Middle St. Croix Watershed Management Organization 2021 Water Monitoring Summary

Prepared For:

Prepared by:

WASHINGTON CONSERVATION DISTRICT

This Page Intentionally Left Blank.

ACKNOWLEDGEMENTS

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

Middle St. Croix WMO (MSCWMO) Board of Managers
Annie Perkins, Secretary
John Dahl
Avis Peters
Brian Zeller, Chair
Joe Paiement
Tom McCarthy, Vice Chair
Mike Runk
Beth Olfelt-Nelson
Ryan Collins
Dan Kyllo, Treasurer

Washington Conservation District
Matthew Downing, MSCWMO Administrator

Metropolitan Council
Brian Johnson
Monica Lorentz
Steven Louwerse
Mike Moger
Patricia Phua
Mallory Vanous
Sarah Voth

Minnesota Department of Natural Resources (MN DNR)
Sandy Fecht

Source Molecular Corporation

The WCD would also like to thank the volunteers and landowners who assist with data collection and allow property access.

TABLE OF CONTENTS

ABBREVIATIONS, DEFINITIONS, ACRONYMS, AND SYMBOLS

Anoxic	Lacking oxygen
BCWD	Brown's Creek Watershed District
Benthic	The area nearest lake bed
Biweekly	Every two weeks
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 zone	The area of a body of water where sunlight penetrates to the sediment and allows aquatic plants (macrophytes) to grow
MCES	Metropolitan Council Environmental Services
mg/L	milligram per liter
mL	milliliter
MN DNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MPN	Most probable number
MSCWMO	Middle St. Croix Watershed Management Organization
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 and stream water quality data collected by the Washington Conservation District (WCD) in 2021, as well as previous years. In 2021 the Middle St. Croix Watershed Management Organization (MSCWMO) monitored water quality and water surface elevation on McKusick Lake and Lily Lake, and flow and water quality at the Greeley Street Inlet to Lily Lake and at Perro Creek at the Diversion Structure (Figure 1). The purpose of this monitoring is to assess and document current water quality conditions of the lakes and streams, as well as continuation of a long-term monitoring program that will enable the MSCWMO to identify trends associated with best management practice (BMP) implementation and land use changes in the watershed. Also included in this report is data collected at the Brown's Creek Diversion Structure, which is a tributary to McKusick Lake that is monitored by the WCD for the Brown's Creek Watershed District (BCWD).

Lake Monitoring

Lily Lake was classified as eutrophic and received a C+ grade in 2021 (APPENDIX A). Two samples exceeded the Minnesota Pollution Control Agency's (MPCA) standard for total phosphorus (TP), four samples exceeded the MPCA standard for chlorophyll-α (chl-α) corrected for pheophytin, three Secchi disk transparency readings exceeded the MPCA standard (APPENDIX A).

In 2021 McKusick Lake was classified as eutrophic and received a grade of B- (APPENDIX A). No samples exceeded the MPCA shallow lake standard for TP. One sample exceeded the MPCA standard for chl-α corrected for pheophytin and two Secchi disk transparency measurements exceeded the MPCA shallow lake standard (APPENDIX A).

Stream and Stormwater Monitoring

Monitoring continued at the Greeley Street inlet to Lily Lake in 2021 and the total recorded discharge was the second lowest recorded at the site at 4,747,103 cubic feet. This was due in large part to severe drought conditions. The average TP concentration from baseflow samples

was 0.081 mg/L, which was the highest since 2015. However, two samples had the lowest sampled concentrations for TP since monitoring began in 2015. The average total suspended solids (TSS) from baseflow samples was 5 mg/L, which was the highest since monitoring began in 2015, but still within the normal range for baseflow concentrations for the site. The average TP concentration from storm samples collected in 2021 was 0.360 mg/L, which was the highest storm average since 2016. The average TSS concentration from storm samples was 49 mg/L, which was the highest since 2018. TP and TSS loads to Lily Lake were calculated during monitored periods, and in 2021 the TP load was 27.1 lbs and the TSS load was 1,968 lbs.

Water quality sampling resumed on Perro Creek at the Diversion Structure in 2021, after no sampling occurred in 2020. Recorded discharge to the St. Croix River was 29,891,691 cubic feet, which included discharge through the overflow structure, and was a decrease from 2020. The average TP concentration from baseflow samples was 0.035 mg/L, which was similar to 2018 and 2019. The average baseflow TSS concentration was 2 mg/L, which was similar to 2019. The average storm sample TP concentration in 2021 was 0.427 mg/L, which was the highest since 2016. The average storm sample TSS was 217 mg/L, which was the highest since monitoring began in 2016. TP and TSS loads to the St. Croix River were calculated during monitored periods, and in 2021 the TP load was 81.5 lbs and the TSS load was 12,601 lbs.

Discharge at the Brown's Creek Diversion Structure site decreased from 2020 to 2021 due to drought conditions, with a volume of 46,792,341 cubic feet exported to McKusick Lake. The total annual TP load also decreased and was 446 lbs. while the annual TSS load increased and was 401,069 lbs. Concentrations of metals tended to be lower in 2021. There were three copper results and five lead results that exceeded MPCA chronic standards.

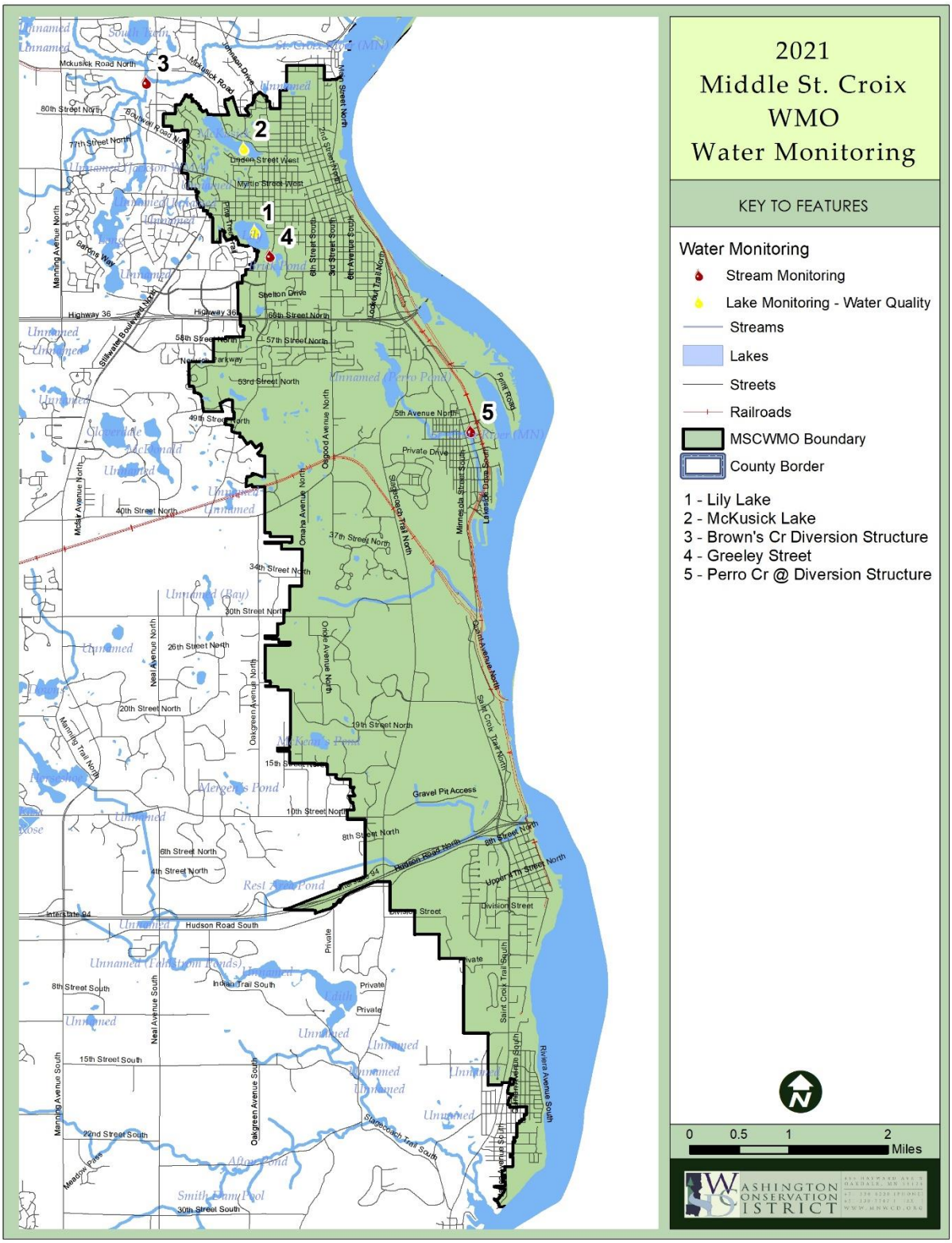


Figure 1. MSCWMO 2021 Water Monitoring Locations

LAKE MONITORING

A. METHODS, RESULTS AND DISCUSSION

In 2021 water quality data was collected biweekly on Lily Lake and McKusick Lake, over seven consecutive months (April–October) by the WCD. Measurements obtained during the summer sampling season (June–September) are averaged for a comparison of individual lake dynamics from year to year between lakes within the watershed and to the Minnesota Pollution Control Agency's (MPCA) impairment standards. Lake grades are based on the averages of samples collected May–September. Average values for all parameters are presented in APPENDIX A and Figure 2 through Figure 5, which show the current and historic summer averages for each parameter. Water quality samples were collected by the WCD with a two-meter (6.56 feet) integrated surface water column sampler. A full description of WCD Standard Operating Procedures (SOP) is available on the Washington Conservation District website at http://www.mnwcd.org/water-monitoring. The Metropolitan Council Environmental Services (MCES) Laboratory analyzed the surface water samples for TP, chl-α, and total Kjeldahl nitrogen (TKN).

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. Excess algal growth, in turn, negatively affects the clarity, or transparency, and ability of light to penetrate the water. The MPCA sets lake eutrophication standards for aquatic life and recreation. 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 less than 15 feet deep, with greater than 80% littoral area, and less than 10 acres. The 2021 summer average of TP values of MSCWMO lakes can be found in Figure 2.

Chlorophyll-α is measured because it's the photosynthetic component found in algae and aquatic plants and is an indicator of algal productivity. The MPCA standard for pheophytin-corrected

chl-α is 14 µg/L for deep lakes and 20 µg/L for shallow lakes. The 2021 summer average chl-α concentrations of MSCWMO lakes can be found in Figure 3.

TKN, the sum of organic nitrogen and ammonia, was analyzed in MSCWMO lakes. While no standard exists for TKN because TP is often the limiting nutrient, TKN can contribute to eutrophication. The 2021 summer average TKN concentrations of MSCWMO lakes can be found in Figure 4.

Field measurements are recorded while collecting lake samples, including Secchi disk transparency. The measurement of light penetration using a Secchi disk gives a simple measure of water transparency, or clarity. A reduction in water transparency is typically the result of turbidity composed of suspended sediments, organic matter and/or phytoplankton (algae). The MPCA standard for Secchi disk transparency is 1.4 meters for deep lakes and 1.0 meter for shallow lakes. The 2021 summer average transparency of MSCWMO lakes can be found in Figure 5.

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 lake 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, the bacteria that decompose them consume DO. Low DO conditions may stress fish populations and under anoxic conditions nutrients may be released from the sediment. 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 https://webapp.pca.state.mn.us/surface-water/search.

A lake grading system is used in this summary, 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 MCES. 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 1. This method has since been replicated and the grading system has been verified with more recent 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 strong correlation when comparing trophic status to the lake grade. Summaries of all lake results are presented in APPENDIX A.

Table 1. Lake Grade Ranges

Grade	Percentile	TP (µg/L)	Chl-α (µg/L)	SD (m)
A	<10	<23	<10	>3.0
B	10-30	23-32	10-20	2.2-3.0
C	30-70	32-68	20-48	1.2-2.2
D	70-90	68-152	48-77	0.70-1.2
F	>90	>152	>77	<0.70

There are several metrics and systems that can also be used to assess lakes including the Carlson Trophic State Index (TSI) and ecoregion values. The Carlson Trophic State Index is used to quantify the relationship between water quality data and trophic status. Trophic states vary from oligotrophic (low biological activity and high clarity) to hypereutrophic (highly productive with very low clarity). The MSCWMO is located in the North Central Hardwood Forest Ecoregion where lakes are often mesotrophic. Ecoregion values are assigned for TP, TKN, chl- α, and Secchi disk transparency. This report will focus on the methods used by the MPCA and the Metropolitan Council, as previously discussed.

Water elevation monitoring was conducted on two lakes, McKusick and Lily, from April to October 2021. Lake elevation readings are compared to the lake's Ordinary High Water level (OHW)[1]. The OHW for Lily and McKusick Lakes are 844.8 ft. and 851.7 ft., respectively. Changes in lake water elevation are often attributed to the changes in precipitation. The highest recorded elevation in 2021 for Lily Lake occurred on 7/7/2021 at 845.70 ft. and on 3/29/2021 at 854.35 ft. for McKusick Lake. Complete lake elevation data for 2021 can be found in APPENDIX A. For historical lake elevations, visit the MN DNR Lake Finder webpage at http://www.dnr.state.mn.us/lakefind/index.html.

1. LILY LAKE

In 2021 WCD staff conducted two-tailed Kendall's Tau statistical analysis based on data collected by professional agencies for both lakes monitored in MSCWMO to determine trends for TP, Secchi, and chl-α ($p<0.05$). Lily Lake had a statistically significant improving trend for TP, and no trend was found for average Secchi disk transparency and chl-α. Lily Lake had an average summertime TP concentration of 0.039 mg/L, which was higher than 2020 (Figure 2). Two of the nine summertime results were greater than the MPCA lake nutrient impairment standard for TP. The 2021 average summertime concentration of chl-α was 14.1 μg/L, lower than the 15.4 μg/L measured in 2020 (Figure 3). Four of the nine water quality results for chl-α impairment exceeded the MPCA lake standard (APPENDIX A). Lily Lake had an average summertime TKN concentration of 0.88 mg/L in 2019; higher than the average of 0.76 mg/L in 2020 (Figure 4). Secchi disk readings were measured in 2021 with a summertime average of 2.40 meters (Figure 5), with three of the nine water quality readings exceeding the MPCA lake standard for Secchi disk transparency (APPENDIX A). Lily Lake received a grade of C+ in 2021, a decline from the B it received in 2020. Temperature and DO profiles indicate that Lily

[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.

Lake exhibited thermal stratification during the summer months with the thermocline between 5 and 7 meters; therefore, the lake was less likely to completely mix throughout the summer. The elevation was above the OHW for the entire monitoring season, reaching its highest recorded level on 7/7/2021 with a level of 845.70 ft. The lowest recorded level of the monitoring season occurred on 4/5/2021 with an elevation of 844.86 ft. A summary of all lake results is presented in APPENDIX A.

2. MCKUSICK LAKE

A two-tailed Kendall's Tau analysis based on data collected by professional agencies showed that McKusick Lake has statistically significant ($p<0.05$) improving trends for TP and Secchi transparency, and no trend is present for chl-α. The McKusick Lake summertime average TP concentration in 2021 was 0.039 mg/L; lower than the 0.065 mg/L observed in 2020 (Figure 2), with no water quality samples exceeding the MPCA TP impairment standard for shallow lakes (APPENDIX A). McKusick Lake had a summertime average chl-α concentration of 8.7 μg/L; higher than the chl-α average of 7.3 μg/L from 2020 (Figure 3). One of the nine summertime samples collected in 2021 exceeded the MPCA shallow lake standard for chl-α. The average summertime TKN concentration in 2021 was 0.78 mg/L, higher than the 0.71 mg/L in 2020 (Figure 4). The 2021 summertime average water transparency measured by Secchi disk was 1.77 meters (Figure 5). Two of the nine summertime Secchi disk readings in 2021 were worse than the MPCA shallow lake impairment standard. McKusick Lake received a grade of a B- in 2021, the same as 2019-2020. No temperature and DO profiles were collected so the occurrence of thermal stratification in the deepest part of the lake cannot be determined. A majority of McKusick Lake is very shallow and does not stratify, and therefore is likely to have mixed throughout the summer. The elevation of McKusick Lake remained above the OHW for the entire monitoring season, reaching its highest recorded level of the season on 3/29/2021 with a level of 854.35 ft. and the lowest recorded level of the season occurred on 10/12/2021 with an elevation of 853.97 ft. A summary of all lake results is presented in APPENDIX A.

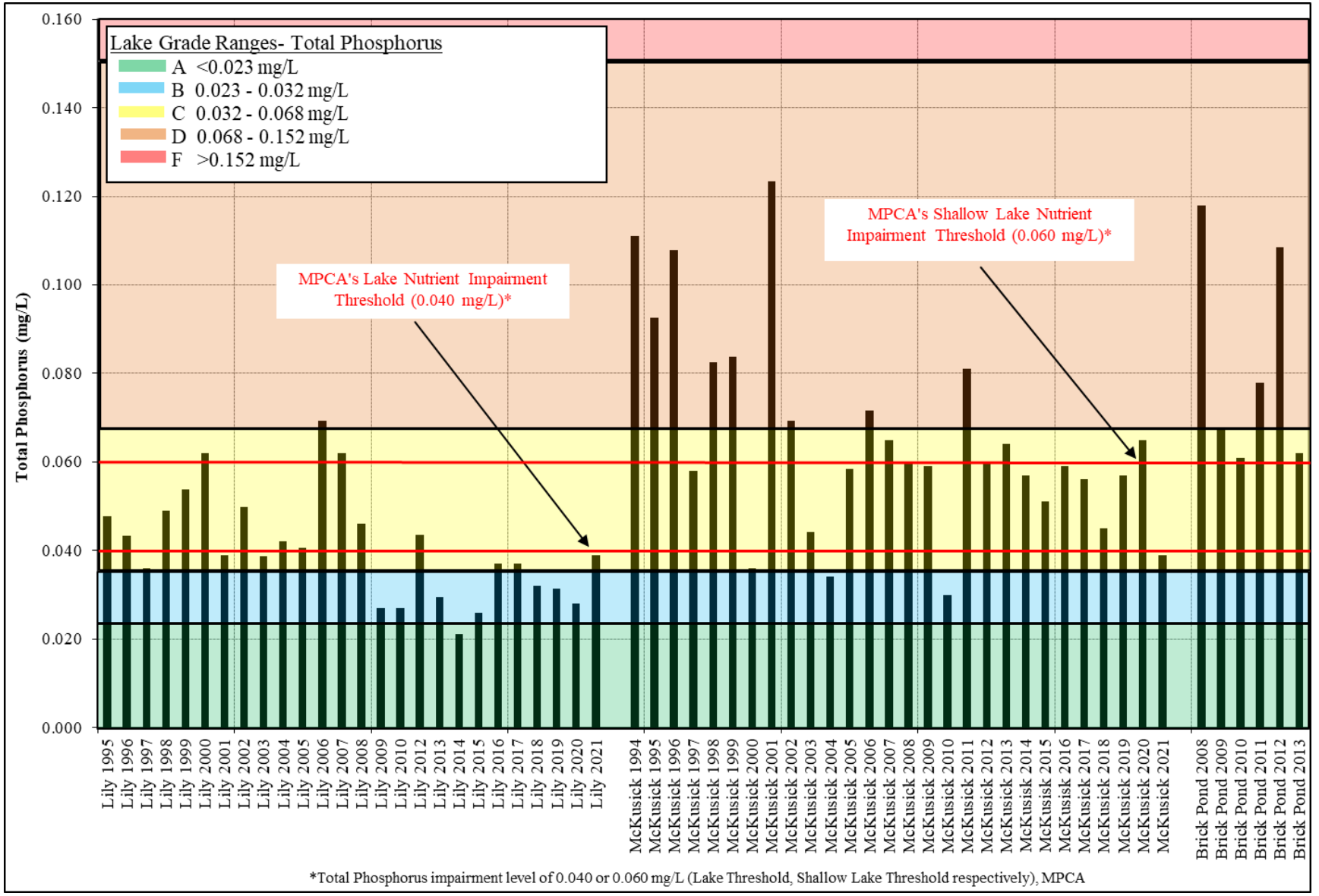


Figure 2. MSCWMO Historic Summer Average Total Phosphorus

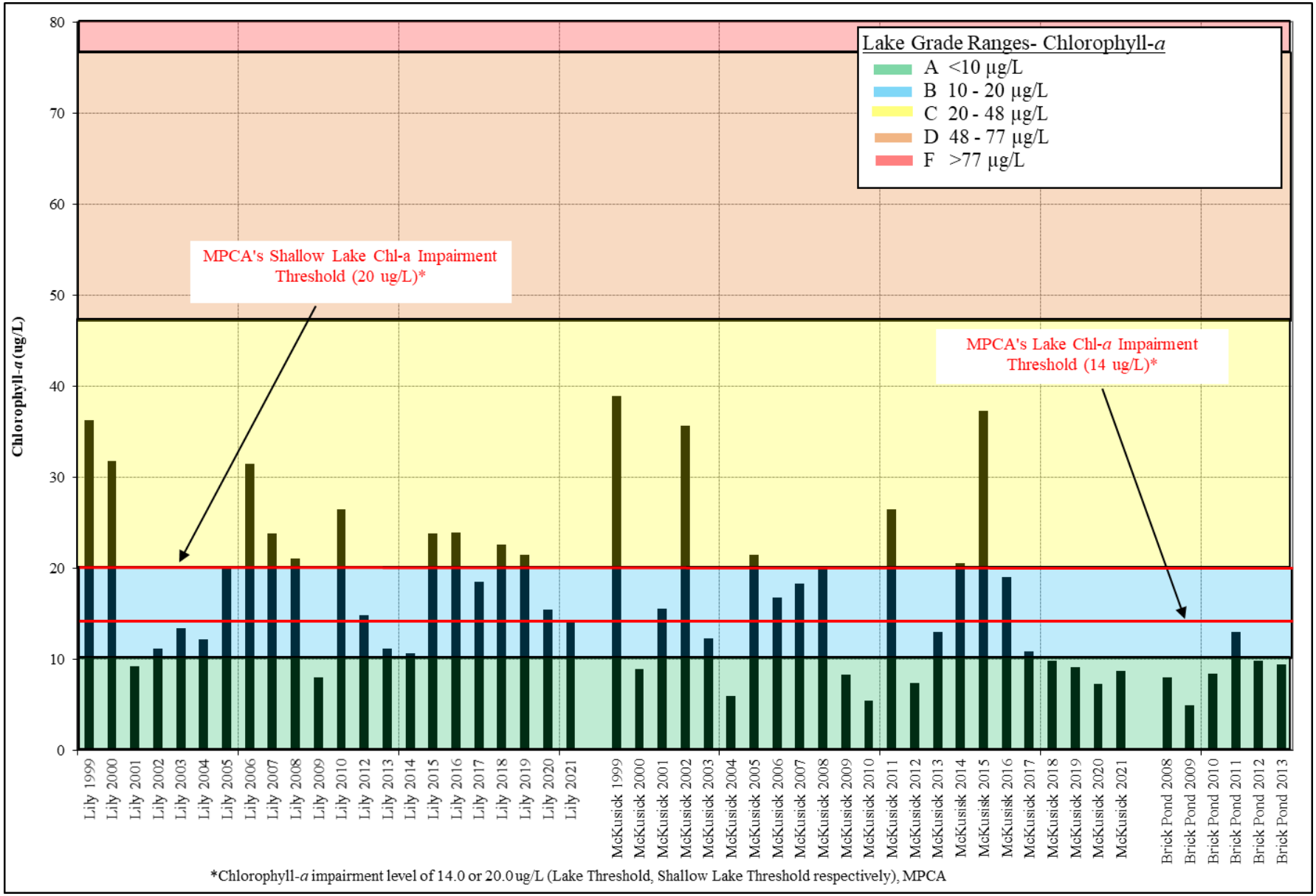


Figure 3. MSCWMO Historic Summer Average Chlorophyll-*α*

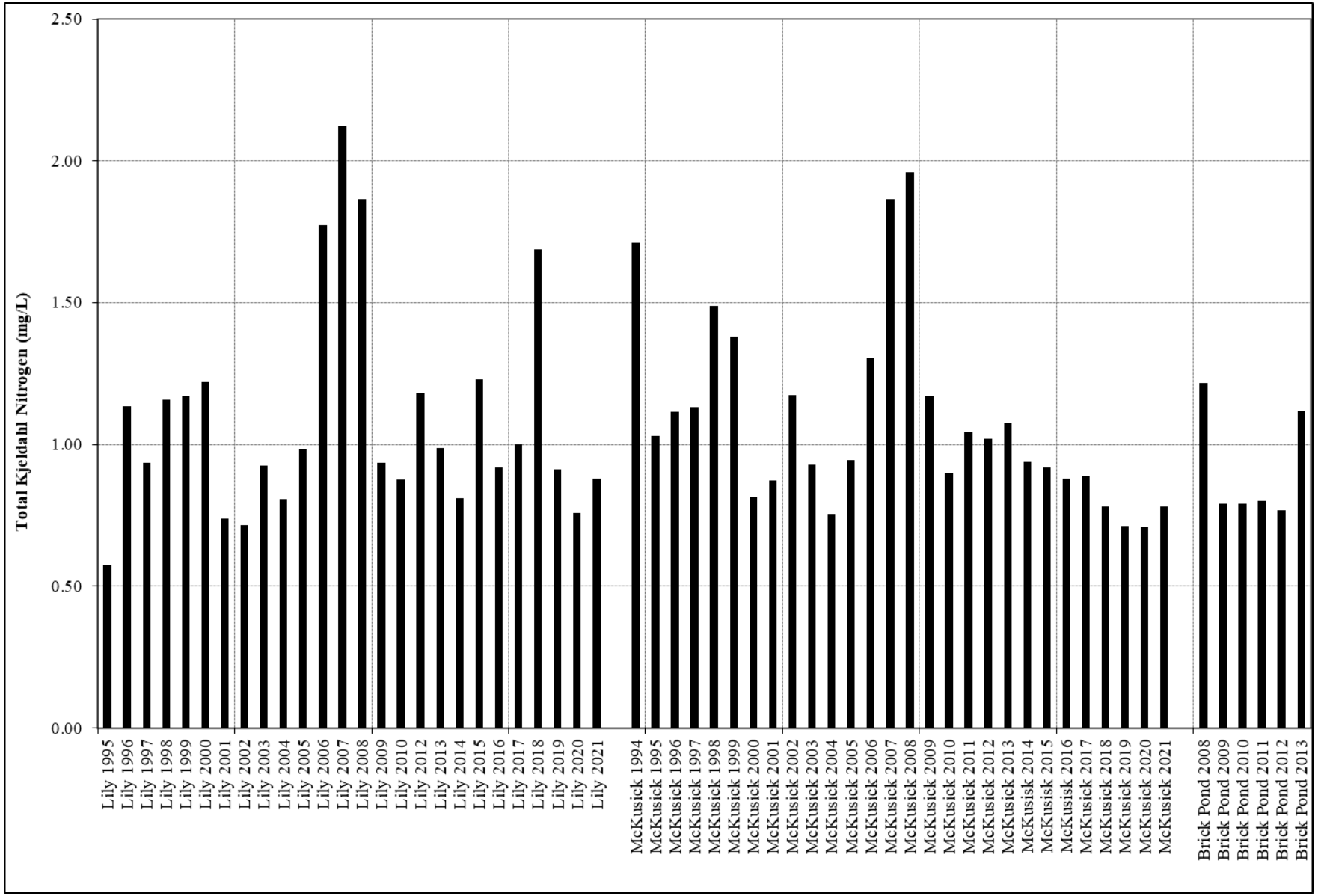


Figure 4. MSCWMO Historic Summer Average Total Kjeldahl Nitrogen

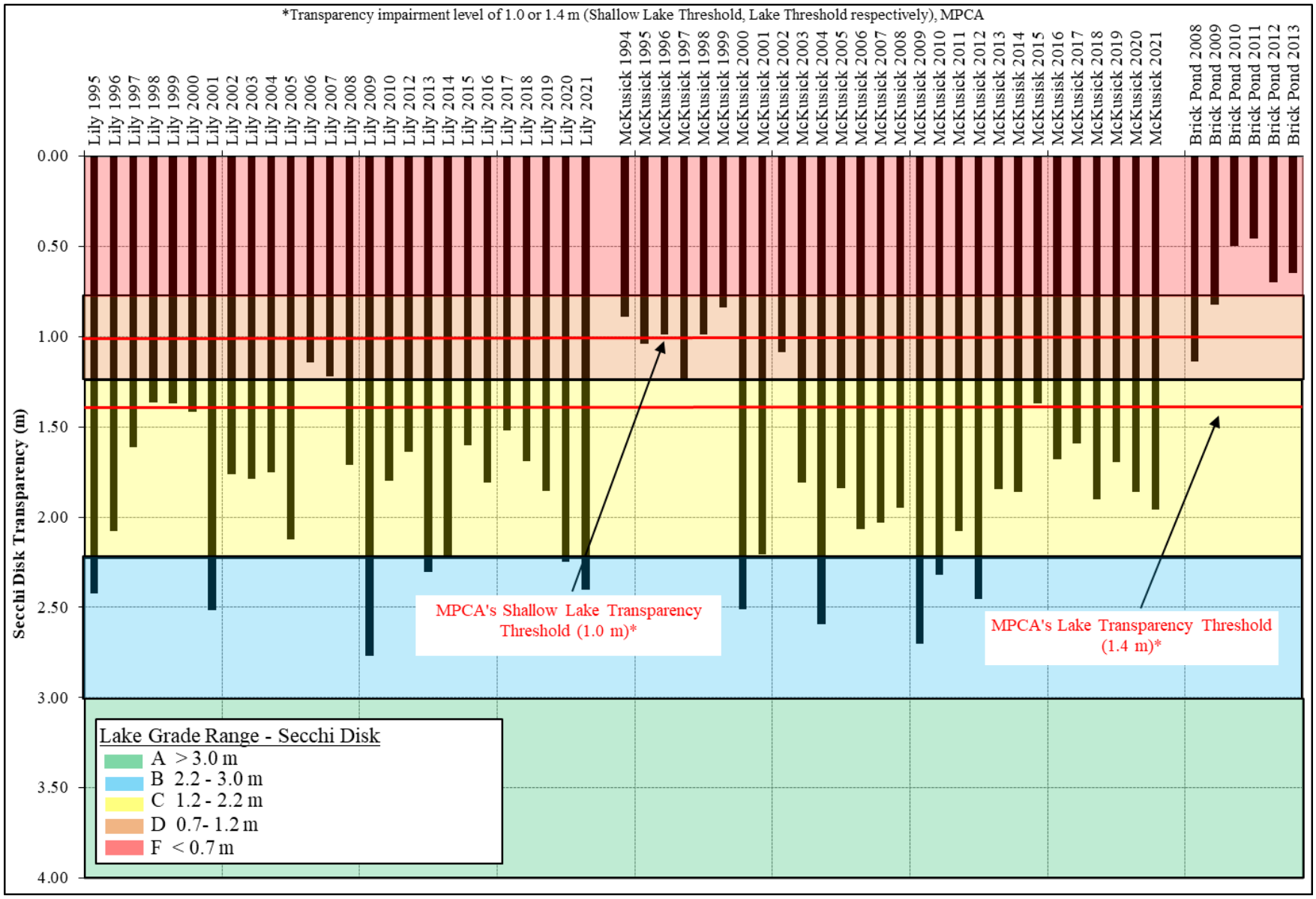


Figure 5. MSCWMO Historic Summer Average Secchi Disk Transparency

STREAM AND STORMWATER MONITORING

A. LILY LAKE INLET TARGETED MONITORING

In 2015 the MSCWMO received grant funding to conduct targeted water quality monitoring on Lily Lake with the goal of identifying priority areas for nutrient load reduction to the lake. The MSCWMO worked closely with the WCD to develop and implement a monitoring plan to achieve this goal.

As in prior years, the monitoring in 2021 focused on the Greeley Street catchment. Continuous 15-minute stage and velocity data were collected in the catchment basin from 4/21/21 – 10/26/21. Discharge was calculated using an area/velocity relationship and the recorded discharge to Lily Lake in 2021 was 4,747,103 cubic feet, which was a decrease from 2020 (Table 2, Figure 6, and Figure 7) and was due in large part to severe drought conditions. There were periods of low or no flow throughout the entire monitoring season, with an extended period in late September and October. Eight water quality grab samples were collected and analyzed for total phosphorus, total Kjeldahl nitrogen, and total suspended solids (Table 3). Similar to previous years, storm sampling in 2021 was limited by the nature of the site as storm events at the Greeley Street catchment can be flashy. Urban storm runoff is transported quickly and this makes capturing a sample more difficult during these periods.

Four water quality grab samples were collected during monthly baseflow sampling from Brick Pond (6/28, 7/26, 8/25, and 9/27) and four grab samples were collected during storm events or immediately following (5/20, 5/27, 7/6, and 8/24). All samples were collected during low flow periods (<1.0 cfs). The 6/28 baseflow sample had very high TP, TKN, and TSS concentrations. This sample contained large amounts of duckweed flowing from Brick Pond and was considered to be representative of the conditions at the time of sampling. The TP and TSS results were excluded from the baseflow averages because it was an outlier. The 7/26 and 9/27 baseflow samples had the lowest sampled concentrations for TP since sampling began in 2015. The TSS results for these two samples were also low and were within historic ranges. The 8/25 sample had higher than average TP and TKN results, but a low TSS concentration that was within

historic ranges for baseflow. The 2021 average TP during baseflow was 0.081 mg/L, which was the highest since 2015 (Table 4). The 2021 baseflow average TSS concentration was 5 mg/L, which was the highest since monitoring began in 2015, but still within the normal range for baseflow concentrations. The average TP concentration from storm samples collected in 2021 was 0.360 mg/L, which was the highest storm average since 2016 (Table 4). The average TSS concentration from storm samples was 49 mg/L, which was the highest since 2018 (518 mg/L) and similar to 2015 (48 mg/L). TP and TSS loads to Lily Lake were calculated during monitored periods, and in 2021 the TP load was 27.1 lbs (Table 2 and Figure 6) and the TSS load was 1,968 lbs (Table 2 and Figure 7).

Table 2. Greeley Street 2021 Monitored Discharge and TP & TSS Loading

Site	Date range	Discharge (cf)	Discharge (ac-ft)	Percent of Total Discharge	TP Load (lbs)	Percent of TP Load	TSS Load (lbs)	Percent of TSS Load
Greeley St. Baseflow[1]	4/21/21 - 10/26/21	4,570,051	104.97	96%	23.1	85%	1426	72%
Greeley St. Stormflow	4/21/21 - 10/26/21	177,052	4.07	4%	4.0	15%	542	28%
Total		4,747,103	109.04	100%	27.1	100%	1,968	100%

[1] *6/28 results were excluded from the TP/TSS averages used for load calculations*

Table 3. Greeley Street 2021 Water Quality Results

Date	Sample Type	TP (mg/L)	TSS (mg/L)	TKN (mg/L)	Discharge (cfs)
5/20/21 10:05	Storm	0.218	88	1.30	0.37
5/27/21 9:21	Storm	0.214	32	1.70	0.54
6/28/21 10:43	Base[1 2]	2.090	220	13.00	0.42
7/6/21 9:29	Storm	0.593	40	2.90	0.18
7/26/21 10:13	Base	<0.020	8	0.92	0.06
8/24/21 9:03	Storm	0.413	36	2.00	0.83
8/25/21 16:01	Base	0.206	5	1.40	0.27
9/27/21 8:47	Base	~0.026	~2	0.61	0.09

[1] *Results excluded from averages*

[2] *Sample contained duckweed flowing from Brick Pond*

Table 4. Greeley Street Historical TP and TSS Averages and Ranges

Greeley Street Sample Type	2015	2016	2017	2018[a]	2019[a]	2020[a]	2021
TP (mg/L) - Baseflow Average	0.091	0.070	0.060	0.066	0.077	0.046	0.081
Baseflow Range	*0.028 - 0.210*	*0.029 - 0.122*	*0.045 - 0.083*	*0.040 - 0.126*	*0.046 - 0.134*	*0.036 - 0.791*	*<0.020 - 2.09*
TP (mg/L) - Stormflow Average	0.219	0.437	0.104	0.316	0.110	0.199	0.360
Stormflow Range	*0.063 - 0.382*	*0.059 - 0.744*	*0.089 - 0.119*	*NA*	*NA*	*NA*	*0.214 - 0.593*
TSS (mg/L) - Baseflow Average	4	2	3	4	2	2	5
Baseflow Range	*1 - 9*	*1 - 6*	*1 - 7*	*1 - 8*	*1 - 3*	*1 - 3*	*2 - 220*
TSS (mg/L) - Stormflow Average	48	233	35	518	8	38	49
Stormflow Range	*2 - 132*	*10 - 616*	*28 - 41*	*NA*	*NA*	*NA*	*32 - 88*

[a] *Only 1 storm sample was collected for the year*

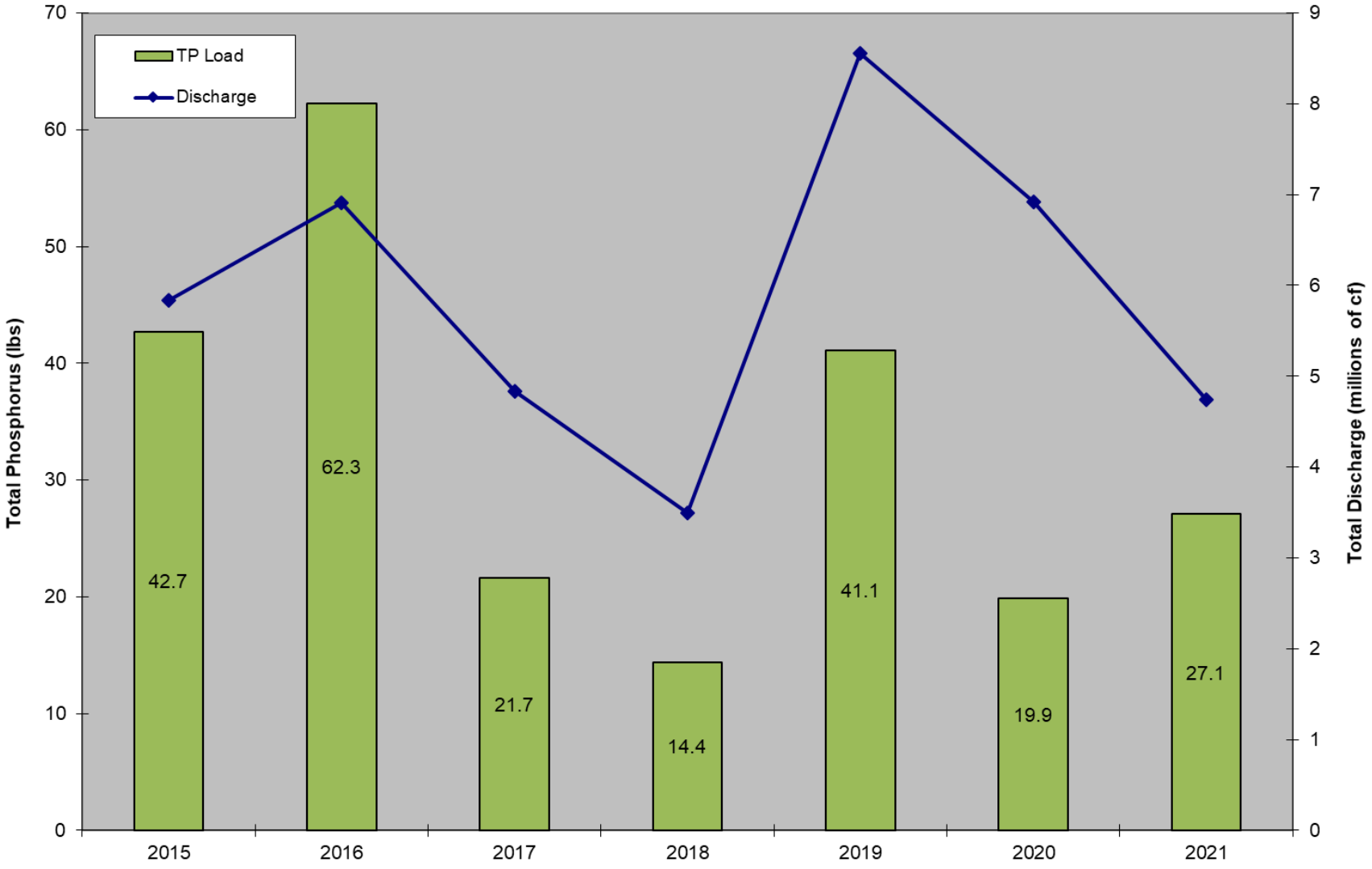


Figure 6. Greeley Street Monitored Discharge and Total Phosphorus Load

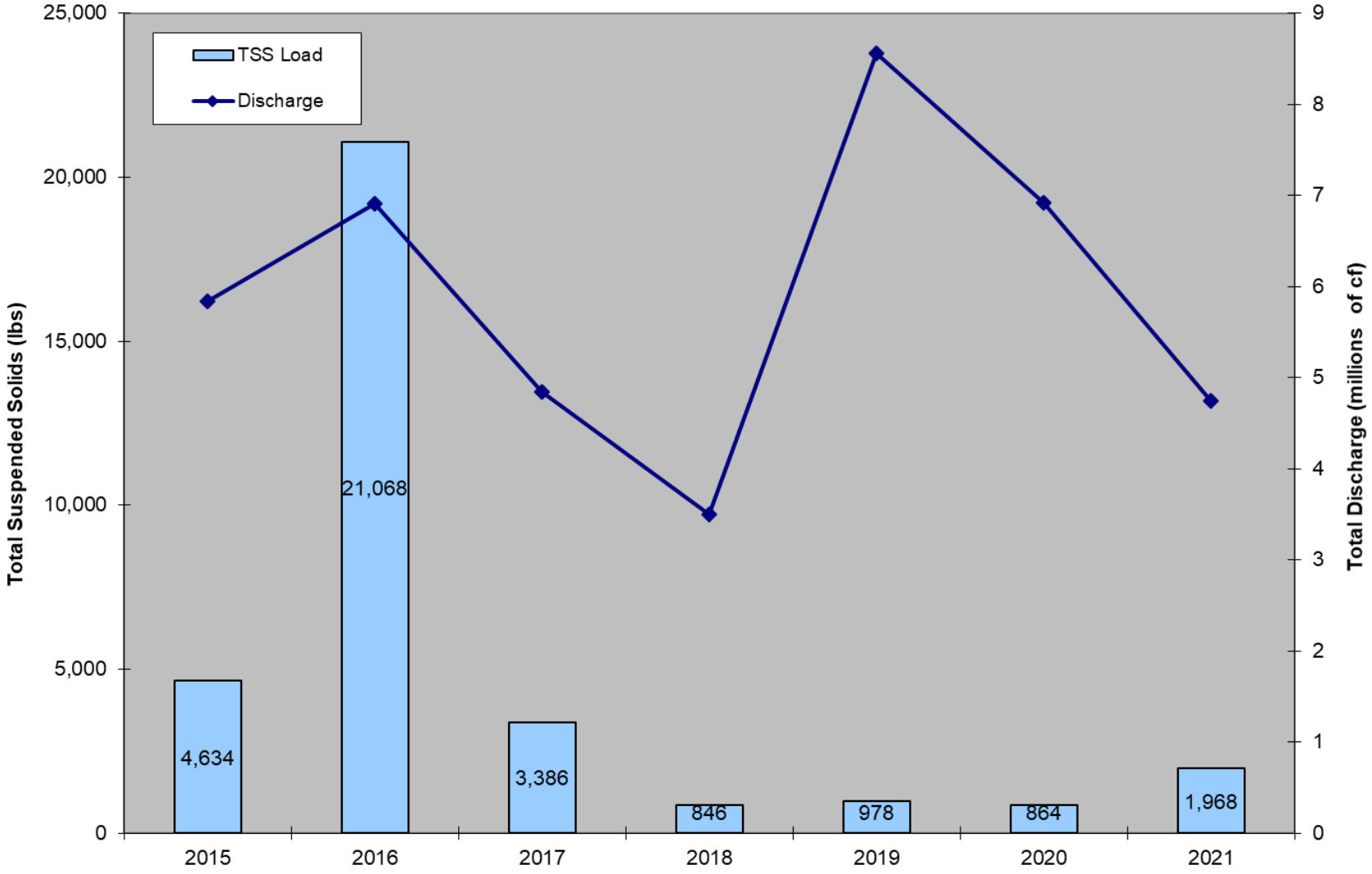


Figure 7. Greeley Street Monitored Discharge and Total Suspended Solids Load

B. PERRO CREEK MONITORING

The goal of monitoring Perro Creek in 2016-2017 was to identify where the greatest contribution of nutrients and sediment to the St. Croix River was occurring. Monitoring continued in 2018 and 2019 to further refine previous observations. In 2020 water monitoring activities were reduced on Perro Creek and no traditional water quality samples were collected. In 2021 water quality sampling resumed at the Perro Creek at the Diversion Structure site by collecting in-stream grabs samples during baseflow periods and using an automated sampler to collect flow-weighted composite storm samples. The automated sampler allowed for multiple samples to be collected during storm events, which were then combined into one sample representing the storm event. This methodology can provide more accurate data for calculating nutrient loads during storm events than grab samples alone. Continuous 15-minute stage and velocity data were collected at the site and in the Diversion Structure Overflow from 5/3/21 – 10/25/21. Discharge was calculated using an area/velocity relationship, and the recorded discharge in 2021 to the St. Croix River was 29,891,691 cubic feet (Table 5).

Fourteen water quality samples were collected and analyzed for several parameters, including total phosphorus, total Kjeldahl nitrogen, and total suspended solids (Table 6). Five were monthly baseflow grab samples collected June – October, one was a baseflow composite sample collected in May when the Perro Pond outlet was opened for the year, and eight were composite storm samples collected June – September. The average TP concentration in 2021 during baseflow was 0.035 mg/L, which was similar to the baseflow averages in 2018 and 2019 (Table 7). A baseflow sample was collected on 6/23 that had TP and TSS results that were more than twice the average. This sample was considered an outlier and the results were excluded from the baseflow averages used for calculating loads. Also excluded were the results from the automated composite sample collected after the pond outlet was opened in May, since the sample was not an in-stream grab sample. The 2021 baseflow average TSS concentration was 2 mg/L, which was similar to the baseflow average in 2019 and less than the average in 2018. The average TP concentration from storm samples collected in 2021 was 0.427 mg/L, which was the highest storm average since 2016 (Table 7). The average TSS concentration from storm samples was 217 mg/L, which was the highest since monitoring began in 2016. TP and TSS loads to the St. Croix

River were calculated for both the creek and the diversion structure overflow during monitored periods. In 2021 the TP load was 81.5 lbs (Table 5 and Figure 8) and the TSS load was 12,601 lbs (Table 5 and Figure 9).

Perro Creek is listed as impaired for TSS on the MPCA's 303(d) Impaired Waters List. The stream is in the Central River Nutrient Region and the MPCA standard is 30 mg/L. The MPCA's protocols for assessments are as follows:

"A stream is considered to exceed the standard for TSS if 1) the standard is violated more than 10% of the days of the assessment season (April through September) as determined from a data set that gives an unbiased representation of conditions over the assessment season, and 2) at least three measurements violate the standard. A stream is considered to meet the standard for TSS if the standard is met at least 90% of the days of the assessment season. A designation of meeting the standard for TSS generally requires at least 20 suitable measurements from a data set that gives an unbiased representation of conditions over at least two different years. However, if it is determined that the data set adequately targets periods and conditions when exceedances are most likely to occur, a smaller number of measurements may suffice."

Perro Creek is also listed as impaired for *E. coli* bacteria on the MPCA's 303(d) Impaired Waters List. *E.* coli is used as an indicator in waterbodies for the possible presence of fecal contamination, including pathogens. The primary source of *E. coli* is human and animal waste, making high *E. coli* presence a concern for human health. A summary table by month can be found in Table 8. The MPCA standard is defined as follows, and is based on the latest ten years of data as per MPCA protocol:

"*Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31*."

Table 5. Perro Creek 2021 Monitored Discharge and TP & TSS Loading

Site	Date range	Discharge (cf)	Discharge (ac-ft)	Percent of Total Discharge	TP Load (lbs)	Percent of TP Load	TSS Load (lbs)	Percent of TSS Load
Perro at Diversion Structure Baseflow [1]	5/3/21 - 10/25/21	24,657,934	566.36	82%	53.9	66%	3079	24%
Perro at Diversion Structure Stormflow	5/3/21 - 10/25/21	305,612	7.02	1%	8.1	10%	4140	33%
Perro at Diversion Overflow Baseflow [1 2]	5/3/21 - 10/25/21	4,572,966	105.04	15%	10.0	12%	571	5%
Perro at Diversion Overflow Stormflow [2]	5/3/21 - 10/25/21	355,179	8.16	1%	9.5	12%	4811	38%
Total to the St. Croix River		29,891,691	686.58	100%	81.5	100%	12,601	100%

[1] *5/17 and 6/23 results were excluded from the TP/TSS averages used for load calculations*

[2] *Results averages from samples collected in-stream at the Diversion Structure were used for Diversion Overflow loading calculations*

Table 6. Perro Creek at Diversion Structure 2021 Water Quality Results

Start	End	Sample Type	TP (mg/L)	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate N (mg/L)	Nitrite N (mg/L)	*E. coli* (mpn/100 mL)	Cadmium (ug/L)	Chromium (ug/L)	Copper (ug/L)	Lead (ug/L)	Nickel (ug/L)	Zinc (ug/L)	Hardness (mg/L_CaCO3)
5/17/21 14:41	5/17/21 17:11	Base Composite [1]	0.210	33		1.00	0.17	0.22	<0.06		<0.10	1.3	4.2	2.3	1.4	16.7	176.0
6/23/21 9:15	6/23/21 9:15	Base Grab [1]	0.078	19	9	0.80	0.09	<0.20	<0.06	172							
7/21/21 8:34	7/21/21 8:34	Base Grab	~0.049	~2	~1	0.49	0.07	0.23	<0.06	119							
8/17/21 14:10	8/17/21 14:10	Base Grab	~0.035	3	~2	0.42	<0.06	<0.20	<0.06	248							
9/23/21 8:55	9/23/21 8:55	Base Grab	~0.024	~1	~1	0.27	<0.06	0.21	<0.06	166							
10/12/21 14:40	10/12/21 14:40	Base Grab	~0.032	~1		0.36	<0.06	0.28	<0.06	569							
6/27/21 18:13	6/27/21 19:57	Storm Composite	0.341	190		2.20	0.12	0.33	<0.06		<0.10	4.2	10.7	12.3	3.2	42.2	133.0
7/13/21 20:28	7/13/21 21:07	Storm Composite	0.862	429	100	5.00	0.83	0.57	<0.06		0.22	9.6	20.9	35.2	7.4	91.0	154.0
7/14/21 13:04	7/14/21 13:32	Storm Composite	0.331	207	47	2.80		3.12	<0.06		0.11	4.7	11.8	19.5	3.8	47.7	115.0
8/5/21 23:34	8/5/21 23:51	Storm Composite	0.600	282	66	3.10					0.15	6.3	14.9	23.4	5.2	66.4	136.0
8/8/21 6:10	8/8/21 6:57	Storm Composite	0.185	102	25	1.30	0.19	0.26	<0.06		0.11	2.8	5.8	8.0	1.9	24.0	61.5
8/24/21 7:37	8/24/21 9:14	Storm Composite	0.283	75	24	1.40	0.13	0.41	<0.06		<0.10	2.2	6.5	6.0	1.8	24.1	117.0
8/29/21 1:05	8/29/21 1:35	Storm Composite	0.235	116		1.10	0.09	0.69	<0.06		0.25	3.0	6.7	12.8	2.5	29.9	71.0
9/17/21 3:44	9/17/21 4:02	Storm Composite	0.578	338	90	2.80	0.51	0.5	<0.06		0.20	6.5	15.3	24.9	5.1	66.9	78.7

[1] *Results excluded from averages*

Table 7. Perro Creek Historical TP and TSS Averages and Ranges

Perro @ Diversion Sample Type	2016	2017	2018	2019	2020	2021 [a]
TP (mg/L) - Baseflow Average	0.051	0.046	0.036	0.034	No Samples	0.035
Baseflow Range	*~0.023 - 0.090*	*<0.020 - 0.120*	*0.020 - 0.058*	*0.021 - 0.065*		*0.024 - 0.210*
TP (mg/L) - Stormflow Average	0.435	0.108	0.124	0.372	No Samples	0.427
Stormflow Range	*0.126 - 1.330*	*~0.023 - 0.218*	*0.047 - 0.252*	*0.133 - 0.597*		*0.185 - 0.862*
TSS (mg/L) - Baseflow Average	16	12	4	2	No Samples	2
Baseflow Range	*<1 - 77*	*~1 - 60*	*1 - 16*	*1 - 3*		*1 - 33*
TSS (mg/L) - Stormflow Average	118	36	20	58	No Samples	217
Stormflow Range	*32 - 308*	*12 - 76*	*8 - 31*	*21 - 97*		*75 - 429*

[a] *Results from base composite sample excluded from averages (Sampled during initial opening of Perro Pond outlet)*

Table 8. Monthly Geometric Means of *E. coli*- Latest Ten Years

Site	April	May	June	July	August	September	October
Perro at Diversion Structure [1]	Insufficient Data	Insufficient Data	392	215	167	814	Insufficient Data

Exceeds geometric mean of 126 #/100mL from not less than 5 samples in a calendar month

[1] *10% of samples taken in the last 10 years exceed 1,260 #/100mL (Doesn't necessarily exceed geometric mean standard)*

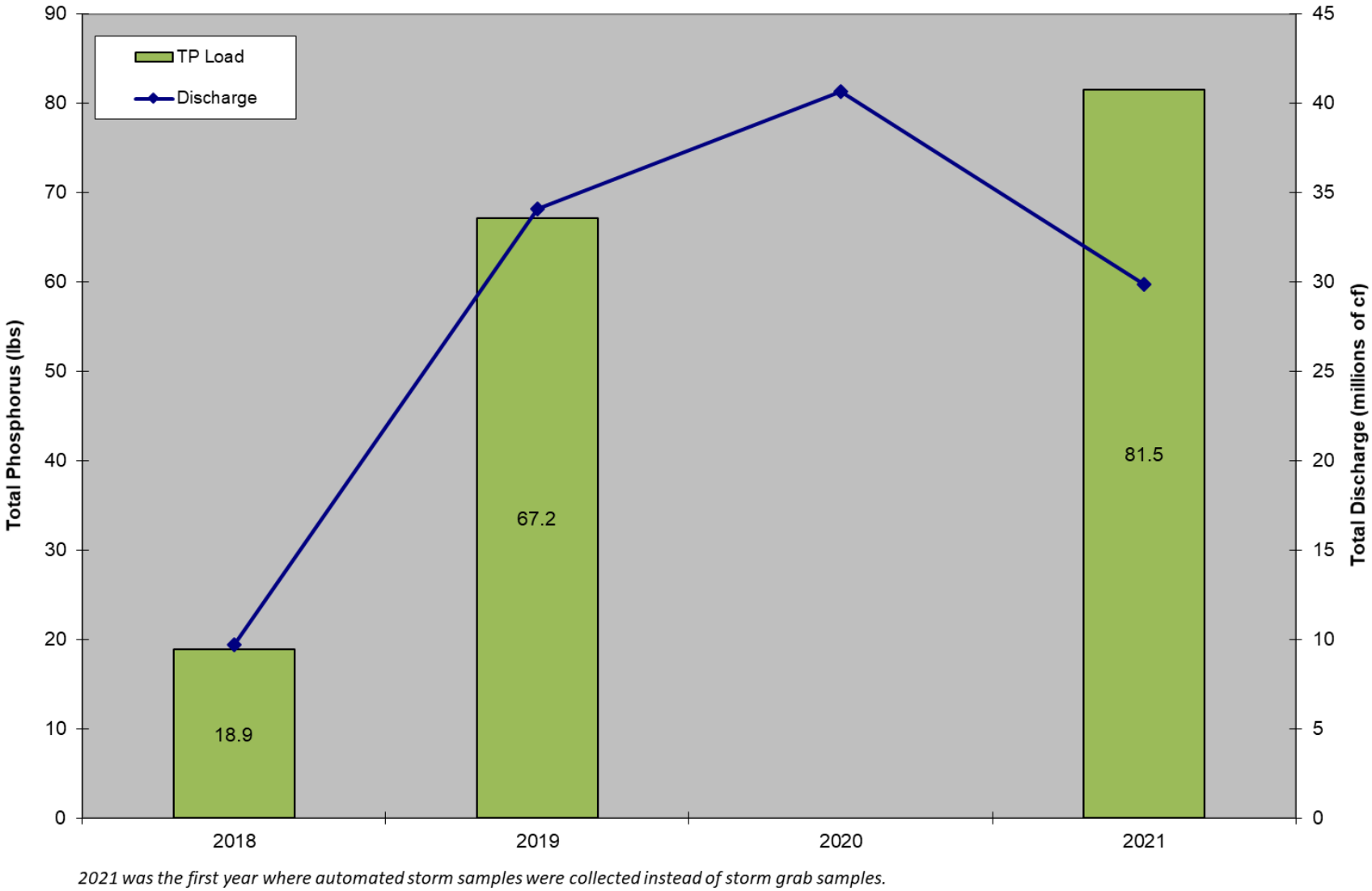


Figure 8. Perro Creek at Diversion Structure Monitored Discharge and Total Phosphorus Load

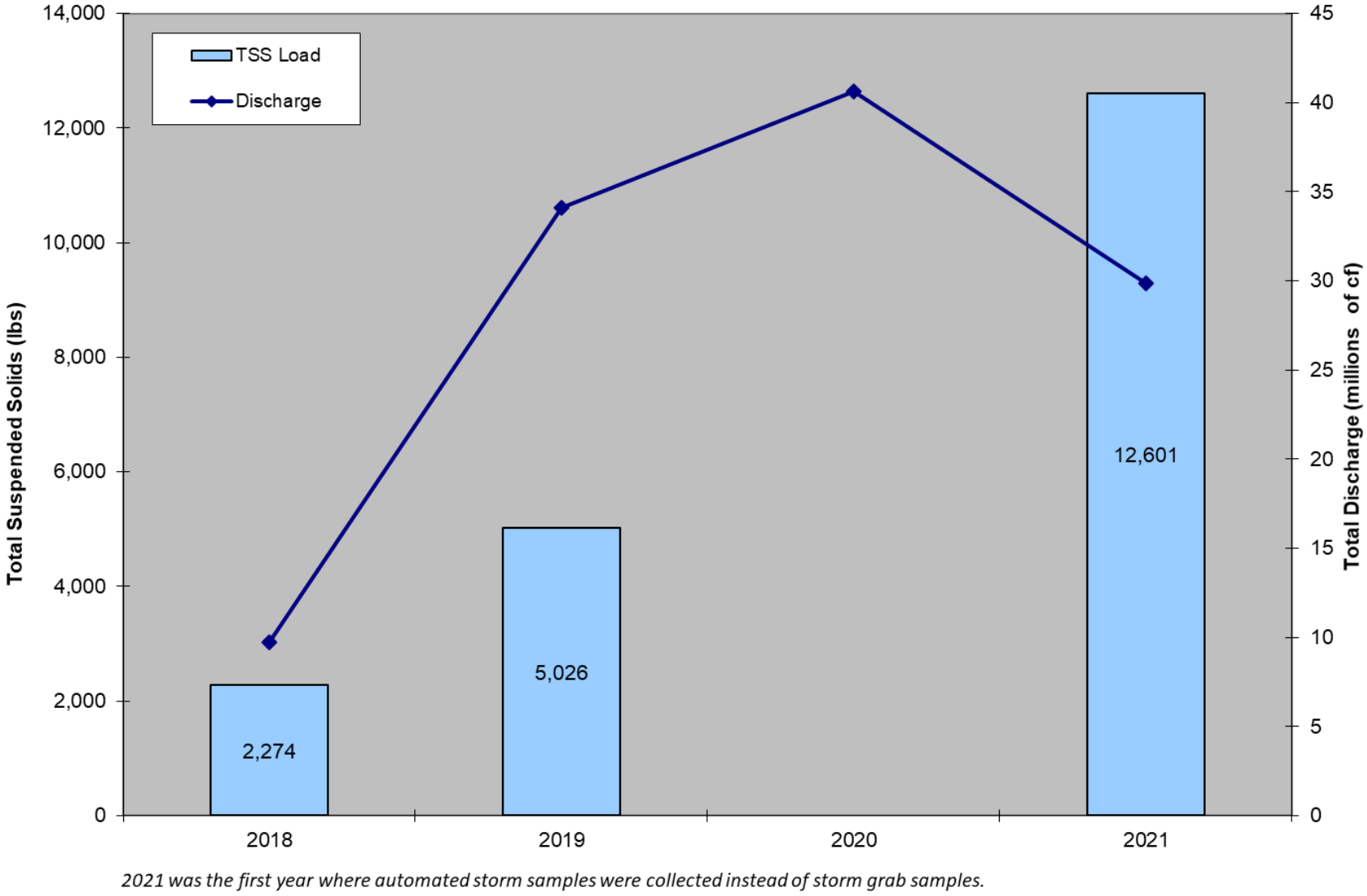


Figure 9. Perro Creek at Diversion Structure Monitored Discharge and Total Suspended Solids Load

C. BROWN'S CREEK DIVERSION STRUCTURE

As part of Brown's Creek Watershed District's long-term monitoring, the WCD collected grab samples and automated flow-weighted samples during both baseflow and storm event conditions at the Brown's Creek Diversion Structure for BCWD in 2021, and that data is provided to the MSCWMO. 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 keeps the warmer urban stormwater runoff from the southern tributary out of the temperature and nutrient sensitive Brown's Creek Ravine, it means that this is discharged to McKusick Lake and does affect the lake water quality. Data collected at this site by the WCD includes continuous stage and total discharge, and water quality samples analyzed for nutrients, sediment, and metals. Discharge decreased from 2020 to 46,792,341 cubic feet exported to McKusick Lake, due to drought conditions in 2021 (Table 9). All stream flow and chemistry data from 2021 can be found in Table 9 and Table 10.

The TP load to McKusick Lake was 446 lbs., or 0.116 lbs. of phosphorus per acre of watershed land, and the TSS load was 401,069 lbs. of sediment, or 104.01 lbs. per acre (Table 9). Erosional head cuts on the tributary branches of the creek have been identified as a source of TP and TSS loads. BCWD repaired one large head cut in 2018 and additional rock vanes were installed between September and October of 2021 to reconnect the drainage tributaries with their floodplains and stabilize the stream bed. The Iron Enhanced Sand Filter (IESF) upstream of the monitoring site also continues to operate to reduce TP loads in the drainage. In early 2021 the City of Stillwater removed 1,246 cubic yards of sediment from the wetland complex at the head of McKusick Lake, in the area where the Diversion Structure drainage discharges to the lake.

There were eight exceedances of the MPCA metal standards in 2021. The calculation of metal standards is described in the Minnesota Administrative Rules Part 7050.0222 and are divided into three categories of toxicity; chronic, maximum, and final acute value (FAV). The chronic standard protects organisms from long term exposure to a pollutant with minimal effects, the maximum standard from short term exposure with no or little mortality, and the FAV is the

concentration at which mortality can be expected. There were three copper results and five lead results that exceeded the chronic standards for those parameters, and no results exceeded the maximum or FAV standards for any parameters. The number and severity of exceedances of metals standards at this site in 2021 were the fifth lowest observed since metals analysis began in 2007, likely primarily due to the dry conditions during a large portion of the year. In most cases, more severe exceedances of metals seem to be associated with extreme TSS concentrations in this drainage. Sources of metals in the drainage may include improperly disposed wastes, such as deep cycle batteries. The combination and concentration of metals observed over time appear to point to this as a possible source.

Table 9. Brown's Creek Diversion Historic Annual Discharge and Loading- Latest Ten Years

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Brown's Creek Diversion Structure										
Discharge (cf)	21,810,789	46,435,271	53,519,017	46,276,327	70,780,581	39,625,672	45,453,990	112,468,888	68,165,935	46,792,341
Total pounds of Phosphorus exported	251	527	392	1,837	1,574	784	964	3,598	760	446
TP (lbs/ac/yr)	0.065	0.137	0.102	0.447	0.408	0.203	0.250	0.933	0.197	0.116
Total pounds of TSS exported	127,435	211,977	99,532	1,008,346	1,533,496	596,382	505,314	2,707,186	246,238	401,069
TSS (lbs/ac/yr)	33.06	54.99	25.82	261.57	397.79	154.70	131.08	702.25	63.87	104.01

Table 10. Brown's Creek Diversion 2021 Chemistry Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	Copper (mg/L)	Nickel (mg/L)	Lead (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Chloride (mg/L)	Nitrite N (mg/L)	Nitrate N (mg/L)	Ammonia Nitrogen (mg/L)	Hardness (mg/L _CaCO3)
Snowmelt Grab	3/8/2021 14:25	3/8/2021 14:25	79	24	1.70	0.348	0.077	0.00260	0.00240	0.00170	0.00960	<0.00010	0.00200	34.8	<0.06	0.33	0.16	107.00
Storm Grab	3/11/2021 10:56	3/11/2021 10:56	101	27	2.30	0.261	~0.029	0.00420	0.00360	0.00220	0.01610	0.00011	0.00310	48.6	<0.06	0.27	0.28	71.10
Storm Composite	4/6/2021 23:16	4/7/2021 7:58	2,410	752	14.00	2.070	~0.047	0.02380	0.02600	0.01840	0.08990	0.00061	0.02770	43.2	<0.06	0.47	<0.06	177.00
Unexplained Event Grab	5/26/2021 8:12	5/26/2021 8:12	21	6	0.70	0.119	0.069	0.00094	0.00130	0.00110	<0.00500	<0.00010	<0.00100	47.1	<0.06	0.68	<0.06	242.00
Storm Composite	5/27/2021 16:51	5/27/2021 23:26	2,610	1,060	0.92	0.150	0.056	0.02250	0.02680	0.01570	0.08530	0.00065	0.02290	41.4	<0.06	0.23	<0.06	233.00
Storm Composite	8/8/2021 7:47	8/8/2021 23:58	1,390	460	3.00	0.475	0.060	0.01930	0.01950	0.01280	0.08340	0.00052	0.01990	43.2	<0.06	0.43	<0.06	221.00
Storm Composite	8/26/2021 15:42	8/27/2021 8:05	631	209	3.10	0.517	0.151	0.00940	0.00920	0.00620	0.03110	0.00024	0.00970	40.5	<0.06	0.34	<0.06	138.00
Base Grab	4/22/2021 9:24	4/22/2021 9:24	7	~1	0.30	0.063	~0.044	<0.00050	0.00057	<0.00050	<0.00500	<0.00010	<0.00100	51.1	<0.06	0.54	<0.06	220.00
Base Grab	6/15/2021 11:22	6/15/2021 11:22	16	5	0.70	0.083	0.060	0.00089	<0.00050	<0.00050	<0.00500	<0.00010	0.00120	67.6	<0.06	0.39	<0.06	123.00
Base Grab	7/26/2021 9:24	7/26/2021 9:24	23	8	0.44	0.100	~0.048	0.00098	0.00074	0.00053	<0.00500	<0.00010	0.00120	41.1	<0.06	1.12	<0.06	268.00
Base Grab	8/25/2021 9:28	8/25/2021 9:28	22	8	0.67	0.122	~0.045	0.00066	0.00096	<0.00050	<0.00500	<0.00050	<0.00100	58.5	<0.06	0.62	<0.06	260.00
Base Grab	9/23/2021 9:23	9/23/2021 9:23	3	~1	0.56	0.055	~0.033	0.00052	0.00050	<0.00050	<0.00500	<0.00010	<0.00100	90.1	<0.06	0.27	<0.06	124.00
Base Grab	10/14/2021 8:39	10/14/2021 8:39	9	3	0.39	0.079	~0.030	<0.00100	0.00056	<0.00050	<0.00500	<0.00010	<0.00100	48.4	<0.06	0.54	<0.06	268.00

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

MSCWMO: CONCLUSIONS AND RECOMMENDATIONS

A. LAKES

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. Low water quality ratings of MSCWMO lakes are most likely due to long-term contribution of urban runoff (Lily Lake) or due to the sensitivity of shallow lakes being prone to summertime mixing (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 heavy algal blooms. This is unlike deeper, stratified lakes where phosphorus below the thermocline is not available for primary production.

The MPCA have listed both Lily and McKusick Lake on the 303(d) Impaired Waters list for nutrient/eutrophication impairment; however, McKusick Lake was delisted in 2012, and Lily Lake is scheduled to be delisted in 2022. 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 was postponed. The MSCWMO, BCWD, and the City of Stillwater will utilize the City of Stillwater's existing Lake Management Plan, 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.

Summertime (June-September) TP, chlorophyll-α, and Secchi disk transparency averages have remained relatively consistent over the last twenty years in Lily Lake with the exceptions of 1995, 2001, 2009, 2013, and 2014 where overall water quality dramatically improved (Figure 2, Figure 3, and Figure 5). In 2001 phosphorus and chl-α levels dropped and the lake grade improved significantly. In 2006-2008, summer average TP, chl-α, and Secchi disk transparency deteriorated when compared to the averages seen from 2001 to 2005. In 2021 Lily Lake received a grade of a C+, the long-term average lake grade.

The cause of these one-year increases (1995, 2001, 2009, 2013, and 2014) in water quality is presently unknown, and there may be several possible explanations which could be investigated further in the future. Lily Lake has received herbicide and algaecide treatments from 1995-2011 and 2016-2018. In 2018-2021 the City of Stillwater and the Lily Lake Association did not request any large-scale herbicide and algaecide treatments but individual landowner treatments have occurred. In 2010 a native buffer planting was installed at the public access and the Lily Lake watershed underwent a subwatershed assessment. As a result, fifteen raingardens were constructed in the Lily Lake watershed from 2011-2012, six large raingardens were installed in 2014, a gully stabilization project installed at Lakeview Hospital discharging to Brick Pond in 2017, and a large gully stabilization and stormwater treatment system discharging to Brick Pond in 2018. In 2019 another raingarden was installed. Construction began for a large infiltration basin in 2021, which is expected to be completed in 2022, along with an alum treatment. The effects of these BMPs may have been seen from 2012 to 2021 monitoring seasons with the 2016-2021 seasons having a statistically significant ($p<0.05$) improving trend for total phosphorus. Continued monitoring is needed to show changes to long term trends due to the implementation of these BMPs. In 2019 the Lily Lake Phosphorus Reductions for Delisting grant was secured. More information about the Lily Lake Impaired Waters Delisting Road Map can be found at http://www.mscwmo.org/subwatershed-assessments.

A subwatershed assessment was conducted on the McKusick Lake watershed in 2010. In 2011 six raingardens were constructed as a result of the subwatershed assessment. With renewed funding, seven additional raingardens were planned to be installed in the McKusick Lake watershed in 2013 but were not due to issues with utilities; instead, six larger raingardens were

installed in 2014. The impacts of previously installed raingardens may have been seen in 2017-2021 with statistically significant ($p<0.05$) improving trends for average TP and average Secchi disk transparency. For more information on the McKusick Lake subwatershed assessment refer to the McKusick Lake Stormwater Retrofit Assessment found at http://www.mscwmo.org/subwatershed-assessments.

B. TARGETED MONITORING

The targeted monitoring of Lily Lake had the goal of more accurately identifying the major sources of nutrients to the lake and to help steer targeting and design of stormwater management practices. Based on 2016 results, approximately 78% of phosphorus loading to Lily Lake occurs during storm events and the Greeley Street catchment was one of the highest contributing stormwater catchments during those events. The remaining 22% of the phosphorus load was from Brick Pond discharging to Lily Lake during baseflow conditions. Baseflow from Brick Pond accounted for 65% of the total discharge to the lake in 2016 but the average TP concentrations during those periods were lower than during storm events.

The results in 2021 support previous years' conclusions that TP and TSS concentrations from samples collected during baseflow are on average lower than concentrations during storm events. The drought conditions in 2021 caused a decrease in flow and affected baseflow and stormflow sampling. Both baseflow and stormflow average results were higher than in recent years and all samples were collected during periods with discharge <1.0 cfs. Of the four base sample results for TP, one was considered an outlier, one was near the top end of the historic range, and two had the lowest concentrations since sampling began in 2015. Stormflow periods in 2021 accounted for only 4% of the monitored discharge to Lily Lake, but 15% of the TP load and 28% of the TSS load occurred during these periods.

Baseflow samples should continue to be collected during all flow periods to help evaluate possible changes in TP and TSS loading to Lily Lake. More storm samples should also be collected to calculate more accurate TP and TSS loadings and to better characterize storm events. Continued monitoring will also help assess the impact of potential BMPs installed in the Greeley Street catchment.

C. STREAMS

In 2021 water quality sampling resumed at the Perro Creek at the Diversion Structure site by collecting in-stream grab samples during baseflow periods and using an automated sampler to collect flow-weighted composite storm samples. The average TP and TSS concentrations from baseflow samples were similar to previous years while the stormflow averages were the highest for TSS and second highest for TP since sampling began in 2016. This is directly connected to the automated sampler collecting samples throughout entire storm events, leading to a better characterization of storm concentrations and more accurate load calculations. In 2021, stormflow periods accounted for only 2% of the monitored discharge to the St. Croix River but 22% of the TP load and 71% of the TSS load occurred during these periods. Flow-weighted composite samples should continue to be collected to more accurately calculate TP and TSS loads during storm events.

Perro Creek is listed as impaired for TSS on the MPCA's 303(d) Impaired Waters List and is assessed using an unbiased dataset. Flow-weighted composite samples are considered biased towards higher flow periods because more samples are collected during the higher flows, and these samples are therefore not used for TSS assessments. In 2021 there were no TSS results from grab samples that exceeded the MPCA standard of 30 mg/L. Water quality grab samples should continue to be collected at Perro Creek during different levels of flow to provide an unbiased dataset for assessing the stream for the TSS impairment.

Perro Creek is listed as impaired for *E. coli* bacteria on the MPCA's 303(d) Impaired Waters List. Samples collected in 2021 at the Diversion Structure in June, July, and September were less than the monthly geometric means from the last 10 years of data for that site, while the August sample was higher than the monthly geometric mean. The sample collected in October had the highest *E. coli* result in 2021 but there currently is an insufficient dataset to calculate a geometric mean for October at that site. The 10-year geometric means in June, July, August, and September exceed the MPCA standard. Monthly *E. coli* samples should continue to be collected from May through October at Perro Creek to expand the dataset for calculating monthly geometric means.

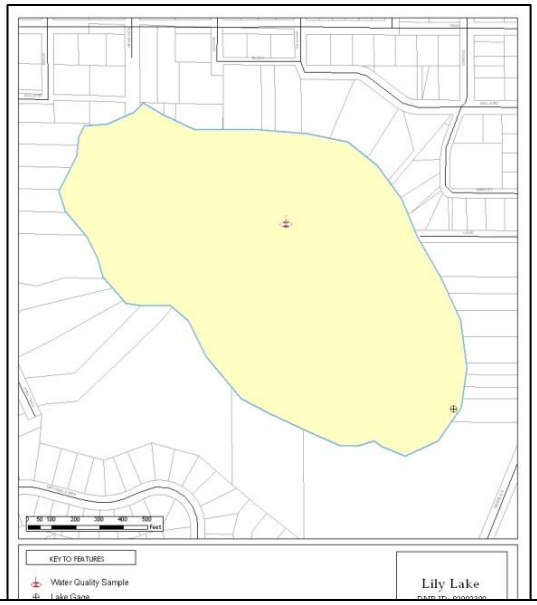
APPENDIX A
WATER QUALITY DATA – LILY LAKE AND MCKUSICK LAKE

This Page Intentionally Left Blank.

LILY LAKE

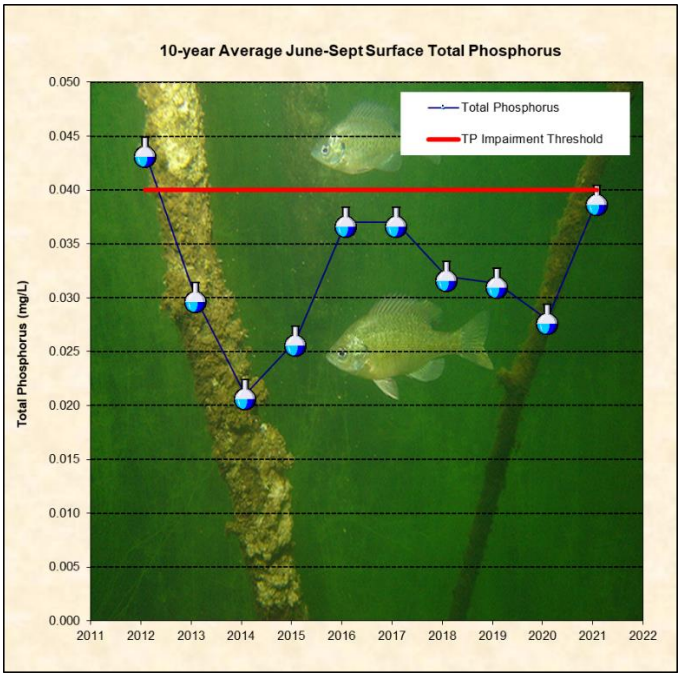
2021 Lake Grade: C+

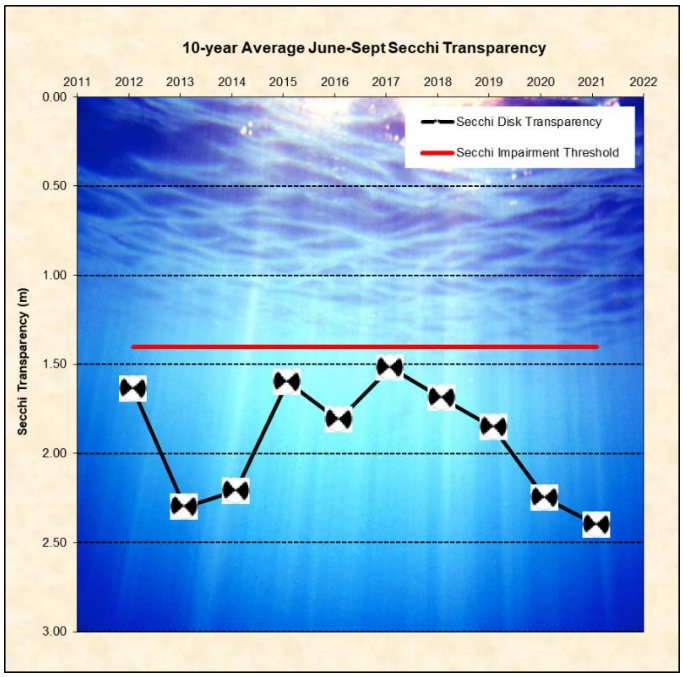
- DNR ID #: 820023
- Municipality: City of Stillwater
- Location: NE ¼ Section 32, T30N-R20W
- Lake Size: 35.90 Acres
- Maximum Depth (2021): 47 ft
- Ordinary High Water Mark: 844.8 ft
- 55%Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.
- Publicly accessible



Summary Points

- Based on the chlorophyll-α results Lily Lake was considered eutrophic in 2021, 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 trend is present for average Secchi transparency or average chlorophyll-α.
- The major land use is urban/residential.
- The lake stratified in 2021 with the thermocline between 5-7 meters deep.
- Lily Lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List but is scheduled to be delisted in 2022.





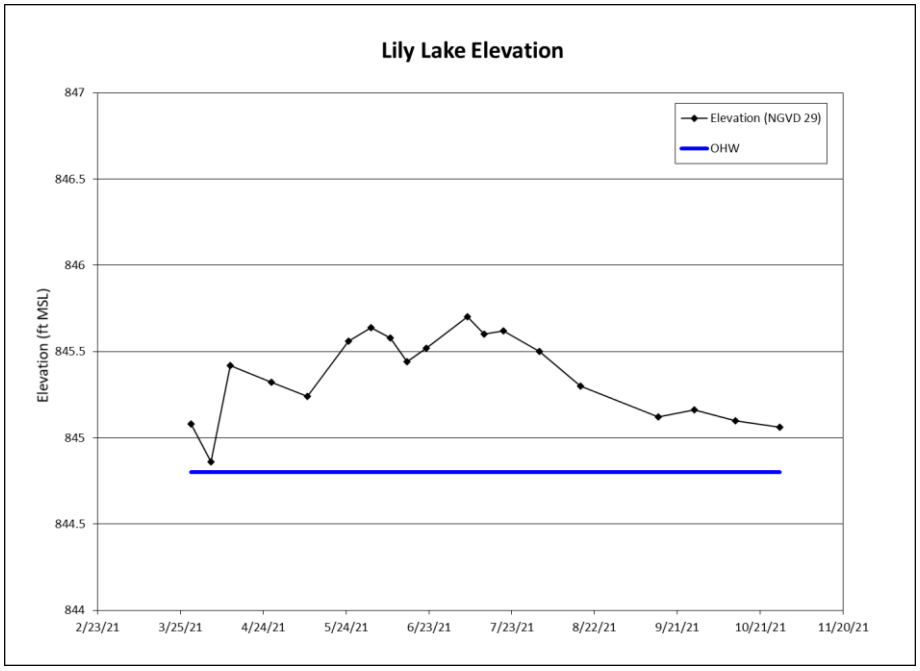
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
4/12/2021 11:17	0.159	19.0	18.0	1.40	2.13	11.4	11.25
4/27/2021 7:58	0.025	23.0	22.0	0.91	2.74	9.1	12.16
5/10/2021 11:45	0.058	33.0	30.0	1.00	1.37	15.1	12.61
5/25/2021 8:36	0.025	1.1	1.0	0.76	3.81	22.9	7.77
6/9/2021 8:51	0.063	2.8	2.4	0.77	3.81	27.6	8.42
6/22/2021 8:15	0.032	4.7	4.3	0.73	4.27	22.1	7.64
7/7/2021 8:49	0.054	8.3	7.2	0.69	3.05	25.9	6.39
7/20/2021 7:56	0.027	6.0	5.3	0.75	2.59	26.6	8.41
8/2/2021 10:39	0.040	37.0	36.0	1.30	0.91	25.4	7.65
8/17/2021 7:58	0.040	23.0	22.0	0.97	1.22	24.3	7.88
8/30/2021 9:41	0.039	26.0	24.0	0.95	1.07	23.9	7.36
9/14/2021 10:50	0.025	11.0	10.0	0.82	2.90	21.1	7.63
9/27/2021 8:30	0.032	17.0	16.0	0.96	1.83	18.4	9.11
10/12/2021 8:12	0.033	14.0	13.0	0.82	2.29	19.0	8.10
2021 Average	0.047	16.1	15.1	0.92	2.43	20.9	8.74
2021 Summer Average	0.039	15.1	14.1	0.88	2.40	23.9	7.83

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
2021 Elevation (ft)	845.70	7/7/2021	844.86	4/5/2021	845.36

*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."



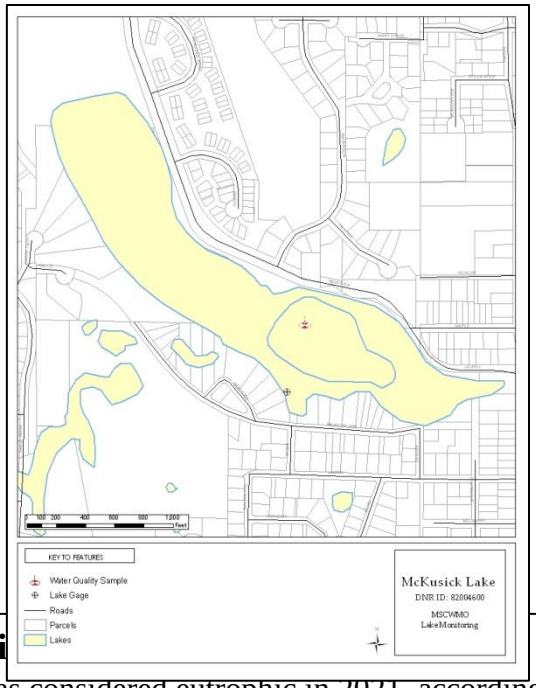
Lake Water Quality Summary										
	Summertime Lake Grades (May-Sept)									
	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012
Total Phosphorus (mg/L)	C	B	B	B	C	C	B	A	B	C
Chlorophyll-*a* (ug/L)	C	B	B	B	B	C	C	B	B	B
Secchi depth (ft)	B	B	C	C	C	B	C	B	B	C
Overall	**C+**	**B**	**B-**	**B-**	**C+**	**C+**	**C+**	**B+**	**B**	**C+**

MCKUSICK LAKE

2021 Lake Grade: B-

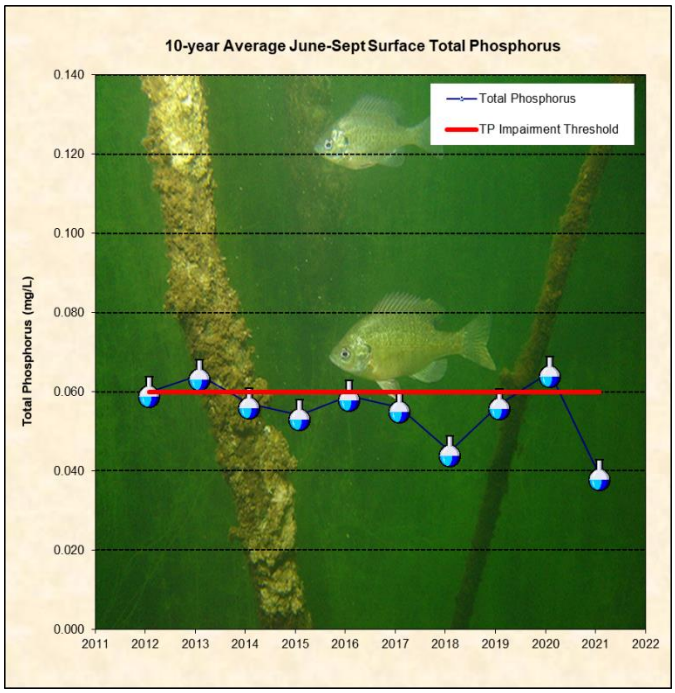
DNR ID #: 820020

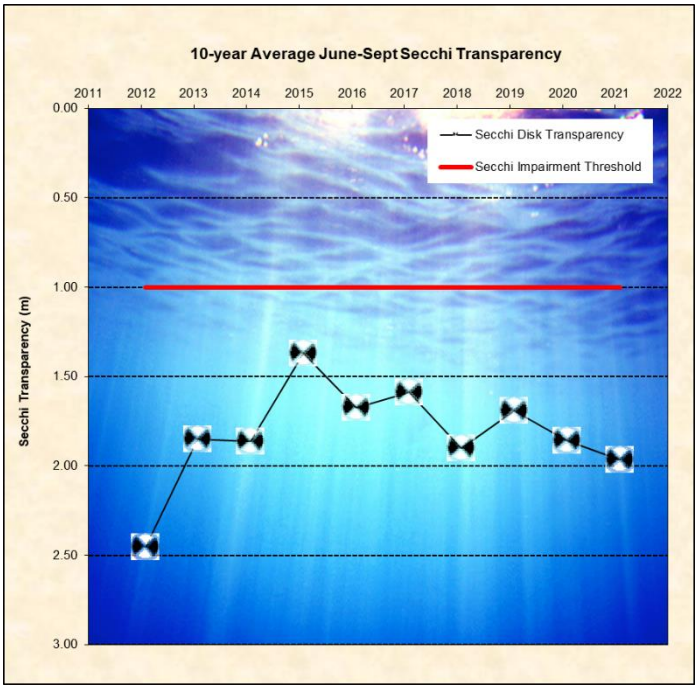
- Municipality: City of Stillwater
- Location: NE ¼ Section 29, T30N-R20W
- Lake Size: 46 Acres
- Maximum Depth (2021): 15 ft
- Ordinary High Water Mark: 851.7 ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Poi

- Based on the chlorophyll-α results McKusick Lake was considered eutrophic in 2021, 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 average total phosphorus, and no trend for average chlorophyll-α.
- The major land use is urban/residential.
- Temperature and dissolved oxygen profiles were not collected in 2021 so stratification cannot be determined.
- McKusick Lake was delisted in 2012 for its impairment for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





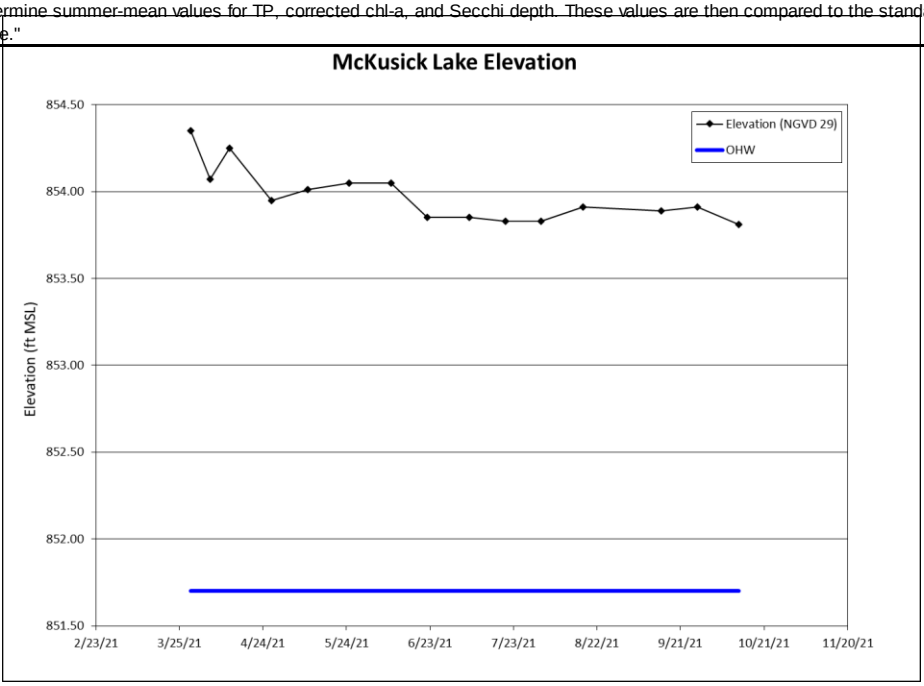
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
4/12/2021 12:03	0.062	20.0	17.0	0.69	1.37	11.3	8.84
4/27/2021 8:20	0.052	17.0	15.0	0.84	1.22	8.9	10.65
5/10/2021 12:14	0.033	8.0	6.1	0.78	1.52	15.4	9.71
5/25/2021 9:06	0.037	4.7	3.7	0.70	2.44	23.3	8.72
6/9/2021 9:17	0.030	3.1	2.9	0.71	3.51	27.9	9.42
6/22/2021 8:54	0.045	10.0	9.6	0.73	1.98	21.9	5.30
7/7/2021 9:14	0.048	11.0	9.1	0.75	0.76	24.6	2.99
7/20/2021 8:22	0.040	4.3	4.0	0.81	1.83	25.0	3.28
8/2/2021 9:46	0.037	6.0	5.1	0.78	0.61	24.1	1.25
8/17/2021 8:24	0.028	4.7	3.2	0.68	2.29	23.4	5.52
8/30/2021 9:15	0.057	26.0	22.0	0.86	1.98	22.8	6.33
9/14/2021 11:18	0.029	11.0	10.0	0.72	2.59	19.8	5.72
9/27/2021 9:05	0.037	7.0	6.4	0.88	2.13	17.0	8.02
10/12/2021 8:39	0.031	5.9	4.8	0.73	1.98	18.3	5.97
2021 Average	0.040	9.9	8.5	0.76	1.87	20.3	6.55
2021 Summer Average	0.039	9.2	8.0	0.77	1.96	22.9	5.31

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
2021 Elevation (ft)	854.35	3/29/2021	853.81	10/12/2021	853.97

*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 (May-Sept)									
	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012
Total Phosphorus (mg/L)	C	C	C	C	C	C	C	C	C	C
Chlorophyll-*a* (ug/L)	A	A	A	B	B	B	C	C	B	A
Secchi depth (ft)	C	C	C	C	C	C	C	C	C	B
Overall	**B-**	**B-**	**B-**	**C+**	**C+**	**C+**	**C**	**C**	**C+**	**B**