.18*
Base			*9*	*0.108*	*10/9/2015 2:15*	*10/20/2015 8:15*	*920,751*	*21.15*	*517*	*6.21*
Base Grab	10/21/2015 10:08	10/21/2015 10:08	4	0.110	10/20/2015 8:15	10/23/2015 8:15	169,174	3.89	42	1.16
Storm			*2,296*	*3.599*	*10/23/2015 8:15*	*10/24/2015 14:15*	*334,197*	*7.68*	*47,901*	*75.08*
Base			*9*	*0.108*	*10/24/2015 14:15*	*10/27/2015 9:15*	*469,541*	*10.78*	*264*	*3.17*
*Base**			*9*	*0.108*	*10/27/2015 9:15*	*11/11/2015 17:00*	*1,125,315*	*25.85*	*632*	*7.59*
*Storm**			*2,296*	*3.599*	*11/11/2015 17:00*	*11/12/2015 5:00*	*259,200*	*5.95*	*37,151*	*58.23*
*Base**			*9*	*0.108*	*11/12/2015 5:00*	*1/1/2016 0:00*	*2,151,000*	*49.41*	*1,209*	*14.50*
Storm Composite Average			2,296	3.599						
Unexplained Event Average			585	0.669						
Base Average			9	0.108						
All Average			532	0.904						
Total							**46,276,327**	**1,063**	**1,008,346**	**1,837**
Brown's Creek Major Subwatershed Total Acres							3,855			
Total TSS/TP(lb/ac/yr)									261.57	0.477
Total TSS/TP (kg/ha/yr)									293.17	0.534

Italics indicate estimated concentrations based on average base and storm flow concentrations.

*Interval volumes from 1/1/15 0:00 to 4/7/15 10:15 and 10/27/15 9:15 to 1/1/16 0:00 were estimated using similar flow conditions.

**Storm Grab samples were ommited while calculating storm average concentration

Table 7. Brown's Creek Diversion Structure Drainage 2015 Primary Water Quality Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	*E. coli* (mpn/100 mL)	Iron (mg/L)	Dissolved Iron (mg/L)
Snowmelt Grab	3/9/2015 14:46	3/9/2015 14:46	110	51	2.30	0.341	0.084		3.70	~0.10
Storm Composite	6/7/2015 1:27	6/7/2015 10:57	552	180	6.00	0.924	0.060		11.60	~0.08
Storm Grab	6/22/2015 10:23	6/22/2015 10:23	22	15	2.10	0.359	~0.046		4.70	~0.06
Storm Grab	7/6/2015 8:34	7/6/2015 8:34	11	4	1.20	0.233	0.133		1.20	~0.32
Storm Composite	7/18/2015 3:20	7/18/2015 5:09	782	216	2.60	0.453	~0.048		6.10	~0.22
Storm Grab	8/18/2015 14:36	8/18/2015 14:36	53	18	1.00	0.337	0.106		2.90	~0.08
Storm Composite	8/22/2015 21:34	8/23/2015 0:33	3,450	1,010	24.00	5.210	0.065		66.90	~0.17
Storm Composite	9/17/2015 7:23	9/17/2015 16:22	4,440	1,020	29.00	7.880	0.079		129.00	~0.44
Storm Grab	9/17/2015 8:35	9/17/2015 8:35	396	84	2.70	0.533	0.090		4.30	~0.15
Unexplained Event Composite	9/3/2015 16:14	9/5/2015 2:30	646	294	7.50	0.806	~0.048		8.20	~0.04
Unexplained Event Composite (Duplicate)	9/3/2015 16:14	9/5/2015 2:30	410	157	6.10	0.675	~0.037		6.00	~0.03
Unexplained Event Composite	9/14/2015 15:57	9/15/2015 12:54	524	260	6.50	0.532	<0.020		7.80	~0.06
Base Grab	4/28/2015 9:25	4/28/2015 9:25	4	~2	0.44	0.053	~0.030		~0.33	~0.03
Base Grab	5/14/2015 15:06	5/14/2015 15:06	8	4	0.49	0.061	~0.035		~0.38	~0.03
Base Grab	5/27/2015 9:24	5/27/2015 9:24	13	5	0.76	0.084	~0.035	147	~0.62	~0.04
Base Grab	6/25/2015 8:48	6/25/2015 8:48	13	6	0.68	0.175	~0.045	411	1.50	
Base Grab	7/22/2015 9:32	7/22/2015 9:32	11	4	0.82	0.155	~0.037	194	1.20	~0.27
Base Grab	8/7/2015 8:53	8/7/2015 8:53	8	3	0.59	0.121	~0.045		~0.94	~0.03
Base Grab	8/26/2015 8:46	8/26/2015 8:46	7	3	0.69	0.108	~0.042	365	~0.87	~0.12
Base Grab	9/8/2015 7:46	9/8/2015 7:46	15	6	0.87	0.136	<0.020		~0.97	~0.14
Base Grab	9/29/2015 9:52	9/29/2015 9:52	4	~2	0.57	0.078	~0.033		~0.66	~0.09
Base Grab	10/21/2015 10:08	10/21/2015 10:08	4	~2	0.60	0.110	~0.033	26	~0.47	~0.07

(green)	Exceeds Water Quality Standard
(pink)	Exceeds Water Quality Standard for Turbidity(TSS Value used to calculate)

Table 8. Brown's Creek Diversion Structure Drainage 2015 Secondary Water Quality Results

Sample Type	Start	End	Copper (mg/L)	Nickel (mg/L)	Lead (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Chloride (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Ammonia Nitrogen (mg/L)	Hardness (mg/L _CaCO3)
Snowmelt Grab	3/9/2015 14:46	3/9/2015 14:46	0.00280	0.00300	0.00220	<0.01000	<0.00020	0.00340	71.8	<0.03	0.71	0.29	228
Storm Composite	6/7/2015 1:27	6/7/2015 10:57	0.01250	0.00890	0.00610	0.03430	~0.00028	0.00780	42.1	<0.03	0.31	<0.02	94
Storm Grab	6/22/2015 10:23	6/22/2015 10:23	0.00280	0.00370	0.00240	0.01020	<0.00020	0.00310	46.1	<0.03	0.30	0.38	142
Storm Grab	7/6/2015 8:34	7/6/2015 8:34	<0.00500	0.00150	0.00057	0.00400	<0.00020	0.00096	17.6	<0.03	0.33	~0.03	54
Storm Composite	7/18/2015 3:20	7/18/2015 5:09	0.00640	0.00590	0.00460	0.02220	~0.00022	0.00580	39.6	<0.03	0.21	~0.02	78
Storm Grab	8/18/2015 14:36	8/18/2015 14:36	<0.00500	0.00170	0.00110	0.01090	<0.00020	0.00180	47.1	<0.03	0.90	<0.02	222
Storm Composite	8/22/2015 21:34	8/23/2015 0:33	0.04160	0.04540	0.05660	0.16600	0.00130	0.04690	24.1	0.04	0.64	~0.02	100
Storm Composite	9/17/2015 7:23	9/17/2015 16:22	0.06360	0.07180	0.08360	0.29700	0.00220	0.07910	26.4	0.10	0.37	<0.02	92
Storm Grab	9/17/2015 8:35	9/17/2015 8:35	0.00440	0.00420	0.00290	0.02080	<0.00020	0.00460					88
Unexplained Event Composite	9/3/2015 16:14	9/5/2015 2:30	0.01040	0.01140	0.00600	0.04110	~0.00033	0.00900	66.7	<0.03	0.08	0.09	58
Unexplained Event Composite (Duplicate)	9/3/2015 16:14	9/5/2015 2:30	0.00740	0.00710	0.00410	0.03030	~0.00023	0.00600	66.3	<0.03	0.08	0.09	58
Unexplained Event Composite	9/14/2015 15:57	9/15/2015 12:54	0.00860	0.00920	0.00480	0.04040	~0.00032	0.00730	63.2	<0.03	0.08	0.06	62
Base Grab	4/28/2015 9:25	4/28/2015 9:25	~0.00045	0.00088	~0.00013	<0.00080	<0.00020	0.00043	57.4	<0.03	0.77	<0.02	238
Base Grab	5/14/2015 15:06	5/14/2015 15:06	0.00075	0.00110	~0.00020	0.00270	<0.00020	0.00045	53.4	<0.03	0.43	0.06	244
Base Grab	5/27/2015 9:24	5/27/2015 9:24	<0.00100	0.00220	~0.00027	<0.00500	<0.00020	0.00053	47.6	<0.03	0.45	~0.04	232
Base Grab	6/25/2015 8:48	6/25/2015 8:48	0.00076	0.00160	~0.00044	0.00270	<0.00020	0.00068	50.8	<0.03	0.60	0.07	244
Base Grab	7/22/2015 9:32	7/22/2015 9:32	0.00076	0.00130	~0.00039	0.00260	<0.00020	0.00062	58.6	<0.03	0.28	~0.04	130
Base Grab	8/7/2015 8:53	8/7/2015 8:53	~0.00058	0.00085	~0.00038	0.00910	<0.00020	0.00058	49.1	<0.03	0.56	~0.04	226
Base Grab	8/26/2015 8:46	8/26/2015 8:46	<0.00100	0.00100	~0.00031	0.00460	<0.00020	0.00054	49.6	<0.03	0.43	~0.04	172
Base Grab	9/8/2015 7:46	9/8/2015 7:46	<0.00100	0.00110	0.00052	0.00240	<0.00020	0.00071	54.1	<0.03	0.21	~0.04	118
Base Grab	9/29/2015 9:52	9/29/2015 9:52	<0.00030	~0.00049	~0.00016	0.00610	<0.00020	<0.00050	50.5	<0.03	0.40	~0.04	146
Base Grab	10/21/2015 10:08	10/21/2015 10:08	<0.00500	~0.00058	~0.00025	~0.00091	<0.00020	0.00030	50.3	<0.03	0.40	~0.03	172

(grey)	No Exceedance Determinable
(yellow)	Exceeds Chronic Standard
(cyan)	Exceeds Max Standard
(dark red)	Exceeds Final Acute Standard

Table 9. Brown's Creek Diversion Structure Drainage 2015 Field Measurement Results

Date/Time	Transparency (cm)	Water Temperature (C)	Dissolved Oxygen (mg/L)	Conductivity (umhos/cm)	pH
3/9/2015 14:46	16	1.1	12.27	618	7.7
4/28/2015 9:25	>100	6.7	11.15	593	8.6
5/27/2015 9:24	86	11.7	9.10	522	7.9
6/22/2015 10:23	16				
6/25/2015 8:48	65	14.7	8.63	586	8.2
7/22/2015 9:32	64	19.9	7.80	433	7.8
8/26/2015 8:46	72	12.6	9.21	477	8.1
9/17/2015 8:35	11				
10/21/2015 10:08	95	10.3	9.63	410	8.2

Exceeds Water Quality Standard

Table 10. Brown's Creek Diversion Structure Drainage Historical Annual Discharge and Loading Amounts

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Brown's Creek Diversion Structure										
Discharge (cf)	33,916,362	49,768,967	29,397,219	31,166,264	38,197,468	52,981,553	21,810,789	46,435,271	53,519,017	46,276,327
Total pounds of Phosphorus exported	676	653	206	544	608	2,099	251	527	392	1,837
TP (lbs/ac/yr)	0.175	0.169	0.053	0.141	0.158	0.544	0.065	0.137	0.102	0.447
Total pounds of TSS exported	455,793	232,190	59,313	227,372	353,007	1,387,050	127,435	211,977	99,532	1,008,346
TSS (lbs/ac/yr)	118.23	60.23	15.39	58.98	91.57	359.81	33.06	54.99	25.82	261.57

C. MSCWMO STREAMS: CONCLUSIONS AND RECOMMENDATIONS

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The following is the WCD's recommendation to the MSCWMO:

- Continue to evaluate loading estimates at the Brown's Creek Diversion Structure Drainage site to determine if future water quality improvement projects are helping to reduce loading to McKusick Lake.
- Continue to monitor Lily Lake inlets to investigate the source of the majority of the nutrient load entering Lily Lake.

Appendix A
Water Quality Data– McKusick Lake, Lily Lake

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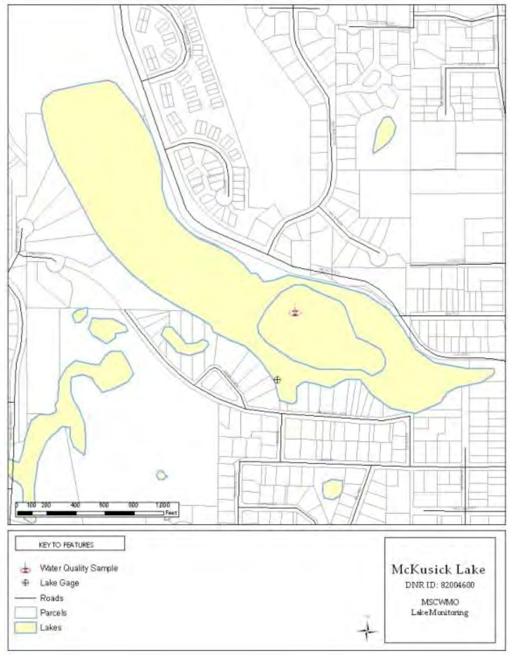
McKusick Lake

2015 Lake Grade: C

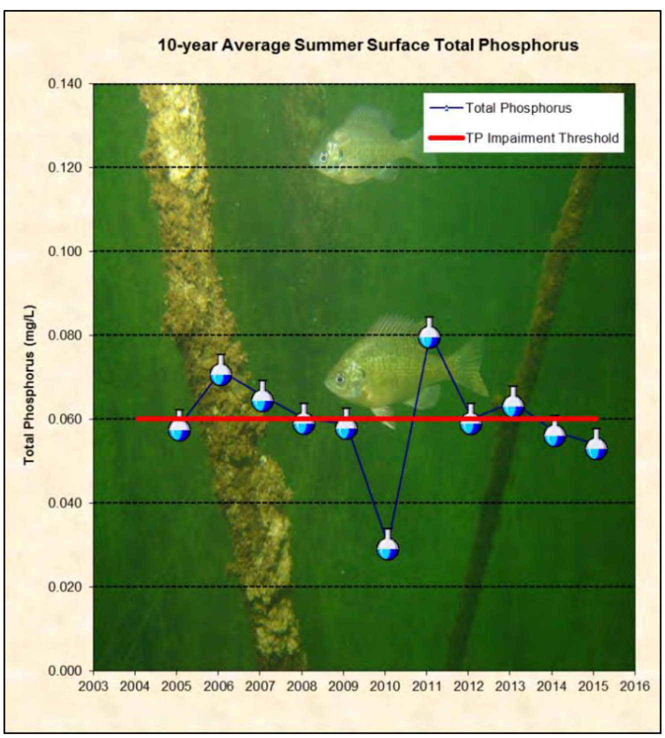
DNR ID #: 820020

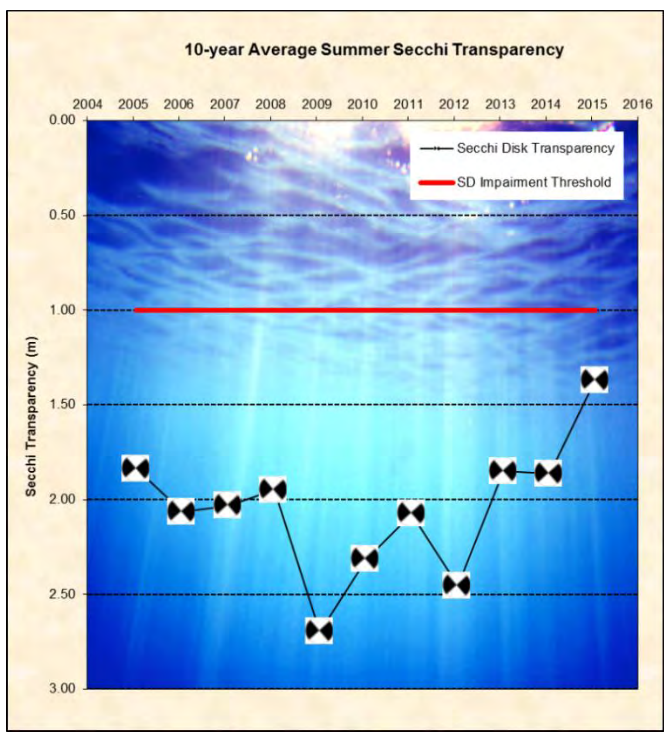
- Municipality: City of Stillwater
- Location: NE ¼ Section 29, T30N-R20W
- Lake Size: 46 Acres
- Maximum Depth (2015): 16.0ft
- Ordinary High Water Mark: 851.7 ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on the chlorophyll-*a* results McKusick Lake was considered eutrophic in 2015, according to the Carlson Trophic State Index.
- Using a Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for average Secchi transparency and a statistically significant **improving** trend for average total phosphorus.
- The major land use is urban/residential.
- The lake stratified in 2015 with the thermocline around 3 meters deep.
- McKusick Lake has been delisted for its impairment for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





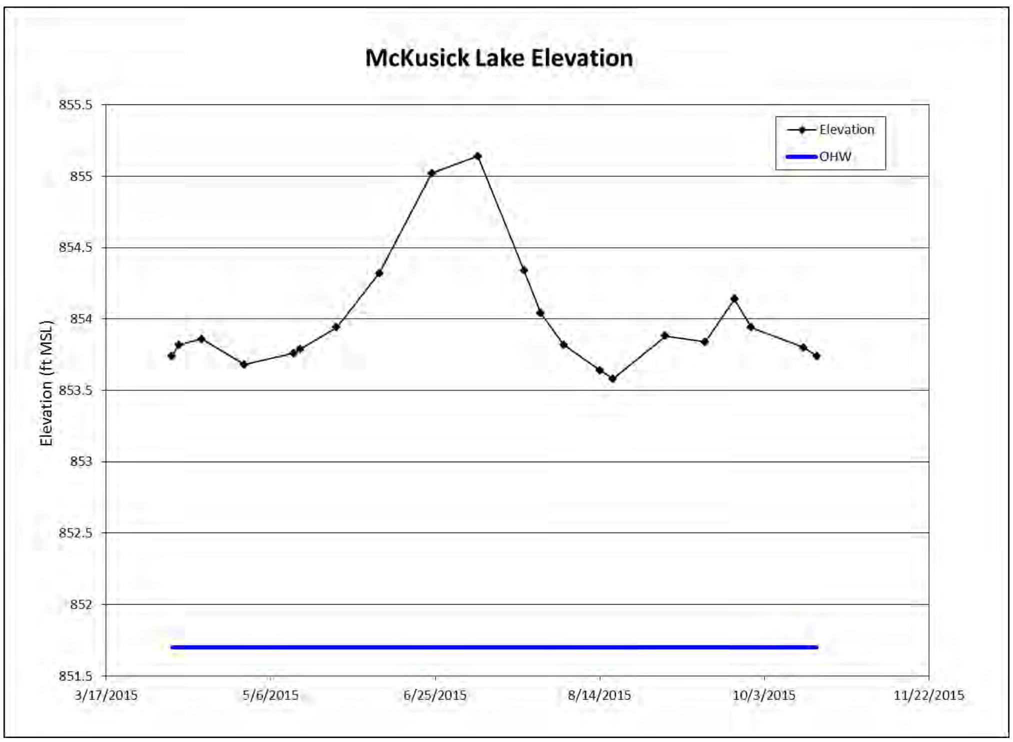
Date	Total Phosphorus (mg/L)	Chlorophyll-a (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depths (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
4/15/2015 12:51	0.062	25.0	1.00	1.52	14.1	11.08
4/28/2015 12:44	0.057	11.0	1.00	1.22	14.2	11.71
5/13/2015 11:42	0.061	21.0	1.00	0.91	14.6	8.83
5/26/2015 13:29	0.060	17.0	1.20	1.52	18.5	8.60
6/8/2015 14:52	0.047	8.1	0.82	1.83	24.1	8.03
6/24/2015 15:47	0.044	8.8	0.96	1.68	26.6	8.52
7/8/2015 15:34	0.031	11.0	0.91	1.22	24.1	6.77
7/22/2015 10:14	0.045	6.3	0.71	1.22	24.6	7.15
8/3/2015 14:36	0.044	33.0	0.95	1.37	24.8	6.92
8/18/2015 10:45	0.130	240.0	1.50	0.46	23.9	2.84
9/2/2015 9:35	0.031	10.0	0.81	1.68	23.4	8.07
9/15/2015 12:06	0.047	4.5	0.90	1.52	21.3	8.38
9/29/2015 13:19	0.039	14.0	0.74	1.37	19.8	6.08
10/13/2015 13:47	0.052	22.0	1.40	1.98	13.1	9.02
2015 Average	0.054	30.8	0.99	1.39	20.5	8.00
2015 Summer Average	0.051	37.3	0.92	1.37	23.6	6.97

Water quality thresholds are 0.04 mg/L TP, 14 µg/L CL-a, 1.4 m Secchi depth*

Shallow lake water quality thresholds are 0.06 mg/L TP, 20 µg/L CL-a, 1.0 m Secchi depth*

	High	High Date	Low	Low Date	Average
2015 Elevation (ft)	855.14	7/8/2015	853.58	8/18/2015	853.99

*MPCA description of Impaired Lake's Listing criteria: "At a minimum, a decision that a given lake is impaired for the 303(d) list due to excessive nutrients will be supported by data for both causal and response factors. Data requirements for 303(d) listing consist of 12 or more TP measurements collected from June through September over the most recent 10-year period. Ideally this should represent 12 separate visits to the lake over the course of two summers; however it might also reflect four monthly samples over the course of three years (a typical sampling regimen for many lake monitoring programs). In addition to exceeding the TP guideline thresholds, lakes to be considered for 303(d) listing should have at least 12 Secchi measurements and 12 chlorophyll-a measurements. This amount of data will allow for at least one season (preferably more) for paired TP, chlorophyll-a, and Secchi disk data and provide a basis for evaluating their interrelationships and hence the trophic status of the lake."

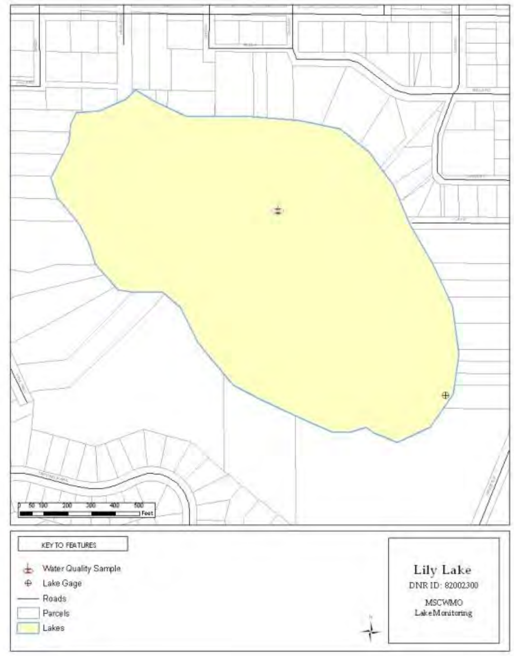


Lake Water Quality Summary										
	Summertime Lake Grades									
	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006
Total Phosphorus (mg/L)	C	C	C	C	D	B	C	C	C	D
Chlorophyll-a (ug/L)	C	C	B	A	C	A	A	B	B	B
Secchi depth (ft)	C	C	C	B	C	B	B	C	C	C
Overall	**C**	**C**	**C+**	**B**	**C-**	**B+**	**B**	**C+**	**C+**	**C**

Lily Lake

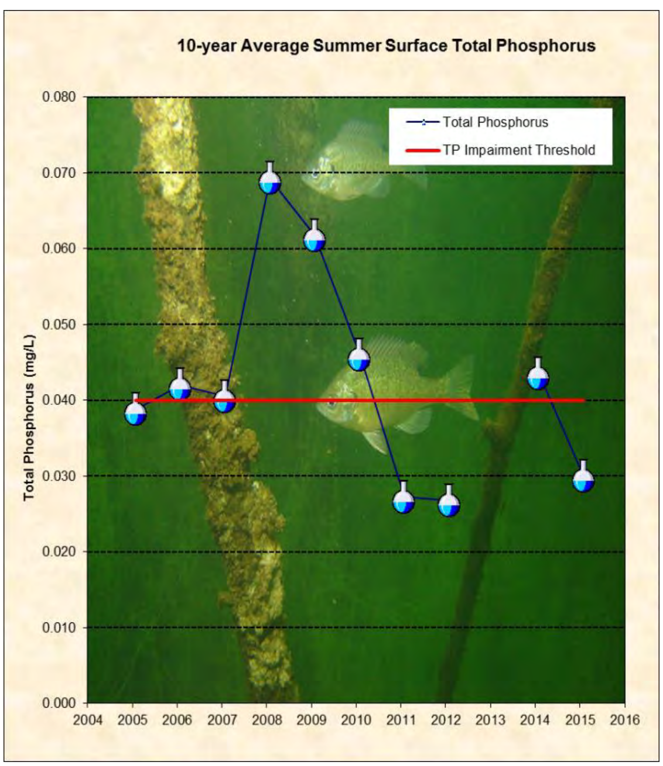
2015 Lake Grade: C+

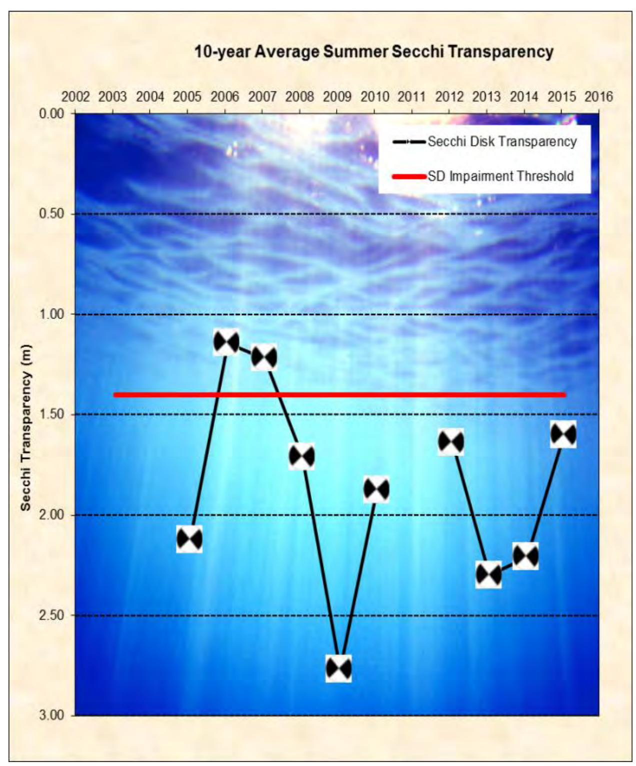
- DNR ID #: 820023
- Municipality: City of Stillwater
- Location: NE ¼ Section 32, T30N-R20W
- Lake Size: 35.90 Acres
- Maximum Depth (2015): 47.5 ft
- Ordinary High Water Mark: 844.8 ft
- 55%Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.
- Public access and public beach present



Summary Points

- Based on the chlorophyll-*a* results Lily Lake was considered eutrophic in 2015, according to the Carlson Trophic State Index.
- Using a Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for average total phosphorus and no statistically significant trend is present for Secchi transparency.
- The major land use is urban/residential.
- Lily Lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





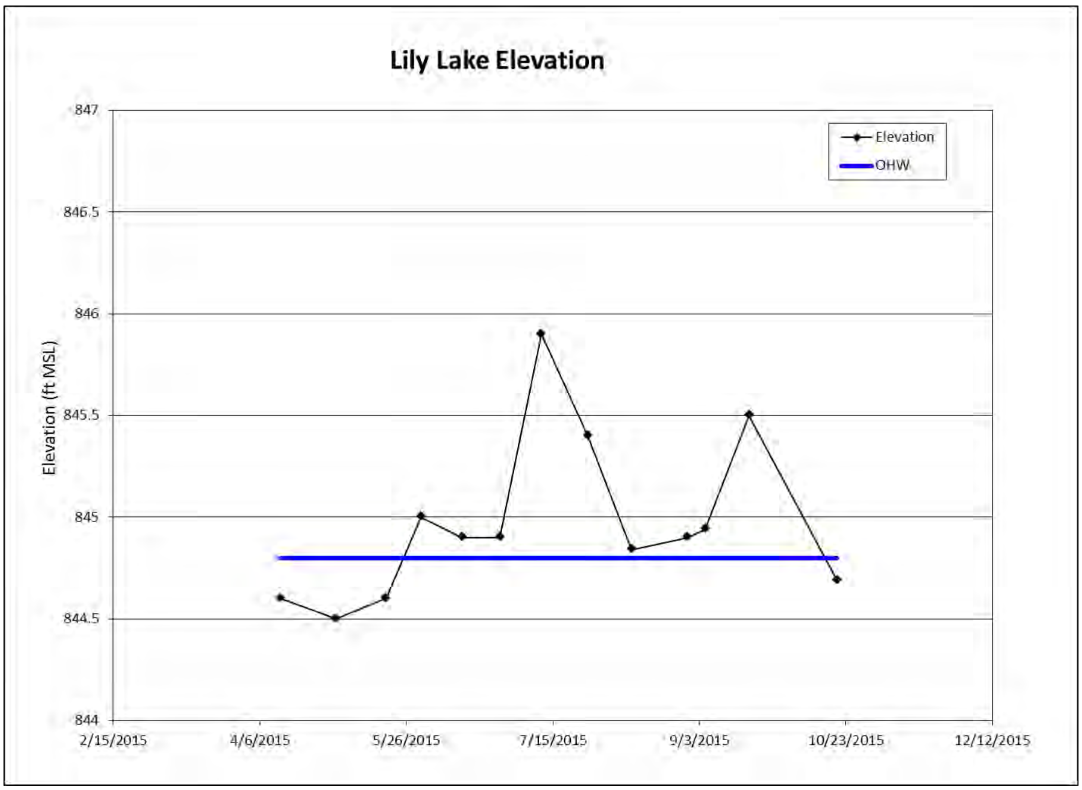
Date	Total Phosphorus (mg/L)	Chlorophyll-a (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depths (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
05/02/2015 19:00	0.011	1.5	0.60	5.0	17.1	NA
05/19/2015 17:50	0.011	2.5	0.64	4.4	19.4	NA
05/31/2015 08:30	0.008	3.3	0.63	4.4	24.5	NA
06/14/2015 19:30	0.008	4.4	0.70	3.0	26.8	NA
06/27/2015 16:00	0.011	13.0	0.98	1.5	29.9	NA
07/11/2015 19:50	0.017	8.6	0.69	2.0	26.3	NA
07/27/2015 19:15	0.017	35.0	1.40	1.0	28.5	NA
08/11/2015 10:50	0.035	43.0	1.89	1.5	25.3	NA
08/30/2015 11:50	0.054	46.0	1.94	1.2	21.7	NA
09/05/2015 16:00	0.033	18.0	1.10	1.1	22.4	NA
09/20/2015 17:50	0.032	22.0	1.10	1.5	20.7	NA
10/20/2015 09:00	0.038	23.0	0.95	1.9	12.4	NA
2015 Average	0.023	18.4	1.05	2.4	22.9	NA
2015 Summer Average	0.026	23.8	1.23	1.6	25.2	NA

Water quality thresholds are 0.04 mg/L TP, 14 µg/L CL-a, 1.4 m Secchi depth*

Shallow lake water quality thresholds are 0.06 mg/L TP, 20 µg/L CL-a, 1.0 m Secchi depth*

	High	High Date	Low	Low Date	Average
2015 Elevation (ft)	845.90	7/11/2015	844.50	5/2/2015	844.97

*MPCA description of Impaired Lake's Listing criteria: "At a minimum, a decision that a given lake is impaired for the 303(d) list due to excessive nutrients will be supported by data for both causal and response factors. Data requirements for 303(d) listing consist of 12 or more TP measurements collected from June through September over the most recent 10-year period. Ideally this should represent 12 separate visits to the lake over the course of two summers; however it might also reflect four monthly samples over the course of three years (a typical sampling regimen for many lake monitoring programs). In addition to exceeding the TP guideline thresholds, lakes to be considered for 303(d) listing should have at least 12 Secchi measurements and 12 chlorophyll-a measurements. This amount of data will allow for at least one season (preferably more) for paired TP, chlorophyll-a, and Secchi disk data and provide a basis for evaluating their interrelationships and hence the trophic status of the



Lake Water Quality Summary										
	Summertime Lake Grades									
	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006
Total Phosphorus (mg/L)	B	A	B	C	NA	B	B	C	C	D
Chlorophyll-*a* (ug/L)	C	B	B	B	NA	C	A	C	C	C
Secchi depth (ft)	C	B	B	C	NA	C	B	C	C	D
Overall	**C+**	**B+**	**B**	**C+**	**NA**	**C+**	**B+**	**C**	**C**	**D+**