Middle St. Croix Watershed Management Organization 2016 Water Monitoring Report

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ACKNOWLEDGEMENTS

Multiple agencies and individuals were directly involved in many aspects of this project, such as data collection, data analysis, as well as technical and administrative assistance.

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

BCWD	Brown's Creek Watershed District
Benthic	The area nearest lake bed
biweekly	Every other week
BMP	Best Management Practice
cf	cubic feet
cfs	cubic feet per second
Chl-α	Chlorophyll-α
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
IESF	Iron Enhanced Sand Filter
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	micrograms 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 2016 as well as previous years. In 2016 the Middle St. Croix Watershed Management Organization (MSCWMO) monitored both water quality and water surface elevation on McKusick Lake and Lily 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 2016 (Table 3). Lily Lake was above the North Central Hardwood Forest Ecoregion (NCHFE) range for chlorophyll-α (chl-α) and within the NCHFE range for total phosphorous (TP), total Kjeldahl nitrogen (TKN) and Secchi disk transparency readings for the 2016 monitoring season. Three samples collected exceeded the MPCA threshold for TP, and five of the fourteen samples collected exceeded the MPCA threshold for chl-α. Four of the Secchi disk transparency readings exceeded the MPCA threshold.

In 2016 McKusick Lake was classified as eutrophic (Table 2) and received a grade of C+ (Table 3). McKusick Lake was above the NCHFE range for TP and within the NCHFE range for chl-α, TKN, and Secchi disk transparency. Three of the fourteen water quality samples exceeded the MPCA shallow lake threshold for TP, and three samples exceeded the MPCA threshold for chl-α. One Secchi disk transparency measurement exceeded the MPCA shallow lake threshold.

The Brown's Creek Diversion Structure site, which exports to McKusick Lake, showed an increase in discharge in 2016 to 70,780,581 cf from 46,276,327 cf in 2015. The phosphorus load decreased from 1,837 lbs. in 2015 to 1,574 lbs. in 2016. TSS also showed an increased exported from the Brown's Creek Diversion Structure to McKusick Lake, from 1,008,346 lbs. in 2015 to 1,533,496 lbs. in 2016 (Table 5). The total discharge and TSS export were the highest recorded values since monitoring the Brown's Creek Diversion Structure began. The phosphorous load in 2016 was the third highest recorded value in the last 10 years.

In 2014 the MSCWMO discontinued monitoring of Brick Pond. The MSCWMO instead focused on problem investigation monitoring strategies for Lily Lake and Brick Pond that began in 2015 and continued 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. The MSCWMO resumed monitoring Perro Creek to identify where the greatest contribution to the Saint Croix River was occurring. This investigatory monitoring was started in 2016 and will continue into 2017.

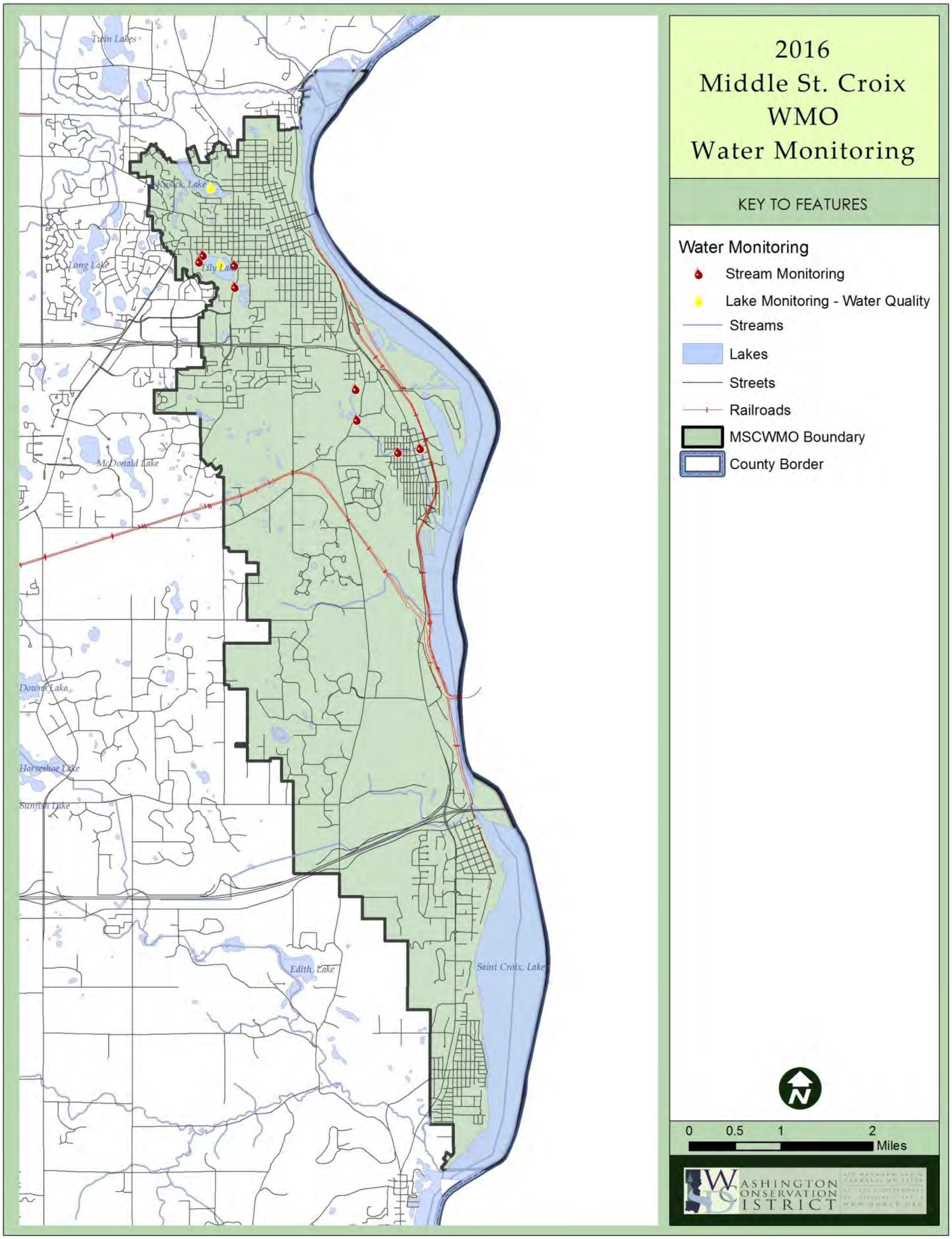

Figure 1. MSCWMO 2016 Water Monitoring Locations

LAKE MONITORING

A. METHODS, RESULTS AND DISCUSSION

In 2016 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, to the average NCHFE values, and to the Minnesota Pollution Control Agency's (MPCA) impairment standards. Measurements used to calculate lake grade averages are based on samples collected May-September. 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-α, 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 2016 summer average of TP values of MSCWMO lakes can be found Figure 4.

Chlorophyll-α 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-α is 5 –

22 µg/L. The MPCA standard for pheophytin-corrected chl-*α* is 14 µg/L for deep lakes and 20 µg/L for shallow lakes. The 2016 summer average chl-*α* 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 may cause 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 2016 summer average TKN concentrations of MSCWMO lakes can be found in Figure 6.

Table 1. North Central Hardwood Forest Ecoregion Values and Average 2016 Parameters

2016 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	*0.037*	*23.9*	*0.92*	*1.81*	Deep
McKusick	*0.059*	*19.0*	*0.88*	*1.68*	Shallow

No heavy metal testing was performed on samples collected on McKusick Lake in 2016. Heavy metal samples were collected in 2012-2014 because many heavy metals are known to be 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 meter for shallow lakes.

User perception and physical/recreational suitability of lakes were recorded, along with temperature and dissolved oxygen (DO) 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 change 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-*α*, 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-*α* 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-*α* 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 May through September average values of TP, uncorrected trichromatic chl-*α*, and Secchi disk transparency. These percentiles use ranked data from 119 lakes sampled from 1980-1988 and are shown in Table 3. This method has since been replicated and the grading system has been verified with this data. 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

Water elevation monitoring was conducted on two lakes, McKusisk and Lily, from May to October 2015. Lake gage readings are compared to the lake's Ordinary High Water level (OHW)[1]. Changes in lake water level elevation are mostly attributed to the changes in monthly precipitation. The highest recorded elevations in 2016 occurred in the late summer, early fall. McKusick Lake recorded a high reading on 9/26/2016 and Lily Lake recorded a high reading on 8/17/2016. Complete lake elevation data for 2016 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 2016 was 0.059 mg/L, higher than the 0.051 mg/L observed in 2015, with three of the nine summertime water quality samples collected exceeding the MPCA TP impairment standard for shallow lakes. In 2016 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; McKusick Lake has seen statistically significant improvements ($p<0.05$) for TP from 1994 to the present (Figure 4). McKusick Lake had a summertime average chl-*α* concentration of 19.0 μg/L, much lower than the chl-*α* average of 37.3 μg/L from 2015 (Figure 5). Of the nine summertime samples collected in 2016, three exceeded the MPCA shallow lakes standard for chl-*α*. The average summertime TKN concentration for 2016 was 0.88 mg/L, slightly lower from the 0.92 mg/L measured in 2015 (Figure 6). The 2016 summertime average water transparency measured by Secchi disk was 1.68 meters. All but one of the Secchi disk readings in 2016 was better than the MPCA lake

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[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.

impairment standard. 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 2016, slightly better than the C received in 2015 Temperature and DO profiles indicate that McKusick Lake exhibited thermal stratification during the summer months of 2016 with the thermocline around 3 meters. A majority of McKusisk Lake is very shallow, and therefore is likely to have mixed throughout the summer. The elevation of McKusick Lake remained above the OHW for the entire 2016 monitoring season, reaching its highest recorded level on 9/26/2016 with a level of 854.86 ft. and falling to its lowest recorded level on 5/24/2016 with an elevation of 853.76 ft. (Figure 2). Summaries of all lake results are presented in Appendix A.

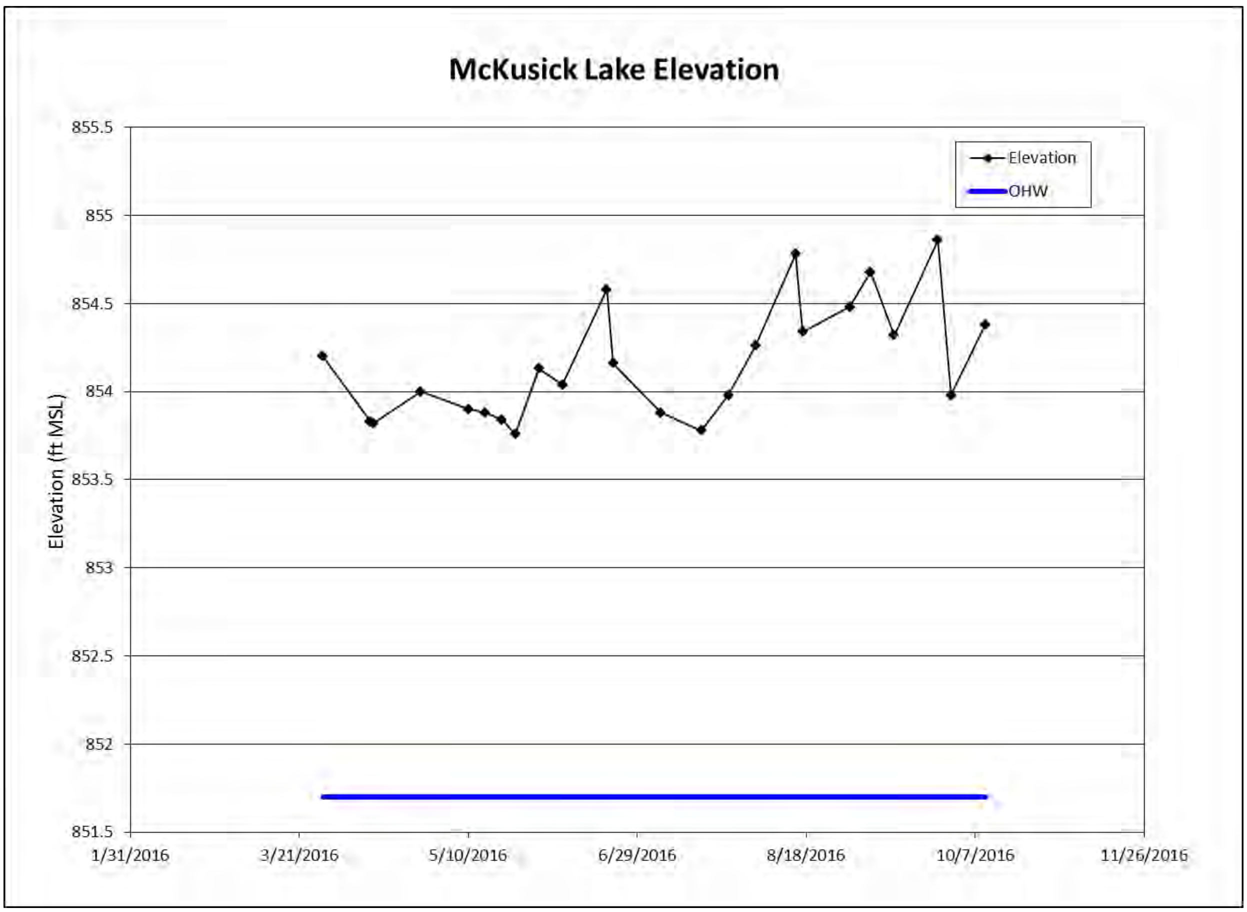

Figure 2. McKusick Lake 2016 Elevations

2. LILY LAKE

Lily Lake had an average summertime TP concentration of 0.037 mg/L, higher than the 2015 average summertime TP concentration of 0.026 mg/L, below the MPCA lake nutrient impairment threshold for TP (Figure 4). Three of the nine summertime results were greater than the MPCA lake nutrient impairment standard for TP. A two-tailed Kendall Tau statistical trend analysis was conducted and Lily Lake had a statistically significant improving trend found in the historical summer TP data ($p<0.05$). The 2016 average summertime concentration of chl-α was 23.9 µg/L, very close to the 23.8 µg/L measured in 2015, with five of the nine water quality results exceeding the MPCA lake standard for chl-α impairment (Figure 5). Lily Lake had an average summertime TKN concentration of 0.92 mg/L in 2016, lower than the 1.23 mg/L seen in 2015 (Figure 6). Secchi disk readings were measured in 2016 with a summertime average of 1.81 meters, with four of the nine water quality readings exceeding the MPCA lake standard for Secchi disk transparency impairment (Figure 7). No statistically significant trend in Secchi disk transparency could be determined ($p<0.05$). Lily Lake received a grade of C+ in 2016, unchanged from 2015. Temperature and DO profiles indicate that Lily Lake exhibited thermal stratification during the summer months of 2016 with the thermocline around 5 meters; therefore the lake was less likely to completely mix throughout the summer. Lily Lake was below the OHW for four elevation readings, falling to its lowest recorded level on 5/24/2016 with an elevation of 844.94 ft. The elevation was above the OHW for most of the monitoring season, reaching its highest recorded level on 8/17/2016 with a level of 845.42 ft. (Figure 3). Summaries of all lake results are presented in Appendix A.

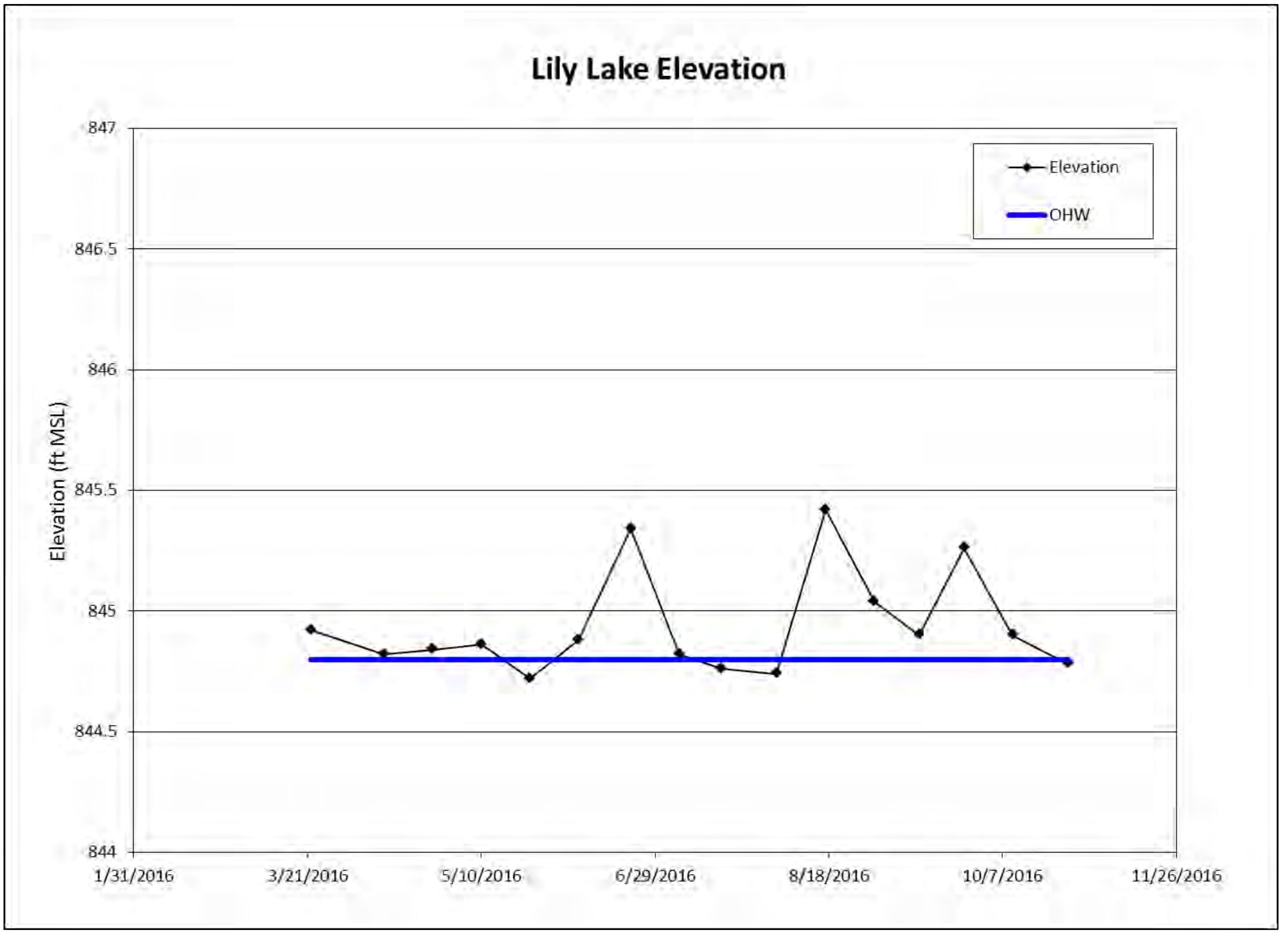

Figure 3. Lily Lake 2016 Elevations

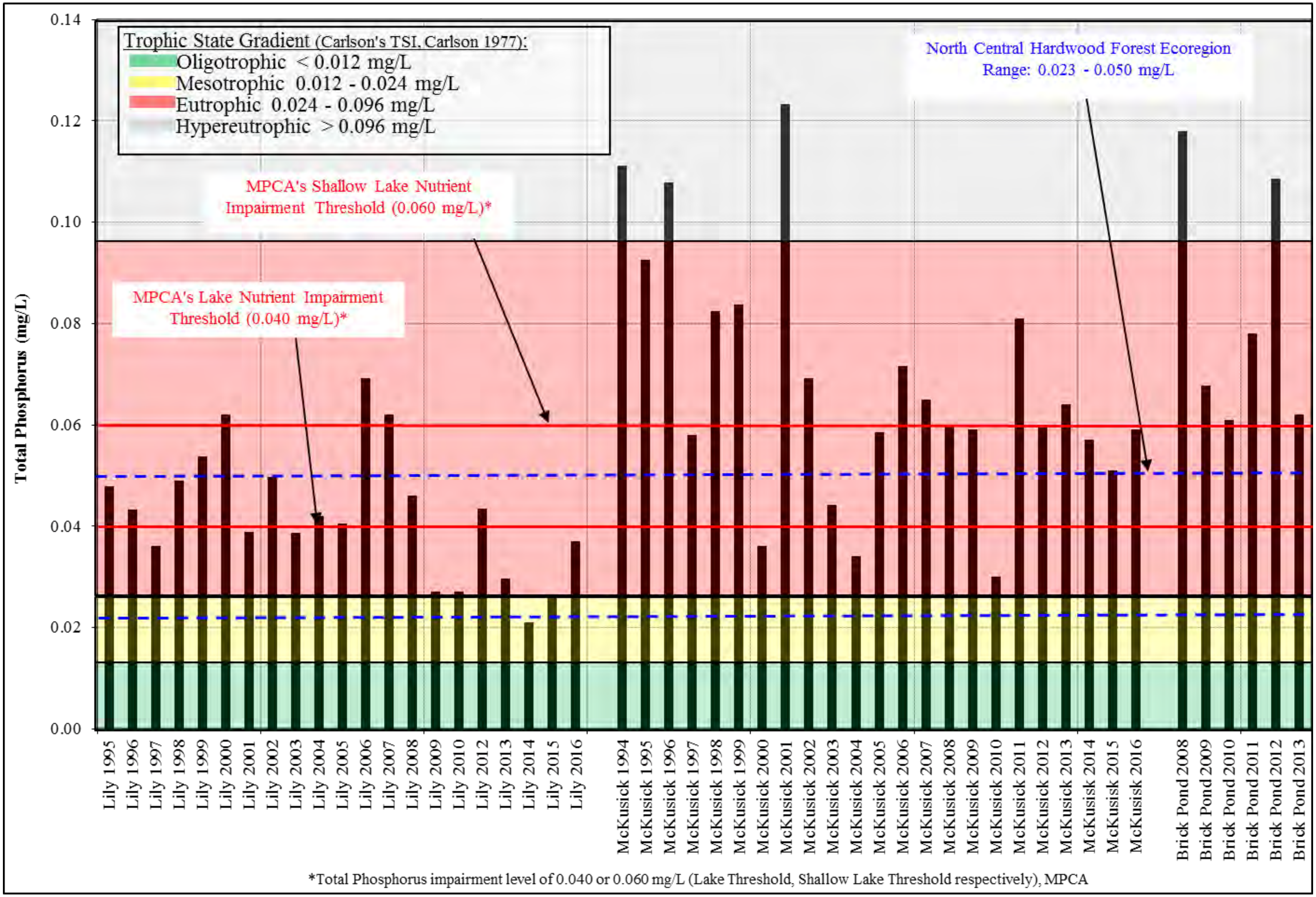

Figure 4. MSCWMO Historic Summer Average Total Phosphorus Data

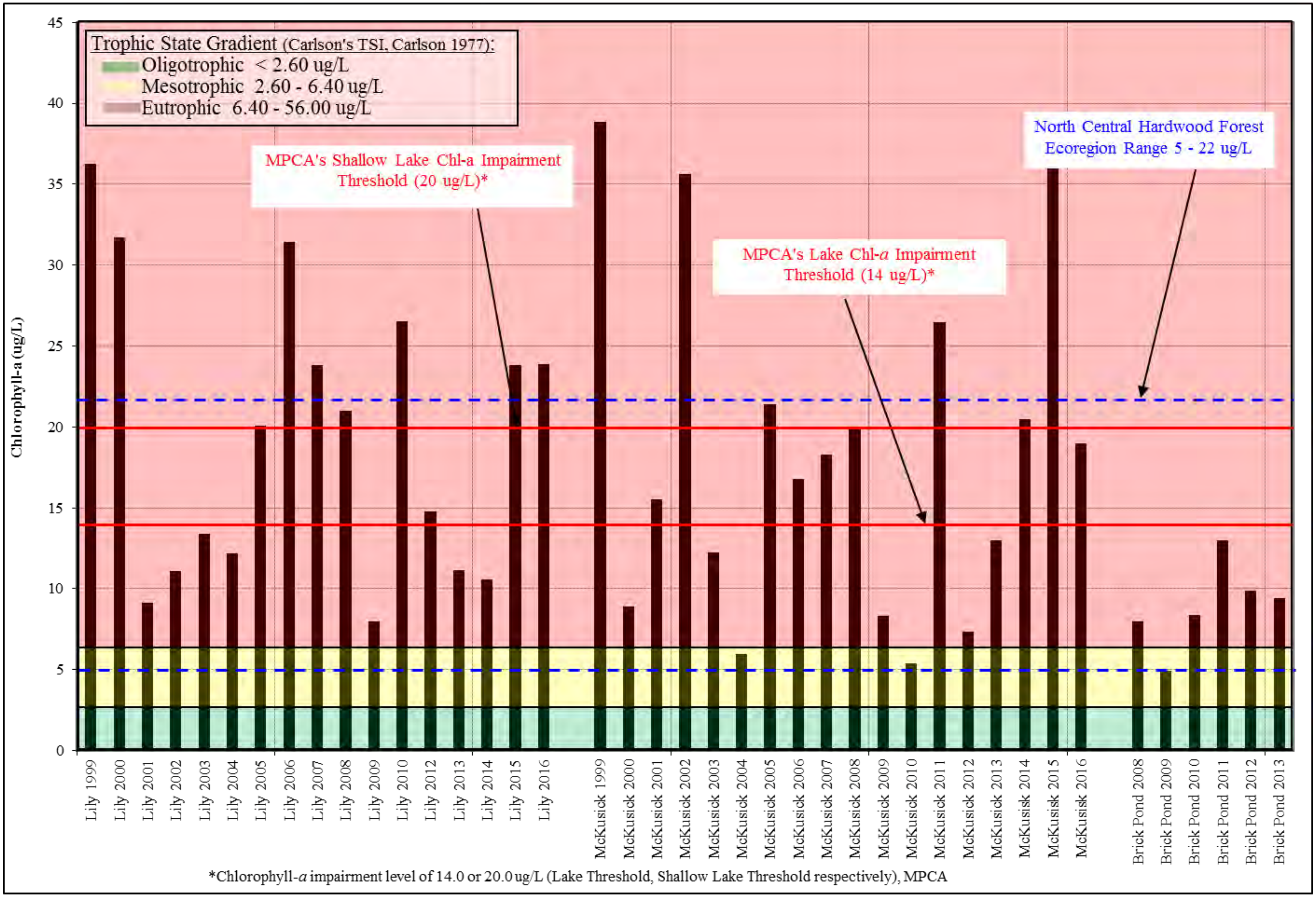

Figure 5. MSCWMO Historic Summer Average Chlorophyll-*a* Data

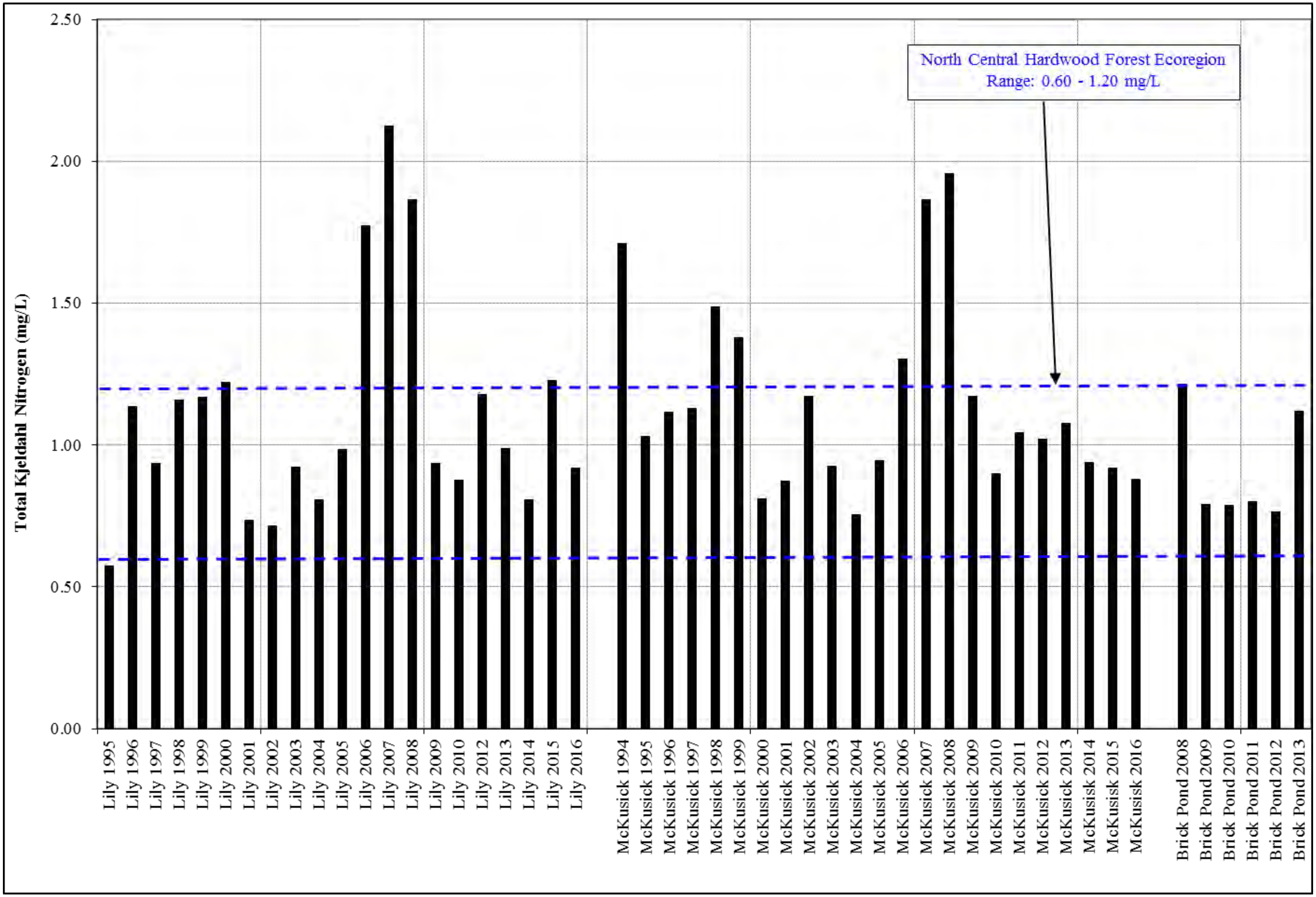

Figure 6. MSCWMO Historic Summer Average Total Kjeldahl Nitrogen Data

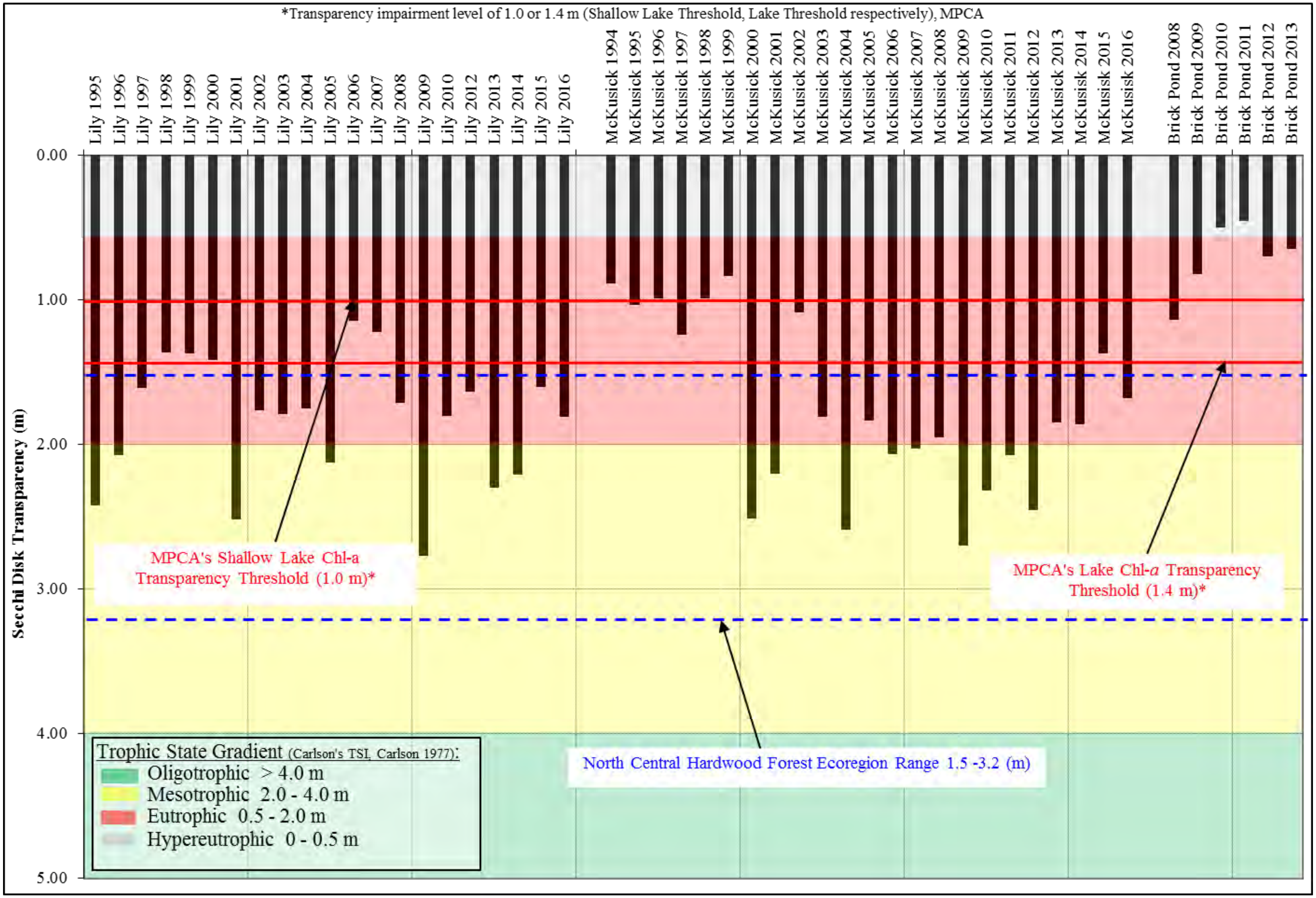

Figure 7. MSCWMO Historic Summer Average Secchi Data

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 with abundant aquatic macrophytes or in 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 TMDL has been postponed. 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.

Summertime TP, chl-*α*, and Secchi disk transparency averages for 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). In 2001 phosphorus and chl-*α* levels dropped and the lake grade improved significantly. In 2006 and 2007, summer average TP, chl-*α*, 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 (2007 and 2016). 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. Six large raingardens were installed in 2014. The first effects of these BMPs may have been seen from 2013 to 2016 monitoring seasons, continued monitoring is needed to show changes to long term trends of these BMPs. 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.

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 addressing some of the water quality and quantity concerns. All associated data can be found in Table 4 through Table 8. A subwatershed assessment was 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, six larger raingardens were installed in 2014. The impacts of previously installed raingardens were not seen in the 2016 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.

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. In 2016 four catchments that contributed the majority of the nutrient load to Lily Lake were monitored; this data is presented in Appendix B.

2. PERRO CREEK MONITORING

In 2016 monitoring of Perro Creek was undertaken to identify where the greatest contribution to the Saint Croix River was occurring. Automated data loggers were installed at the outlets of Perro Pond to Perro Creek and the direct pipe to the Saint Croix River, and at the Perro Creek diversion structure in the main channel and the overflow pipe. Grab samples were collected at these sites and analyzed for Total Phosphorus (TP), Total Kjeldhal Nitrogen (TKN), Total Suspended Solids (TSS) and *E. coli.* Additionally, samples were collected at the historic 6th Street monitoring location for *E. coli* only. This data and a brief summary are presented in Appendix C.

3. 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 2016. 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 discharged to 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 2016 can be found in Table 4 through Table 8.

The diversion drainage was again monitored at the diversion structure for nutrients, sediment, metals, and bacteria, as well as continuous stage and discharge. A secondary level logger installed at the diversion weir shows no water was directly discharged to Brown's Creek. Discharge increased from the year prior to a total volume of 70,780,581 cubic feet exported to McKusick Lake (Table 4 and Table 5). Much of this increase is due to the high volume of precipitation observed throughout the monitoring season. Although frequent precipitation and a few intense storms occurred, the secondary level logger at the base of the diversion structure indicates no water was directly discharged to Brown's Creek.

Throughout the summer a number of non-precipitation related events occurred at Diversion, one of which was successfully sampled. It is assumed based on the timing, shape of hydrograph, and duration of the events that these events are due to manipulation of the outlet at the upstream Jackson WMA Pond, likely through clearing brush from the outlet. Similarly, beavers plugged the Diversion pipe on October 28, causing water to back up well over the pipe until city crews cleared the blockage in November.

The TP load to McKusick Lake actually decreased in 2016 from the year prior, despite the wet weather, to 1,574 pounds of phosphorus (0.408 pounds per acre) (Table 4 and Table 5). The state standard for 2B waters is 0.100 mg/L. The drainage is meeting state standards for TP 2B waters with some exceptions at base flow, but has an extremely high storm loading rate (Table 5). The June sample had an extremely high TP concentration compared to other base flow samples and was excluded when completing loading calculations.

The TSS load increased from the year prior to 1,533,496 pounds of sediment, equating to 397.79 pounds per acre of watershed land (Table 4 and Table 5). The state standard for 2B waters is 30 mg/L, this site is below the standard during base flow conditions (Table 6).

One source of the high TP and TSS loads in the diversion drainage is an erosional head cut north of Boutwell Road, upstream of the monitoring location. The creek is eroding its bed and banks at this location, and actions taken to address this issue will significantly reduce TP and TSS loads to McKusick Lake. The Iron Enhanced Sand Filter (IESF) upstream of the monitoring site continues to operate to reduce TP loads in the drainage.

Heavy metals exceedances occurred with frequency in 2016. The final acute value (FAV) for copper was exceeded three times, and the chronic standard four times. The max standard for lead was exceeded once, and the chronic standard in ten of the thirteen other storm samples. The max standard for zinc was exceeded three times, and the chronic standard for cadmium twice. A summary of metals results can be seen in (Table 7). The frequency of exceeding the FAV to McKusick Lake and its wetland complex are particularly concerning due to the potential to kill aquatic life almost, as opposed to nutrient or sediment loading which typically degrades habitat and populations of aquatic life over time. The most likely source of these elevated metals is the erosion occurring upstream of the site. Additional sources may be from unseen deposits of improperly disposed waste, such as batteries, on the landscape from decades of settlement.

Water quality results showed no field data measurements exceeded the standard threshold for pH, and no field data measurements exceeded the standard threshold for dissolved oxygen (mg/L) (Table 8).

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 2014-2016 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. Brown's Creek Diversion Structure Drainage Historical Annual Discharge and Loading Amounts

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Brown's Creek Diversion Structure										
Discharge (cf)	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	70,780,581
Total pounds of Phosphorus exported	653	206	544	608	2,099	251	527	392	1,837	1,574
TP (lbs/ac/yr)	0.169	0.053	0.141	0.158	0.544	0.065	0.137	0.102	0.447	0.408
Total pounds of TSS exported	232,190	59,313	227,372	353,007	1,387,050	127,435	211,977	99,532	1,008,346	1,533,496
TSS (lbs/ac/yr)	60.23	15.39	58.98	91.57	359.81	33.06	54.99	25.82	261.57	397.79

Table 5. Brown's Creek Diversion Structure Drainage 2016 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*			12	0.098	1/1/2016 0:00	3/15/2016 4:00	1,602,000	36.80	1,200	9.80
Storm Grab**	3/16/2016 9:34	3/16/2016 9:34	180	0.332	3/15/2016 4:00	3/16/2016 17:00	1,998,000	45.89	22,451	41.41
Base*			12	0.098	3/16/2016 17:00	3/29/2016 14:45	4,460,400	102.45	3,341	27.29
Base			12	0.098	3/29/2016 14:45	3/29/2016 23:45	29,848	0.69	22	0.18
Storm			1,410	1.154	3/29/2016 23:45	3/30/2016 23:45	171,173	3.93	15,067	12.33
Base			12	0.098	3/30/2016 23:45	4/24/2016 6:45	2,158,880	49.59	1,617	13.21
Storm			1,410	1.154	4/24/2016 6:45	4/24/2016 21:45	101,243	2.33	8,911	7.29
Base			12	0.098	4/24/2016 21:45	4/25/2016 8:45	69,560	1.60	52	0.43
Storm Composite[xy]	4/25/2016 12:40	4/25/2016 18:13	6,190	3.540	4/25/2016 8:45	4/25/2016 21:45	206,940	4.75	79,965	45.73
Base Grab	4/26/2016 13:30	4/26/2016 13:30	16	0.074	4/25/2016 21:45	4/27/2016 17:45	300,452	6.90	300	1.39
Storm			1,410	1.154	4/27/2016 17:45	4/30/2016 0:45	514,405	11.82	45,278	37.06
Base			12	0.098	4/30/2016 0:45	5/3/2016 13:45	416,693	9.57	312	2.55
Lake Draining			538	0.706	5/3/2016 13:45	5/4/2016 0:45	153,748	3.53	5,164	6.78
Base			12	0.098	5/4/2016 0:45	5/5/2016 9:45	130,359	2.99	98	0.80
Lake Draining Comp	5/5/2016 10:41	5/6/2016 4:07	538	0.706	5/5/2016 9:45	5/6/2016 4:45	183,244	4.21	6,154	8.08
Base			12	0.098	5/6/2016 4:45	5/6/2016 8:45	17,924	0.41	13	0.11
Lake Draining			538	0.706	5/6/2016 8:45	5/7/2016 3:45	120,767	2.77	4,056	5.32
Base			12	0.098	5/7/2016 3:45	5/9/2016 15:45	166,096	3.82	124	1.02
Storm			1,410	1.154	5/9/2016 15:45	5/10/2016 15:45	103,522	2.38	9,112	7.46
Base			12	0.098	5/10/2016 15:45	5/17/2016 8:45	738,475	16.96	553	4.52
Base Grab	5/18/2016 9:10	5/18/2016 9:10	2	0.055	5/17/2016 8:45	5/19/2016 14:45	125,479	2.88	16	0.43
Lake Draining			538	0.706	5/19/2016 14:45	5/20/2016 4:45	118,217	2.72	3,970	5.21
Base			12	0.098	5/20/2016 4:45	5/25/2016 10:45	249,076	5.72	187	1.52
Storm Composite	5/25/2016 13:16	5/26/2016 1:56	472	0.610	5/25/2016 10:45	5/26/2016 9:45	237,910	5.46	7,010	9.06
Base			12	0.098	5/26/2016 9:45	5/29/2016 20:45	385,181	8.85	289	2.36
Storm			1,410	1.154	5/29/2016 20:45	5/30/2016 10:45	84,020	1.93	7,396	6.05
Base			12	0.098	5/30/2016 10:45	6/8/2016 8:45	725,608	16.67	544	4.44
Base Grab	6/9/2016 8:26	6/9/2016 8:26	10	0.089	6/8/2016 8:45	6/13/2016 0:45	166,972	3.84	104	0.93
Storm Composite	6/13/2016 3:33	6/13/2016 11:33	1,100	2.310	6/13/2016 0:45	6/13/2016 11:45	657,883	15.11	45,176	94.87
Storm Grab**	6/13/2016 8:20	6/13/2016 8:20	45	0.218	6/13/2016 11:45	6/13/2016 17:45	442,693	10.17	1,244	6.02
Base			12	0.098	6/13/2016 17:45	6/14/2016 12:45	775,879	17.82	581	4.75
Storm Composite[xy]	6/14/2016 20:19	6/15/2016 13:37	7,150	3.460	6/14/2016 12:45	6/15/2016 13:45	1,273,640	29.25	568,485	275.10
Base			12	0.098	6/15/2016 13:45	6/20/2016 8:45	2,574,050	59.12	1,928	15.75
Base Grab[y]	6/21/2016 9:09	6/21/2016 9:09	26	1.530	6/20/2016 8:45	6/23/2016 14:45	456,940	10.50	742	43.64
Lake Draining			538	0.706	6/23/2016 14:45	6/24/2016 4:45	95,519	2.19	3,208	4.21
Base			12	0.098	6/24/2016 4:45	6/28/2016 13:45	230,448	5.29	173	1.41
Lake Draining			538	0.706	6/28/2016 13:45	6/29/2016 2:45	163,928	3.77	5,506	7.22
Base			12	0.098	6/29/2016 2:45	7/5/2016 14:45	260,632	5.99	195	1.59
Storm			1,410	1.154	7/5/2016 14:45	7/6/2016 3:45	93,379	2.14	8,219	6.73
Base			12	0.098	7/6/2016 3:45	7/20/2016 8:45	909,609	20.89	681	5.56
Base Grab	7/21/2016 8:46	7/21/2016 8:46	16	0.136	7/20/2016 8:45	7/23/2016 10:45	143,297	3.29	143	1.22
Storm Composite	7/23/2016 16:43	7/25/2016 6:45	4,070	2.660	7/23/2016 10:45	7/25/2016 6:45	400,512	9.20	101,760	66.51
Base			12	0.098	7/25/2016 6:45	7/27/2016 14:45	405,851	9.32	304	2.48
Storm Composite	7/27/2016 16:28	7/27/2016 22:54	2,290	0.980	7/27/2016 14:45	7/27/2016 23:45	210,398	4.83	30,078	12.87
Base			12	0.098	7/27/2016 23:45	8/1/2016 19:45	1,874,020	43.04	1,404	11.46
Storm			1,410	1.154	8/1/2016 19:45	8/2/2016 4:45	91,318	2.10	8,038	6.58
Base			12	0.098	8/2/2016 4:45	8/4/2016 7:45	391,146	8.98	293	2.39
Storm			1,410	1.154	8/4/2016 7:45	8/5/2016 0:45	381,577	8.76	33,587	27.49
Base			12	0.098	8/5/2016 0:45	8/10/2016 20:45	1,178,250	27.06	883	7.21
Storm Composite	8/10/2016 21:13	8/11/2016 7:45	846	1.140	8/10/2016 20:45	8/11/2016 7:45	811,114	18.63	42,837	57.72
Base Grab	8/11/2016 8:18	8/11/2016 8:18	10	0.216	8/11/2016 7:45	8/12/2016 8:45	1,815,710	41.70	1,133	24.48
Base			12	0.098	8/12/2016 8:45	8/23/2016 23:45	6,172,990	141.79	4,624	37.76
Storm Composite	8/24/2016 0:55	8/24/2016 9:01	2,380	0.184	8/23/2016 23:45	8/24/2016 9:45	261,623	6.01	38,870	3.01
Base Grab	8/26/2016 8:43	8/26/2016 8:43	10	0.074	8/24/2016 9:45	8/29/2016 22:45	2,259,810	51.91	1,411	10.44
Storm Composite	8/29/2016 23:56	8/30/2016 8:46	1,120	1.590	8/29/2016 22:45	8/30/2016 9:45	583,228	13.40	40,778	57.89
Base			12	0.098	8/30/2016 9:45	9/5/2016 3:45	3,070,210	70.52	2,300	18.78
Storm			1,410	1.154	9/5/2016 3:45	9/5/2016 10:45	124,965	2.87	11,000	9.00
Base			12	0.098	9/5/2016 10:45	9/6/2016 2:45	254,240	5.84	190	1.56
Storm Composite	9/6/2016 5:34	9/6/2016 16:30	314	0.594	9/6/2016 2:45	9/7/2016 5:45	1,417,410	32.56	27,784	52.56
Base			12	0.098	9/7/2016 5:45	9/15/2016 16:45	4,229,930	97.16	3,169	25.88
Storm			1,410	1.154	9/15/2016 16:45	9/16/2016 9:45	413,732	9.50	36,417	29.81
Base			12	0.098	9/16/2016 9:45	9/16/2016 20:45	224,381	5.15	168	1.37
Storm			1,410	1.154	9/16/2016 20:45	9/17/2016 3:45	177,846	4.08	15,654	12.81
Base			12	0.098	9/17/2016 3:45	9/20/2016 11:45	1,504,780	34.56	1,127	9.21
Lake Draining			538	0.706	9/20/2016 11:45	9/21/2016 18:45	872,045	20.03	29,288	38.43
Storm Composite	9/21/2016 20:19	9/22/2016 14:47	101	0.315	9/21/2016 18:45	9/22/2016 20:45	2,767,670	63.57	17,450	54.42
Base Grab	9/26/2016 10:41	9/26/2016 10:41	11	0.072	9/22/2016 20:45	9/30/2016 9:45	4,627,920	106.30	3,178	20.80
Lake Draining			538	0.706	9/30/2016 9:45	10/2/2016 8:45	552,706	12.70	18,563	24.36
Base			12	0.098	10/2/2016 8:45	10/5/2016 2:45	291,604	6.70	218	1.78
Storm			1,410	1.154	10/5/2016 2:45	10/6/2016 6:45	320,094	7.35	28,175	23.06
Base			12	0.098	10/6/2016 6:45	10/6/2016 20:45	127,018	2.92	95	0.78
Storm			1,410	1.154	10/6/2016 20:45	10/7/2016 20:45	580,013	13.32	51,053	41.78
Base			12	0.098	10/7/2016 20:45	10/12/2016 13:45	1,554,190	35.70	1,164	9.51
Lake Draining			538	0.706	10/12/2016 13:45	10/14/2016 11:45	707,708	16.26	23,769	31.19
Base			12	0.098	10/14/2016 11:45	10/17/2016 12:45	506,088	11.62	379	3.10
Storm			1,410	1.154	10/17/2016 12:45	10/18/2016 6:45	215,947	4.96	19,008	15.56
Base			12	0.098	10/18/2016 6:45	10/23/2016 9:45	720,765	16.56	540	4.41
Base Grab	10/24/2016 9:29	10/24/2016 9:29	8	0.069	10/23/2016 9:45	10/25/2016 21:45	280,622	6.45	140	1.21
Storm			1,410	1.154	10/25/2016 21:45	10/27/2016 5:45	411,821	9.46	36,249	29.67
Base			12	0.098	10/27/2016 5:45	11/7/2016 10:15	1,443,290	33.15	1,081	8.83
Base*			12	0.098	11/7/2016 10:15	12/25/2016 12:00	2,076,750	47.70	1,556	12.71
Storm*			1,410	1.154	12/25/2016 12:00	12/26/2016 20:00	432,000	9.92	38,025	31.12
Base*			12	0.098	12/26/2016 20:00	1/1/2017 0:00	223,200	5.13	167	1.37
Storm Composite Average			1,410	1.154						
Lake Draining Average			538	0.706						
Base Average			12	0.098						
All Average			702	0.660						
Total							**70,780,581**	**1,626**	**1,533,496**	**1,574**
Brown's Creek Major Subwatershed Total Acres							3,855			
Total TSS/TP(lb/ac/yr)									397.79	0.408
Total TSS/TP (kg/ha/yr)									445.86	0.458

Italics indicate estimated concentrations based on average base and storm flow concentrations.
*Interval volumes from 1/1/16 0:00 to 3/29/16 14:45 and 11/7/16 10:15 to 1/1/17 0:00 were estimated using similar flow conditions.
**Storm Grab samples were ommited when calculating storm average concentration.
[x]TSS result excluded from averages.
[y]TP result excluded from averages.

Table 6. Brown's Creek Diversion Structure Drainage 2016 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)
Storm Grab	3/16/2016 9:34	3/16/2016 9:34	180	45	1.80	0.332	0.057		4.60	~0.46
Storm Composite	4/25/2016 12:40	4/25/2016 18:13	6,190	2,380	34.00	3.540	~0.036		44.90	~0.11
Lake Drain Composite	5/5/2016 10:41	5/6/2016 4:07	538	230	7.60	0.706	~0.027		6.10	~0.09
Storm Composite	5/25/2016 13:16	5/26/2016 1:56	472	176	4.40	0.610	~0.020		7.50	~0.07
Storm Composite	6/13/2016 3:33	6/13/2016 11:33	1,100	304	13.00	2.310	0.080		24.50	~0.46
Storm Grab	6/13/2016 8:20	6/13/2016 8:20	45	~15	1.20	0.218	0.103		1.70	~0.37
Storm Composite	6/14/2016 20:19	6/15/2016 13:37	7,150	1,940	19.00	3.460	0.059		52.00	~0.52
Storm Composite	7/23/2016 16:43	7/25/2016 6:45	4,070	1,770	25.00	2.660	~0.046		48.00	~0.11
Storm Composite	7/27/2016 16:28	7/27/2016 22:54	2,290	740	7.90	0.980	<0.020		13.00	~0.21
Storm Composite	8/10/2016 21:13	8/11/2016 7:45	846	280	7.80	1.140	0.095		14.80	~0.35
Storm Composite	8/24/2016 0:55	8/24/2016 9:01	2,380	685	11.00	0.184	0.053		28.30	
Storm Composite	8/29/2016 23:56	8/30/2016 8:46	1,120	372	11.00	1.590	0.075		22.70	
Storm Composite	9/6/2016 5:34	9/6/2016 16:30	314	98	3.20	0.594	0.511		6.60	~0.24
Storm Composite	9/21/2016 20:19	9/22/2016 14:47	101	35	1.70	0.315	0.070		2.60	~0.36
Base Grab	4/26/2016 13:30	4/26/2016 13:30	16	6	0.81	0.074	~0.031		~0.60	~0.05
Base Grab	5/18/2016 9:10	5/18/2016 9:10	~2	~1	0.37	0.055	~0.048	219	~0.24	~0.02
Base Grab	6/9/2016 8:26	6/9/2016 8:26	10	4	0.56	0.089	~0.048		~0.79	~0.03
Base Grab	6/21/2016 9:09	6/21/2016 9:09	26	14	1.70	1.530	~0.020	120	1.00	~0.17
Base Grab	7/21/2016 8:46	7/21/2016 8:46	16	7	1.30	0.136	~0.035	1,553	1.20	~0.06
Base Grab	8/11/2016 8:18	8/11/2016 8:18	10	~5	1.30	0.216	0.077			~0.41
Base Grab	8/26/2016 8:43	8/26/2016 8:43	10	5	1.30	0.074	~0.030		~0.65	~0.11
Base Grab	9/26/2016 10:41	9/26/2016 10:41	11	6	1.00	0.072	<0.020	68	~0.37	~0.06
Base Grab	10/24/2016 9:29	10/24/2016 9:29	8	3	0.52	0.069	~0.024	13	~0.65	~0.09

(green) Exceeds Water Quality Standard

Table 7. Brown's Creek Diversion Structure Drainage 2016 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)
Storm Grab	3/16/2016 9:34	3/16/2016 9:34	<0.00500	0.00390	0.00270	0.01010	<0.00020	0.00370	37.9	<0.03	0.61	~0.04	92
Storm Composite	4/25/2016 12:40	4/25/2016 18:13	0.03820	0.05550	0.22800	0.19600	0.00200	0.03080	32.4	<0.03	0.26	<0.02	380
Storm Composite	5/5/2016 10:41	5/6/2016 4:07	0.00530	0.00700	0.00400	0.02740	~0.00023	0.00540	30.0	<0.03	0.18	<0.02	352
Storm Composite	5/25/2016 13:16	5/26/2016 1:56	0.00660	0.00660	0.00470	0.02430	~0.00030	0.00590	33.3	<0.03	0.09	~0.06	120
Storm Composite	6/13/2016 3:33	6/13/2016 11:33	0.01580	0.01640	0.01260	0.05850	0.00050	0.01680	18.0	<0.03	0.32	0.09	144
Storm Grab	6/13/2016 8:20	6/13/2016 8:20	<0.00500	0.00180	0.00100	0.00570	<0.00020	0.00140	15.3	<0.03	0.21	0.08	52
Storm Composite	6/14/2016 20:19	6/15/2016 13:37	0.03010	0.03570	0.03090	0.12900	0.00110	0.02960	33.4	<0.03	0.08	~0.02	208
Storm Composite	7/23/2016 16:43	7/25/2016 6:45	0.04290	0.05540	0.02810	0.18700	0.00190	0.03520	55.1	<0.03	<0.05	<0.02	88
Storm Composite	7/27/2016 16:28	7/27/2016 22:54	0.00950	0.01160	0.00750	0.04080	~0.00035	0.00920	34.1	<0.03	0.20	<0.02	128
Storm Composite	8/10/2016 21:13	8/11/2016 7:45	0.01160	0.01240	0.00870	0.04160	~0.00035	0.01290	23.3	<0.03	0.23	~0.03	24
Storm Composite	8/24/2016 0:55	8/24/2016 9:01	0.02080	0.02350	0.01760	0.03100	0.00075	0.02080	35.8	0.06	0.22	0.13	20
Storm Composite	8/29/2016 23:56	8/30/2016 8:46	0.01710	0.01930	0.01350	0.06840	0.00060	0.01830	23.7	0.03	0.34	~0.04	132
Storm Composite	9/6/2016 5:34	9/6/2016 16:30	0.00630	0.00620	0.00440	0.02670	~0.00026	0.00730	22.8	<0.03	0.24	~0.04	116
Storm Composite	9/21/2016 20:19	9/22/2016 14:47	0.00410	0.00310	0.00180	0.00980	<0.00020	0.00400	18.4	<0.03	0.26	<0.02	48
Base Grab	4/26/2016 13:30	4/26/2016 13:30	0.00085	0.00110	~0.00036	0.00160	<0.00020	0.00053	37.7	<0.03	0.20	<0.02	112
Base Grab	5/18/2016 9:10	5/18/2016 9:10	~0.00032	0.00077	~0.00010	~0.00091	<0.00020	0.00035	49.9	<0.03	0.67	<0.02	240
Base Grab	6/9/2016 8:26	6/9/2016 8:26	<0.00100	0.00095	~0.00033	~0.00140	<0.00020	<0.00050	49.4	<0.03	0.67	~0.06	240
Base Grab	6/21/2016 9:09	6/21/2016 9:09	0.00085	0.00100	~0.00042	0.00260	<0.00020	0.00068	47.3	<0.03	0.20	0.11	76
Base Grab	7/21/2016 8:46	7/21/2016 8:46	<0.00030	0.00097	~0.00033	<0.00500	<0.00020	0.00094	54.3	0.09	0.61	0.28	208
Base Grab	8/11/2016 8:18	8/11/2016 8:18								<0.03	0.13	~0.02	68
Base Grab	8/26/2016 8:43	8/26/2016 8:43							54.5	0.04	0.12	0.24	68
Base Grab	9/26/2016 10:41	9/26/2016 10:41	~0.00055	~0.00051	~0.00023	~0.00100	<0.00020	0.00029	27.9	<0.03	0.16	0.10	56
Base Grab	10/24/2016 9:29	10/24/2016 9:29	0.00047	0.00076	~0.00100	0.00060	~0.00020	<0.00020	40.2	<0.03	0.46	0.06	188

No Exceedance Determinable
Exceeds Chronic Standard
Exceeds Max Standard
Exceeds Final Acute Standard

Table 8. Brown's Creek Diversion Structure Drainage 2016 Field Measurement Results

Date/Time	Transparency (cm)	Water Temperature (C)	Dissolved Oxygen (mg/L)	Conductivity (umhos/cm)	pH
3/16/2016 9:34		3.6	9.68		
4/26/2016 13:30	65	10.7	9.95		
6/13/2016 8:20	29				
6/21/2016 9:09		20.4	6.93		
8/26/2016 8:43	95	20.1	6.00	329	8.1
9/26/2016 10:41	>100	17	6.42	215	8.1

Exceeds Water Quality Standard

Appendix A
Water Quality Data– McKusick Lake, Lily Lake

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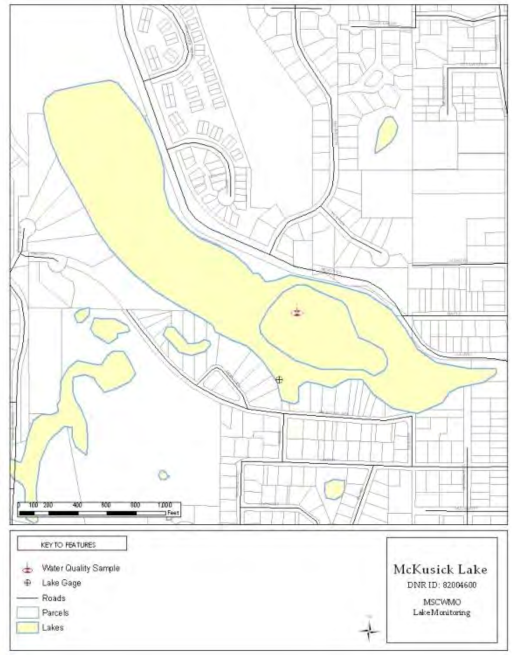
McKusick Lake

2016 Lake Grade: C+

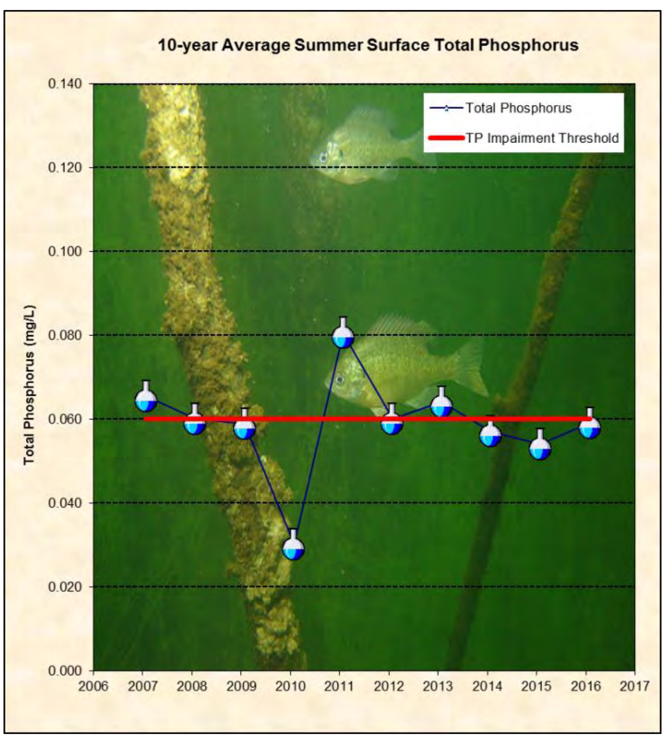
DNR ID #: 820020

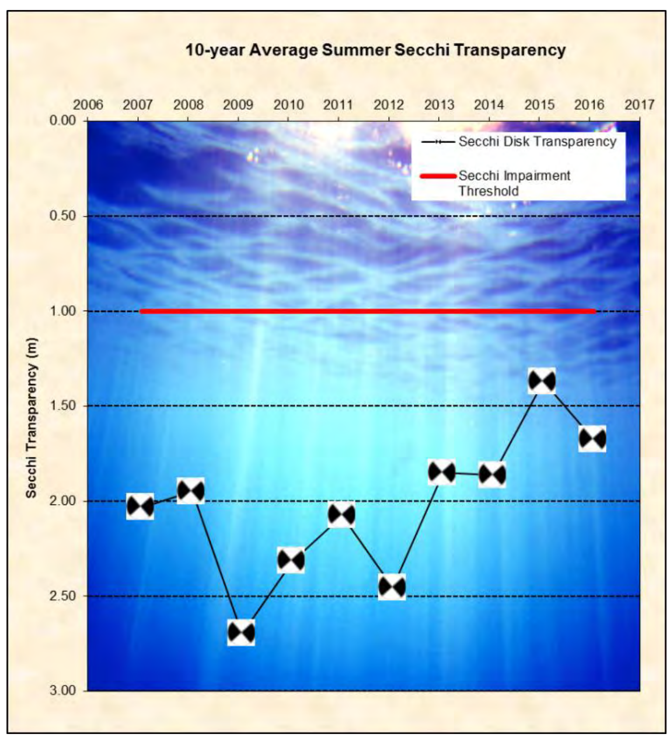
- Municipality: City of Stillwater
- Location: NE ¼ Section 29, T30N-R20W
- Lake Size: 46 Acres
- Maximum Depth (2016): 15.0 ft
- Ordinary High Water Mark: 851.7 ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on the chlorophyll-*α* results McKusick Lake was considered eutrophic in 2016, 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 2016 with the thermocline around 3 meters deep.
- McKusick Lake was delisted in 2012 for its impairment for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





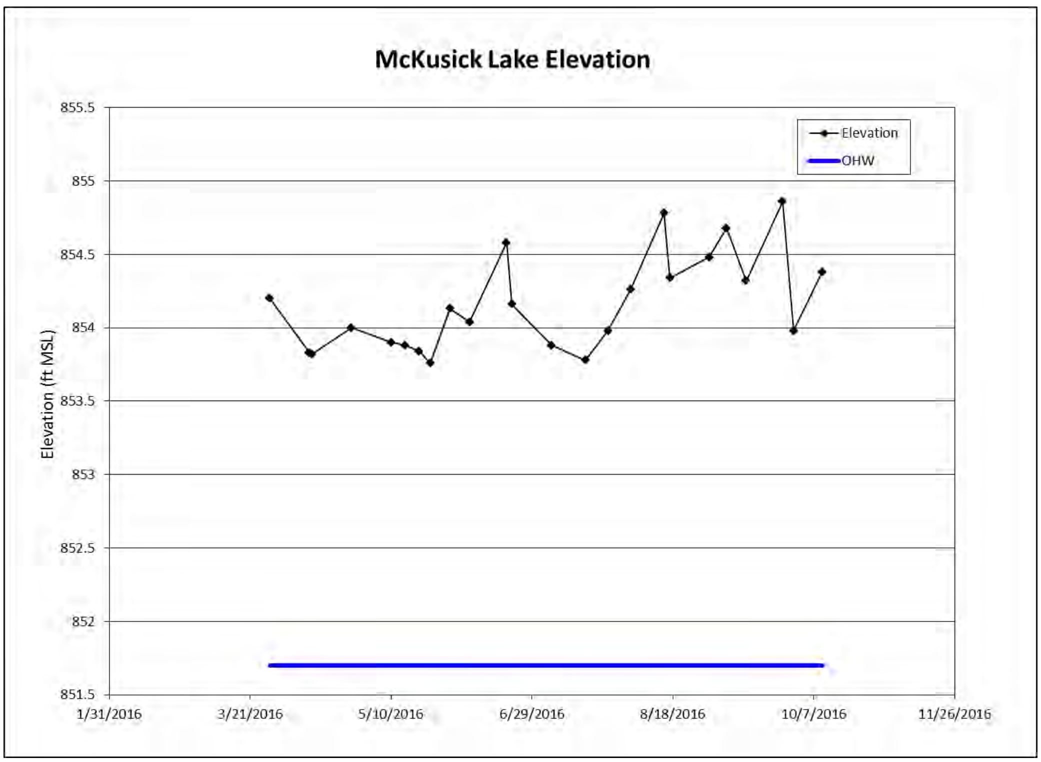
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-a (ug/L)	Pheophytin-Corrected Chlorophyll-a (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
4/12/2016 13:14	0.021	4.1	2.7	0.51	2.74	7.1	12.90
4/26/2016 11:39	0.026	6.8	5.4	1.00	1.83	13.9	8.48
5/10/2016 14:40	0.028	4.2	4.0	0.58	3.05	16.3	10.34
5/24/2016 10:36	0.022	2.0	1.5	0.63	3.51	20.7	9.84
6/7/2016 9:11	0.027	2.0	1.3	0.58	3.05	20.0	6.31
6/22/2016 8:48	0.051	9.2	6.4	0.58	1.52	23.7	5.64
7/6/2016 14:53	0.046	15.0	12.0	0.86	1.52	26.8	3.95
7/18/2016 8:56	0.061	8.4	5.7	0.98	1.83	24.1	4.47
8/3/2016 8:50	0.057	8.7	9.1	0.91	1.83	26.3	4.25
8/17/2016 14:10	0.107	55.0	52.0	1.30	0.61	26.3	6.65
8/31/2016 12:12	0.057	28.0	27.0	1.00	1.37	22.9	5.16
9/13/2016 13:30	0.044	30.0	28.0	0.89	1.98	20.4	3.80
9/26/2016 8:41	0.080	15.0	12.0	0.83	1.37	17.8	3.35
10/10/2016 13:24	0.049	19.0	17.0	0.93	2.44	13.5	8.23
2016 Average	0.048	14.8	13.2	0.83	2.05	20.0	6.67
2016 Summer Average	0.059	19.0	17.1	0.88	1.68	23.1	4.84

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
2016 Elevation (ft)	854.86	9/26/2016	853.76	5/24/2016	854.16

*Data requirements and determinations of use assessment according to the MPCA's Guidance Manual for Assessing the Quality of Minnesota Surface Waters: "Samples must be collected over a minimum of 2 years and data used for assessments must be collected from June to September. Typically, a minimum of 8 individual data points for TP, corrected chlorophyll-a (chl-a corrected for pheophytin), and Secchi are required. Data used for phosphorus and chlorophyll-a calculations are limited to those collected from the upper most 3 meters of the water column (surface). If more than one sample is collected in a lake per day, these values are averaged to yield a daily average value. Following this step, all June to September data for the 10-year assessment window are averaged to determine summer-mean values for TP, corrected chl-a, and Secchi depth. These values are then compared to the standards and the assessment is made."

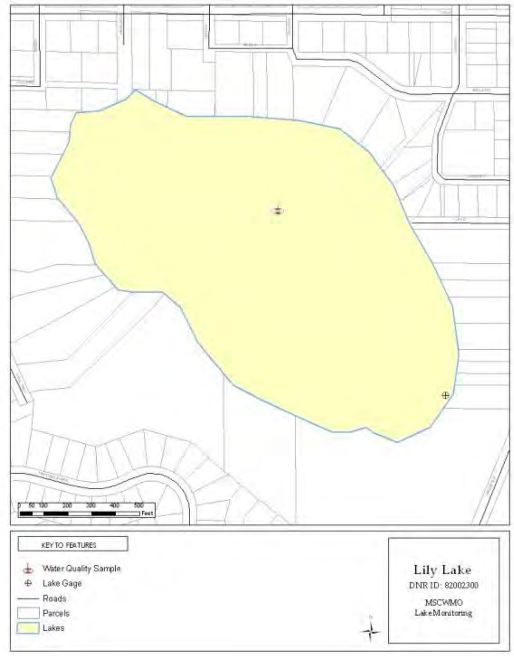


Lake Water Quality Summary										
	Summertime Lake Grades									
	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Total Phosphorus (mg/L)	C	C	C	C	C	D	B	C	C	C
Chlorophyll-*a* (ug/L)	B	C	C	B	A	C	A	A	B	B
Secchi depth (ft)	C	C	C	C	B	C	B	B	C	C
Overall	**C+**	**C**	**C**	**C+**	**B**	**C-**	**B+**	**B**	**C+**	**C+**

Lily Lake

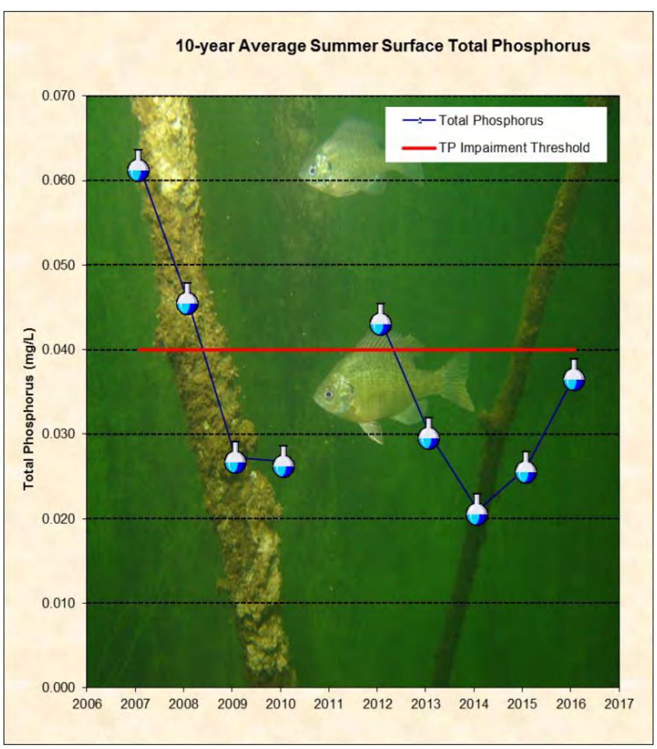
2016 Lake Grade: C+

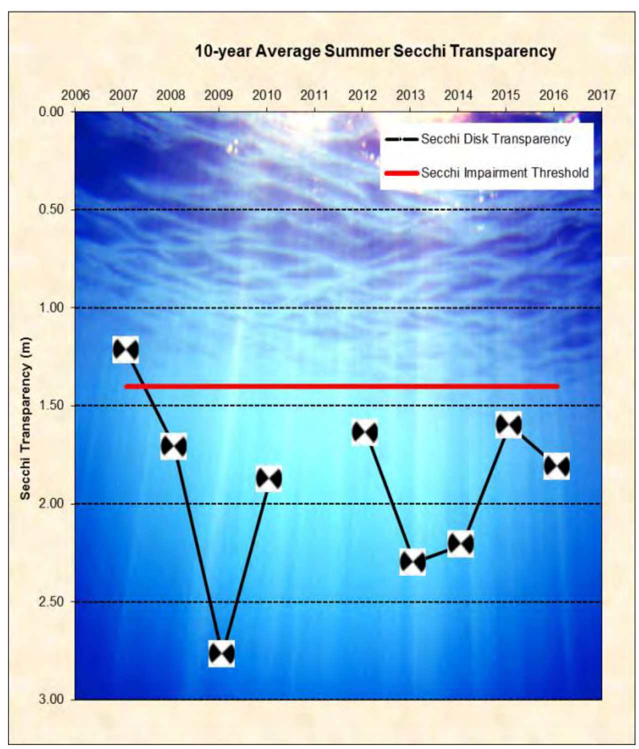
- DNR ID #: 820023
- Municipality: City of Stillwater
- Location: NE ¼ Section 32, T30N-R20W
- Lake Size: 35.90 Acres
- Maximum Depth (2016): 47.0 ft
- Ordinary High Water Mark: 844.8 ft
- 55%Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.
- Public access and public beach present



Summary Points

- Based on the chlorophyll-*a* results Lily Lake was considered eutrophic in 2016, 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.
- The lake stratified in 2016 with the thermocline between 4 and 6 meters deep.
- Lily Lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





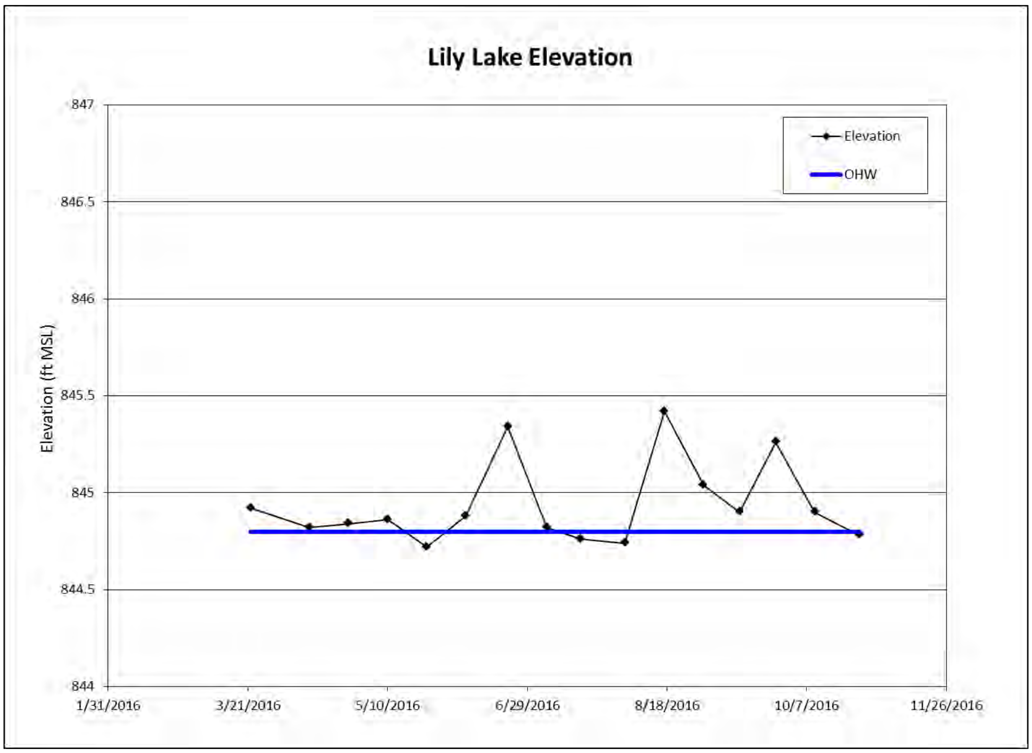
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-a (ug/L)	Pheophytin-Corrected Chlorophyll-a (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
4/12/2016 13:42	0.029	9.6	7.8	0.69	1.98	6.8	12.22
4/26/2016 13:06	0.033	5.6	4.6	1.20	2.44	13.5	9.48
5/10/2016 13:59	0.031	3.1	2.9	0.76	4.57	16.5	8.65
5/24/2016 9:55	0.020	2.9	2.5	0.71	3.66	20.4	9.56
6/7/2016 8:33	0.029	3.0	2.2	0.76	4.42	20.3	7.61
6/22/2016 8:13	0.025	9.5	8.1	0.27	2.13	25.1	7.45
7/6/2016 14:04	0.038	8.7	7.8	0.87	2.44	26.7	6.47
7/18/2016 8:32	0.022	14.0	13.0	0.86	1.98	25.4	7.61
8/3/2016 8:08	0.034	29.0	28.0	1.10	1.07	27.6	9.54
8/17/2016 13:33	0.057	63.0	61.0	1.40	0.61	28.0	9.41
8/31/2016 11:44	0.041	19.0	18.0	1.20	1.52	24.2	5.80
9/13/2016 14:04	0.039	40.0	37.0	0.98	1.07	21.8	7.46
9/26/2016 8:05	0.045	29.0	26.0	0.86	1.07	19.1	5.62
10/10/2016 13:56	0.028	30.0	26.0	0.79	1.98	15.1	7.24
2016 Average	0.034	19.0	17.5	0.89	2.21	20.8	8.15
2016 Summer Average	0.037	23.9	22.3	0.92	1.81	24.2	7.44

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
2016 Elevation (ft)	845.42	8/17/2016	844.72	5/24/2016	844.94

*Data requirements and determinations of use assessment according to the MPCA's Guidance Manual for Assessing the Quality of Minnesota Surface Waters: "Samples must be collected over a minimum of 2 years and data used for assessments must be collected from June to September. Typically, a minimum of 8 individual data points for TP, corrected chlorophyll-a (chl-a corrected for pheophytin), and Secchi are required. Data used for phosphorus and chlorophyll-a calculations are limited to those collected from the upper most 3 meters of the water column (surface). If more than one sample is collected in a lake per day, these values are averaged to yield a daily average value. Following this step, all June to September data for the 10-year assessment window are averaged to determine summer-mean values for TP, corrected chl-a, and Secchi depth. These values are then compared to the standards and the assessment is made."



Lake Water Quality Summary										
	Summertime Lake Grades									
	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Total Phosphorus (mg/L)	C	B	A	B	C	NA	B	B	C	C
Chlorophyll-*a* (ug/L)	C	C	B	B	B	NA	C	A	C	C
Secchi depth (ft)	B	C	B	B	C	NA	C	B	C	C
Overall	**C+**	**C+**	**B+**	**B**	**C+**	**NA**	**C+**	**B+**	**C**	**C**