Middle St. Croix Watershed Management Organization 2011 Water Monitoring Report

Prepared For:

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Washington Conservation District

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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The WCD would also like to thank the volunteers and landowners who assist with data collection and access to our monitoring locations.

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

biweekly	Every other week
cf	cubic feet
cfs	cubic feet per second
Chl-*a*	Chlorophyll-*a*
DO	Dissolved Oxygen
E. Coli	*Escherichia coli*
MCES	Metropolitan Council Environmental Services
mg/L	milligram per liter
MN DNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MSCWMO	Middle Saint Croix Watershed Management Organization
NCHFE	North Central Hardwood Forest Ecoregion
OHW	Ordinary High Water level
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSI	Trophic State Index
TSMP	Trout Stream Mitigation Project
TSS	Total Suspended Solids
µg/L	microgram per liter
µmhos/cm	micromhos per centimeter
VSS	Volatile Suspended Solids
WCD	Washington Conservation District

EXECUTIVE SUMMARY

This report focuses on the summary and comparison of lake and stream water quality data collected by the Washington Conservation District (WCD) in 2011 and previous years. In 2011 the Middle St. Croix Watershed Management Organization (MSCWMO) monitored water quality and elevation on McKusick Lake, water quality on Brick Pond, and elevation on Lily Lake and Perro Pond. Discharge and water quality were monitored on Perro Creek and water quality at Meadowlark Drive and Myrtle Street (Figure 1). Information from the Brown's Creek Diversion Structure site is also included in this report as this affects the water quality of McKusick Lake. The purpose of the monitoring program is to assess and document the current water quality conditions of the lakes and streams and to continue a long-term monitoring program that will enable the MSCWMO to identify trends associated with land use changes in their watershed.

Brick Pond and McKusick Lake had average water quality in 2011. The overall 2011 lake grade for McKusick Lake was a C- and Brick Pond was a C. Both McKusick Lake and Brick Pond were classified as eutrophic in 2011 (Table 2). Lily Lake was scheduled to be monitored by a volunteer, but this did not occur and the volunteer was unable to sample as scheduled, therefore Lily Lake did not receive a lake grade in 2011. In 2010 Lily Lake had received a C+ for a grade (Table 3).

In 2011 McKusick Lake was within the north central hardwood forest ecoregion (NCHFE) range for Secchi disk transparency and worse than the NCHFE range for total phosphorus and chlorophyll-*a*. Eight of fourteen water quality samples exceeded the Minnesota Pollution Control Agency (MPCA) shallow lake threshold for total phosphorus (TP), four of fourteen samples exceeded the threshold for chlorophyll-*a* (chl-*a*), and only one Secchi disk transparency exceeded (was worse than) the MPCA impairment threshold (Table 1).

Brick Pond was poorer than the NCHFE range for TP and for Secchi disk transparency, but was within the NCHFE range for chl-*a* in 2011. Six of seven samples exceeded the shallow lake impairment threshold for TP while all samples exceeded the MPCA impairment threshold for

Secchi disk transparency. Only one sample for chlorophyll-*a* exceeded the MPCA impairment threshold (Table 1).

Lilly Lake was not monitored in 2011, but in 2010 it was within the NCHFE range for TP and Secchi disk transparency, with only one water quality sample exceeding the MPCA threshold for Secchi disk transparency impairment. Lily Lake was worse than the NCHFE range for chl-*a* with three water quality samples exceeding the MPCA threshold. This number was most likely skewed due to missing chl-*a* value for the August 5, 2010 water quality sample collected. The Metropolitan Council Environmental Services (MCES) Lab was unable to analyze the sample due to missing information from the time of collection.

Perro Creek showed a decrease in discharge of 9,815,732 cubic feet (cf) from what was seen in 2010, with 38,802,342 cf discharged in 2010, and 28,986,610 cf discharged in 2011. In 2011 Perro Creek discharged an estimated total of 82 lbs of phosphorus, a decrease of 97 lbs, almost half of what was discharged in 2010. Perro Creek also discharged an estimated 379,634 lbs of suspended solids to the St. Croix River (Table 5). That is up from 191,200 lbs in 2010, 51,874 lbs in 2009 and 29,343 lbs in 2008, almost doubling every year since 2008. One cause for the high TSS loading this year may have been due to the ever changing climate. Another possible cause for the load increase over the past five years could be the further degradation of the up-stream channel.

Total discharge was not estimated at the Myrtle Street and Meadowlark Drive sites, but samples were taken during storm events, and TP and TSS loads have been estimated. When looking at the Myrtle Street and Meadowlark Drive sites for TP and TSS in lbs/day, it can be seen that all values for the Myrtle site are greater than those at the Meadowlark site (Table 9, Table 10). Values from past years have shown a similar trend, where the majority of samples taken at the Myrtle Street site are greater than the samples collected from Meadowlark Drive site (Table 11). This is likely due to the Jaycee's Ballfield wetland complex, located between the two sampling sites, filtering out and treating many of the pollutants going through it.

The Brown's Creek Diversion Structure site showed an increase of 14,784,085 cf, going from 38,197,468 cf in 2010, to 52,981,553 cf in 2011, an increase. TP also increased by 1,491 lbs, almost three and a half times the 2010 value of 608 lbs, to 2,099 lbs in 2011. TSS also showed an increase in the amount exported to McKusick Lake, from 353,007 lbs in 2010, to 1,387,050 lbs in 2011, an increase of 1,034,043 lbs (Table 12, Table 17).

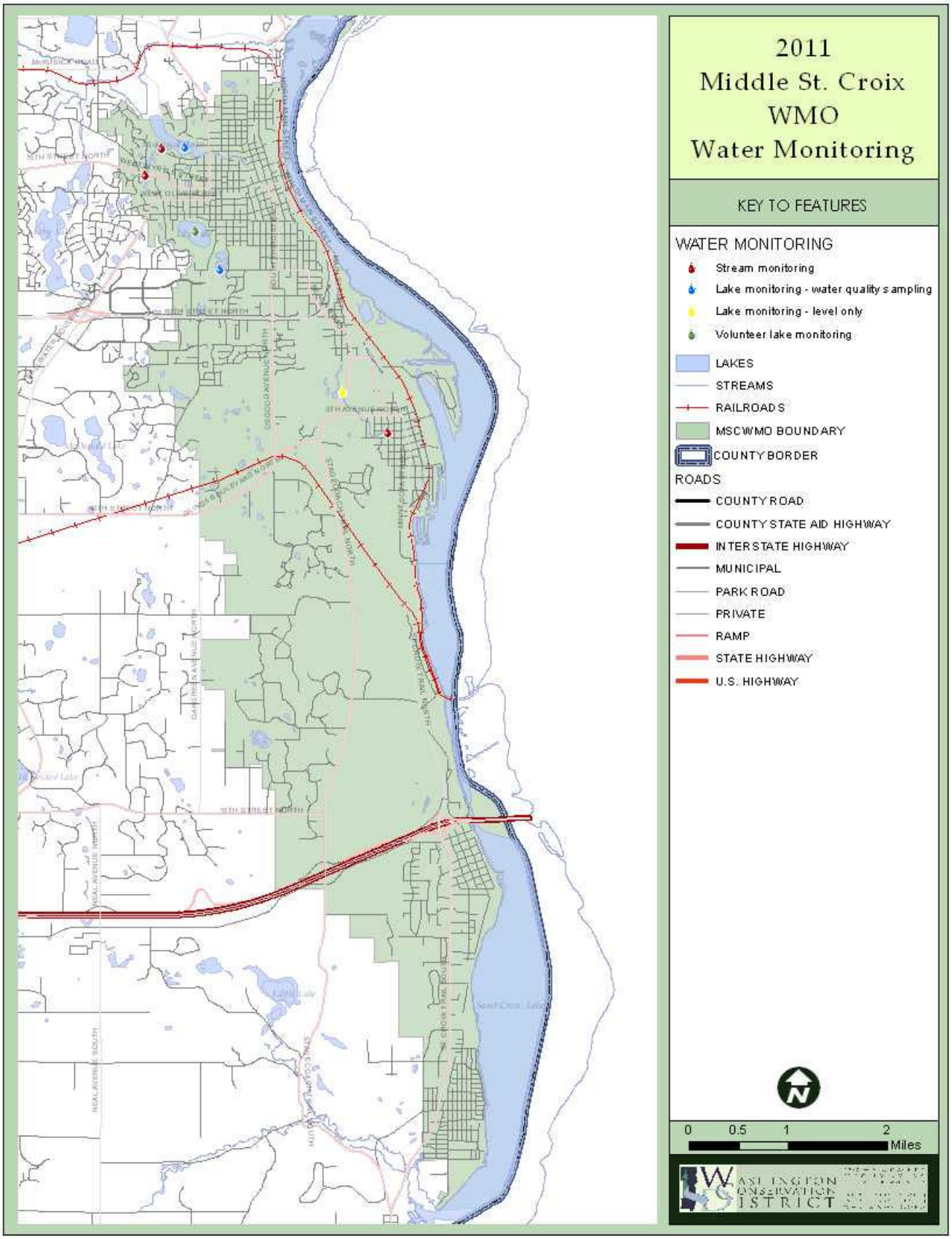

Figure 1. MSCWMO 2011 Water Monitoring Location

LAKE MONITORING

A. METHODS, RESULTS AND DISCUSSION

In 2011 water quality data was collected monthly on Brick Pond and biweekly on McKusick Lake, over seven consecutive months (April–October) by the WCD. Lily Lake was scheduled to have a volunteer collect water quality samples in 2011; however, water quality samples were unable to be collected. Water quality samples are collected with a two-meter (6.56 feet) integrated surface water column sampler. The MCES Lab analyzed these surface samples for TP, chl-*a*, and total Kjeldahl nitrogen (TKN). Field measurements recorded include dissolved oxygen (DO) and temperature profiles, lake level elevation, and Secchi disk transparency. A user perception ranking (physical and recreational suitability) of the lake was also recorded at the time of sample collection. A full description of WCD Standard Operating Procedures is available on the Washington Conservation District website at http://www.mnwcd.org/water_monitoring_standards.php.

Measurements obtained during the summer sampling season (June 1-September 30) are averaged for a comparison of individual lake dynamics from year to year, for a comparison between lakes within the watershed, and a comparison to the average NCHFE values. Average values for all parameters, as well as the typical ranges for lakes in the NCHFE are presented in Table 1. Figure 2, Figure 3, and Figure 4 show the current and historic summer averages for each parameter at each site.

Table 1. North Central Hardwood Forest Ecoregion Values and Average 2011 Parameters

2011 MSCWMO Lakes Summer Averages (June-September)				
Lake/Units	**Total Phosphorus (mg/L)**	**Chlorophyll-a (ug/L)**	**Secchi Disk (meters)**	**Deep Or Shallow**
Eco-Region Value	*0.023-0.050*	*5.0-22.0*	*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	**NA**	**NA**	**NA**	Deep
McKusick	0.081	26.5	2.08	Shallow
Brick Pond	0.078	13.0	0.46	Shallow

1. LAKE WATER QUALITY RESULTS

TRANSPARENCY (SECCHI DISK)

The measurement of light penetration using a Secchi disk gives a simple measure of water transparency, or clarity. It is also a possible 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). The summer average (June-September) water transparency in MSCWMO lakes, as measured by a Secchi disk during the 2011 study period, is 2.08 meters in McKusick Lake, and 0.46 meters in Brick Pond (Table 1), with the typical ranges for the NCHFE between 1.5 – 3.2 meters. In McKusick Lake most summer Secchi disk readings were within the MCHFE range, with only two being worse, and one being better. In 2011 the WCD staff conducted Kendall Tau statistical trend analysis on all lakes monitored within the county ($p<0.01$). McKusick Lake has seen statistically significant improvements ($p<0.01$) in Secchi transparency from 1994 through the present, even though this year did not help this improving trend. While in Brick Pond, every Secchi disk reading exceeded (was poorer than) the NCHFE range. It should be noted that it is difficult for transparency results to fall within the NCHFE range due to the shallowness of Brick Pond, with the maximum depth of the pond approximately 1.52 meters, just over the minimum NCHFE value. The Kendall Tau correlation test is not run for transparency on shallow lakes, such as Brick Pond, when there is rooted vegetation, or the secchi disk is visible to the lake bed. With those being present there is too much error that can alter the long term trends. No Secchi disk readings were taken in Lily Lake in 2011. The 2010 summer average for Lily Lake was 1.8 meters, and no significant trend in Secchi transparency could be seen. Historical Secchi disk summer average values for all three lakes can be found in Figure 2.

CHLOROPHYLL-*a*

Chlorophyll-*a* (chl-*a*) is a photosynthetic component found in algae and aquatic plants. It is also an indication of algal productivity. The 2011 summer average chl-*a* concentrations of MSCWMO lakes can be seen in Table 1. The NCHFE value range for chl-*a* is 5 - 22 μg/L. McKusick Lake had a summer average concentration of 26 μg/L, which is 21 μg/L higher than the 2010 summer average value, and now exceeds the NCHFE value range for the first time since 2002 (Figure 3). Four out of fourteen samples collected in 2011 exceeded the shallow

lakes threshold for Chl-*a.* That number is up from 2010 when none of the samples collected from McKusick Lake exceeded that threshold. The Brick Pond summer average concentration was 13 μg/L. That is 5 μg/L higher than the 2010 value, and the highest concentration seen since monitoring began in 2008, but is still within the NCHFE range for chl-*a*. Only one Brick Pond sample exceeded the shallow lakes threshold for Chl-*a* in 2011, an increase from no samples in 2010. Lily Lake was not sampled for chl-*a* in 2011. The 2010 concentration was 27 μg/L, which exceeded the NCHFE range. It should be noted that there was one chl-*a* sample value missing from Lily Lake, the August 5, 2010 sample collected. The MCES lab was unable to analyze the sample due to incomplete information recorded during sampling. This missing value may have skewed the average number. Historical summer average chl-*a* values can be found in Figure 3.

PHOSPHORUS

Total phosphorus (TP) 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 TP include runoff from agricultural fields, livestock areas, urban areas, lakeshore lawns, and improperly operating septic systems. In most lakes in this region, TP 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 light penetration of the water. The typical range of the NCHFE for total phosphorous is 0.023 – 0.050 mg/L. TP summer average concentrations for McKusick Lake in 2011 were 0.081 mg/L, up from 0.030 mg/L in 2010, and now exceed the NCHFE range (Table 1). McKusick Lake exceeded the shallow lake water quality threshold for TP in eight of the fourteen samples in 2011, which is more than in 2010 when TP concentrations never exceeded this threshold. Overall, McKusick Lake has seen statistically significant improvements ($p<0.01$) for TP from 1994 to the present, even though this year did not help this improving trend. The 2011 TP summer average concentration was 0.078 mg/L in Brick Pond, up from 0.061 mg/L in 2010, and again exceeding the NCHFE range (Table 1). Brick Pond exceeded the shallow lake water quality threshold for TP six of seven samples in 2011, declining from only four out of seven samples exceeding the threshold in 2010. There are not enough years of data to determine any statistically significant trend at this time on Brick Pond. Lilly Lake was not sampled in 2011, but in 2010 the concentration of TP was 0.027 mg/L. While Lily

Lake showed improvement over the 2009 TP values, there was no statically significant trend. Historical summer average TP values can be found in Figure 4.

NITROGEN

Several forms of nitrogen are responsible for health problems and can also increase the rate of lake eutrophication. Total Kjeldahl nitrogen (TKN) is one of these forms, and was measured during the 2011 monitoring season. The NCHFE range for total Kjeldahl nitrogen is 0.60-1.20 mg/L. The average summer TKN concentration in McKusick Lake for 2011 was 1.085 mg/L, an increase from 0.88 mg/L in 2010, and still within the NCHFE range (Table 1). Brick Pond had an average summer TKN concentration of 0.80 mg/L, almost exactly the concentration in 2010 of 0.79 mg/L, and also within the NCHFE range (Table 1). Lily Lake was not sampled in 2011, but the 2010 value was 0.90 mg/L, and was within the NCHFE range. There is no shallow lake threshold for TKN.

TEMPERATURE AND DISSOLVED OXYGEN

In addition to surface water measurements, a temperature and dissolved oxygen (DO) profile was taken at each lake during each sampling event. These profiles were recorded at meter increments from the surface to the lake bottom. Data collected from these profiles are contained in a database at the WCD. 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, bottom nutrients become available and can result in increased algal production. The lake DO data is useful in determining excessive production (algae/plants) in a lake. More production means more DO, for a time, but as plants and algae die off they turn from producers of DO into consumers, as they decay. McKusick Lake exhibited thermal stratification during the summer months of 2011 with the thermocline being around 3 meters, and was therefore less likely to completely mix. McKusick Lake also showed very low DO levels starting in early to mid-July and lasting until mid to late-September. The low DO levels are likely due to the decomposition of algae and plants that had overtaken McKusick Lake earlier in the year. With DO levels remaining so low for so long (2 – 3 months) McKusick Lake went anoxic, ultimately resulting in a fish kill. Brick Pond is a shallow pond

and did not stratify during the summer of 2011, letting it mix throughout the summer and allowing for internal loading. Lily Lake was not monitored in 2011 and neither dissolved oxygen or water temperatures were measured. In 2010 Lily Lake was monitored by a volunteer, but dissolved oxygen was not measured; only water temperature at the water surface was measured.

TROPHIC STATE AND LAKE GRADES

Many water quality scientists classify lakes according to their trophic state. Average summer values of TP, chl-*a*, and transparency (measured with the Secchi disk) are most often used to determine a lake's trophic state. The Carlson Trophic State Index (TSI) is used to quantify the relationship between trophic status and water quality data. Oligotrophic lakes, such as lakes common in the northeastern part of Minnesota, have low biological activity as a result of low phosphorus concentrations, low chl-*a* concentrations, and high Secchi disk transparencies. A good local example of an oligotrophic lake is Square Lake, located in Section 23 of May Township. Mesotrophic lakes have slightly more biological production, and are characteristic of lakes found in the NCHFE of Minnesota. On the other end of the spectrum, lakes with high biological productivity, characterized by high TP concentrations, high chl-*a* concentrations, and low Secchi disk transparencies, are eutrophic or even hypereutrophic (Table 2). Lakes within the eutrophic or hypereutrophic range typically receive excess nutrient loading from sources within their watersheds. Some percentage of these nutrients, however, can also be attributed to internal loading within the lake itself, which is typical of shallow, sediment-rich lakes or lakes that receive large amounts of runoff from the surrounding drainage area.

Based upon the 2011 data and utilizing the Carlson's TSI, McKusick Lake and Brick Pond are both classified as eutrophic, a downgrade from their 2010 classification of mesotrophic. Lily Lake was not monitored in 2011 and could not be classified. In 2010 Lily Lake was classified as mesotrophic.

Table 2. Trophic State Index and Ranges

	Trophic State Index	TP (ug/L)	Chl-*a* (ug/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

To allow for a better understanding of lake water quality data and to aid in the comparison of lakes, a Lake Grading System is also used in this report (Table 3). 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 curve represents percentile ranges for three water quality indicators: the June through September average values for TP, chl-*a*, and Secchi disk transparency. These percentiles use ranked data from 119 lakes sampled from 1980-1988 and are shown in Table 3.

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

The variables used in the grading system strongly relate to open-water nuisance aspects of a lake (i.e. algal blooms), which can indicate accelerated aging (cultural eutrophication). The Lake Grading System was used for the MSCWMO lakes sampled in 2011. The overall water quality of McKusick Lake has degraded when compared to previous years, receiving a grade of C- for 2011. That is the lowest grade McKusick Lake has received since 1999 when it was a D. Brick Pond data also showed that the water quality degraded in 2011, receiving a grade of C. That is the lowest grade Brick Pond has received since monitoring began in 2008. Lily Lake was not monitored in 2011 and therefore did not receive a grade. Lily Lake received a grade of C+ in 2010, which is a little higher than its average of a C. Summaries of all lake results are presented

in Appendix A. Comparing the Lake Trophic Status and the Lake Grading System shows a fair to good correlation between the two systems.

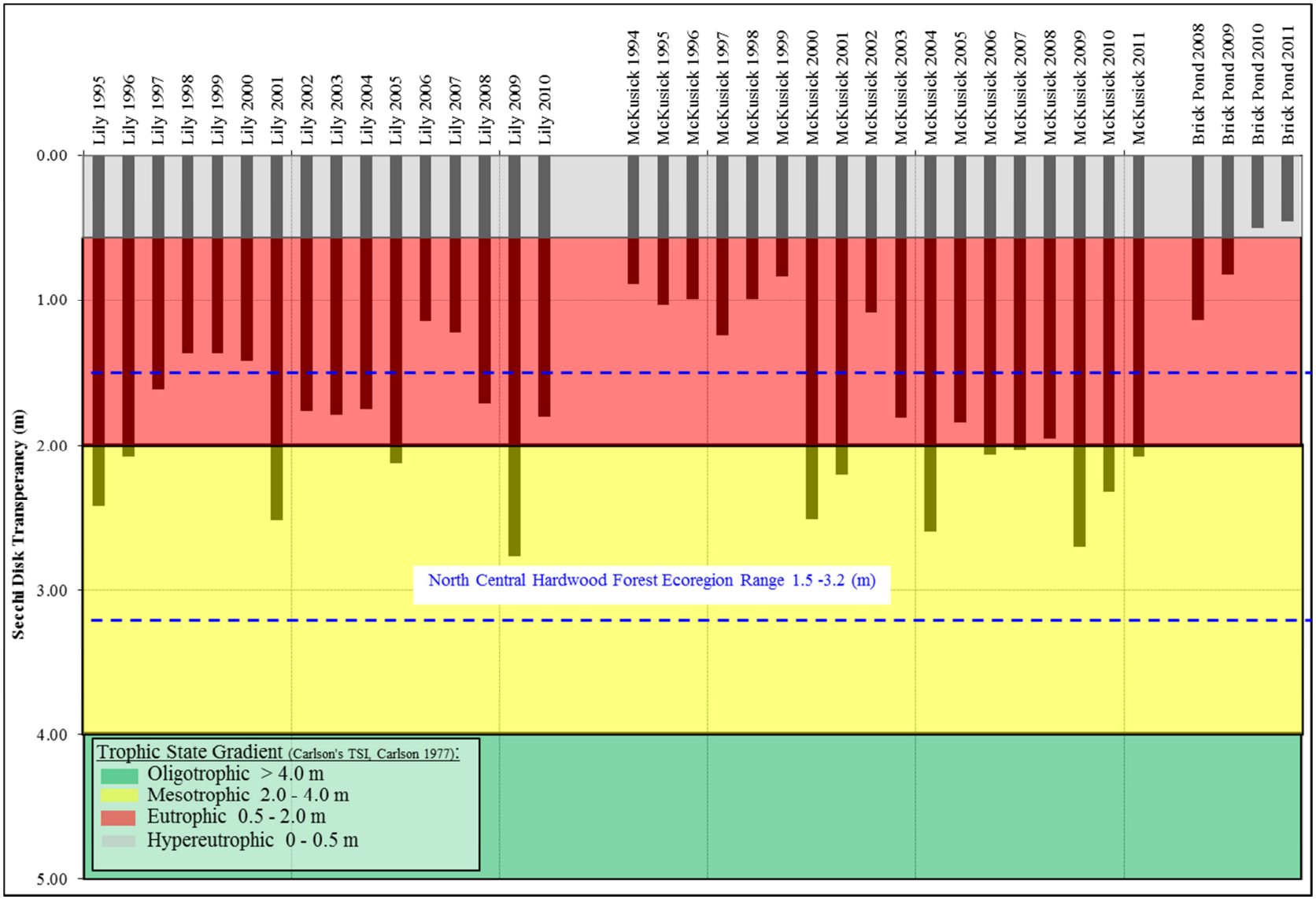

Figure 2. MSCWMO Historic Summer Average Secchi Records

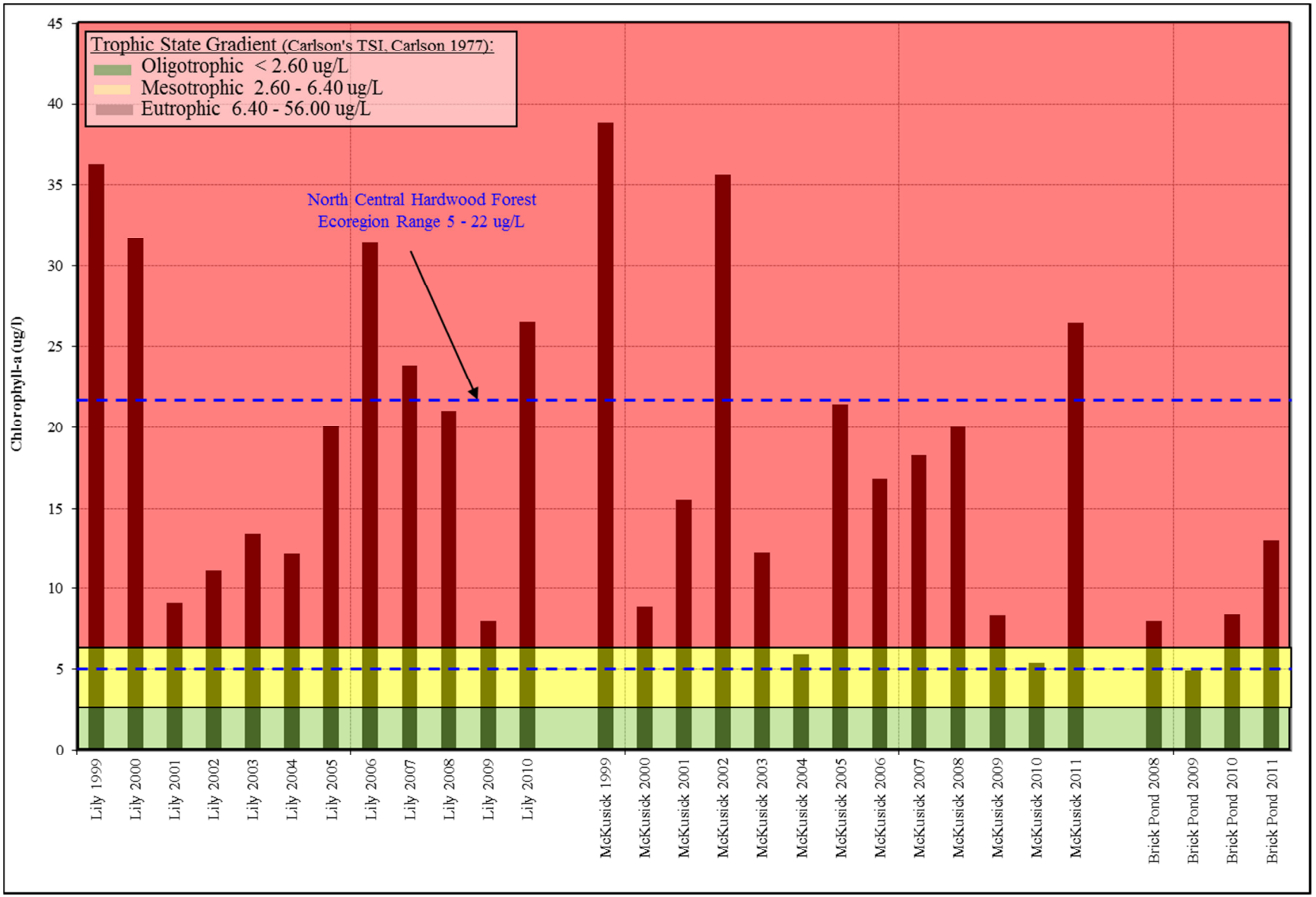

Figure 3. MSCWMO Historic Summer Average Chlorophyll-*a* Data

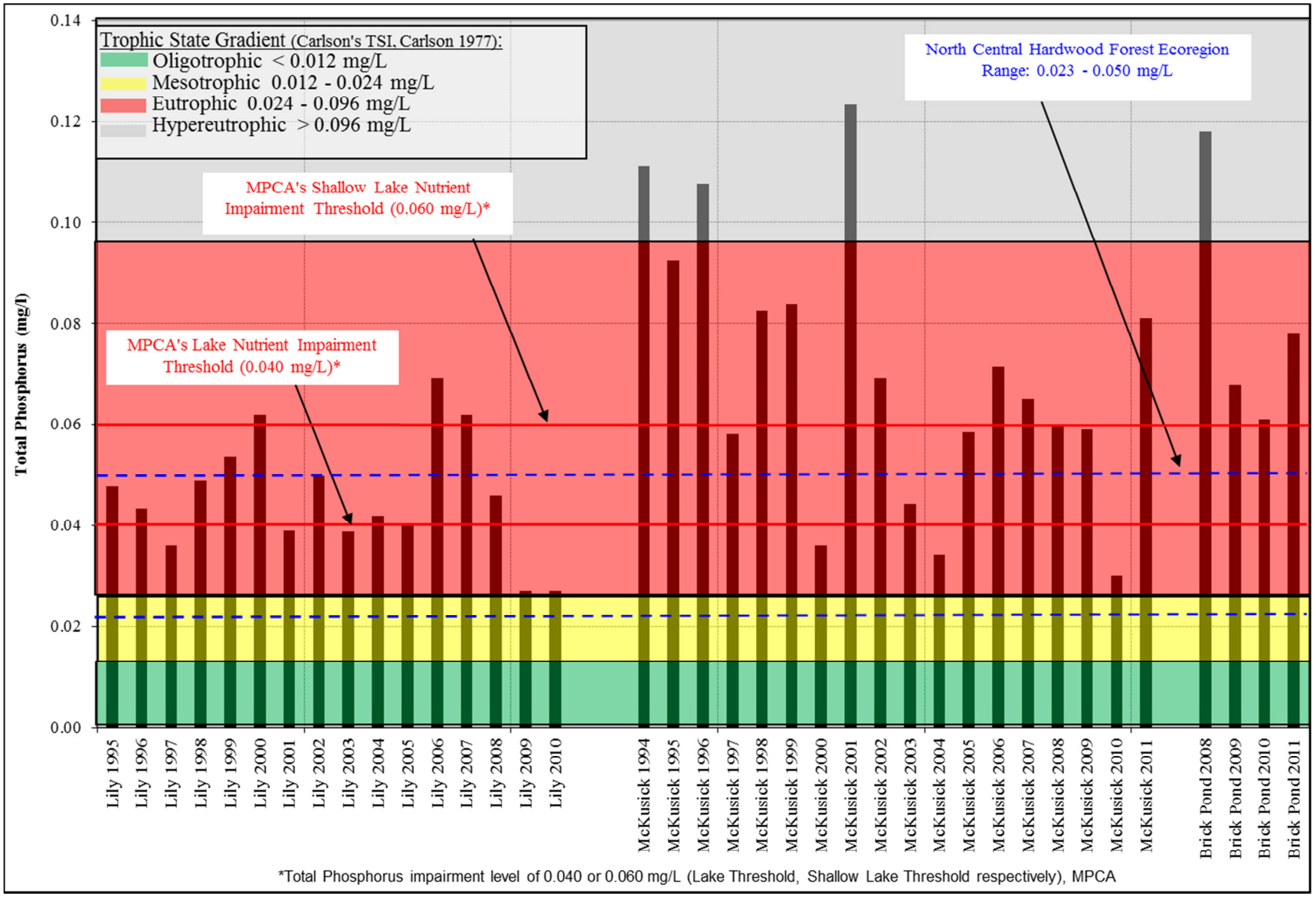

Figure 4. MSCWMO Historic Summer Average Total Phosphorus Data

2. LAKE ELEVATIONS

Lake elevation gages are located on two lakes, Lily and McKusick Lakes, and one wetland, Perro Pond, and are monitored by WCD staff. Complete lake elevation data for 2011 can be found in, Figure 5, Figure 6, and Figure 7.

At the beginning of the monitoring season Lily Lake was below the Ordinary High Water level (OHW)[1] and quickly rebounded, then dipped below the OHW level again in mid-July and again rebounded. In mid-September Lily Lake again fell below the OHW level and this time remained below for the remainder of the monitoring season, reaching its lowest recorded elevation for 2011 on the last reading on October 24th at 844.05 ft. (Figure 5).

The elevation of McKusick Lake remained above the OHW for the entire 2011 monitoring season. McKusick Lake's elevation reached its highest recorded level of 2011 on June 23rd with a level of 855.15 ft. and fell to its lowest recorded level in October, during the last part of the 2011 monitoring season, with an elevation of 853.60 ft. (Figure 6).

Perro Pond does not have an established OHW for comparison purposes. A small dam holds back Perro Pond, which was not open until the beginning of May, keeping the water elevations higher in early spring. On May 3rd, the dam was opened discharging water into Perro Creek, and drawing down Perro Pond. Perro Pond's large elevation increase in July could be attributed to the closure of the outlet structure; however, no records of when this occurs are currently being kept. The lowest recorded elevation for 2011, 744.88 ft., happened towards the end of the monitoring season on October 7th (Figure 7).

[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:

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

All three water bodies reflected significant decreases in elevation towards the end of the 2011 monitoring season, when precipitation was below normal (Figure 8). For historical lake elevations, visit the MN DNR Lake Finder webpage at http://www.dnr.state.mn.us/lakefind/index.html.

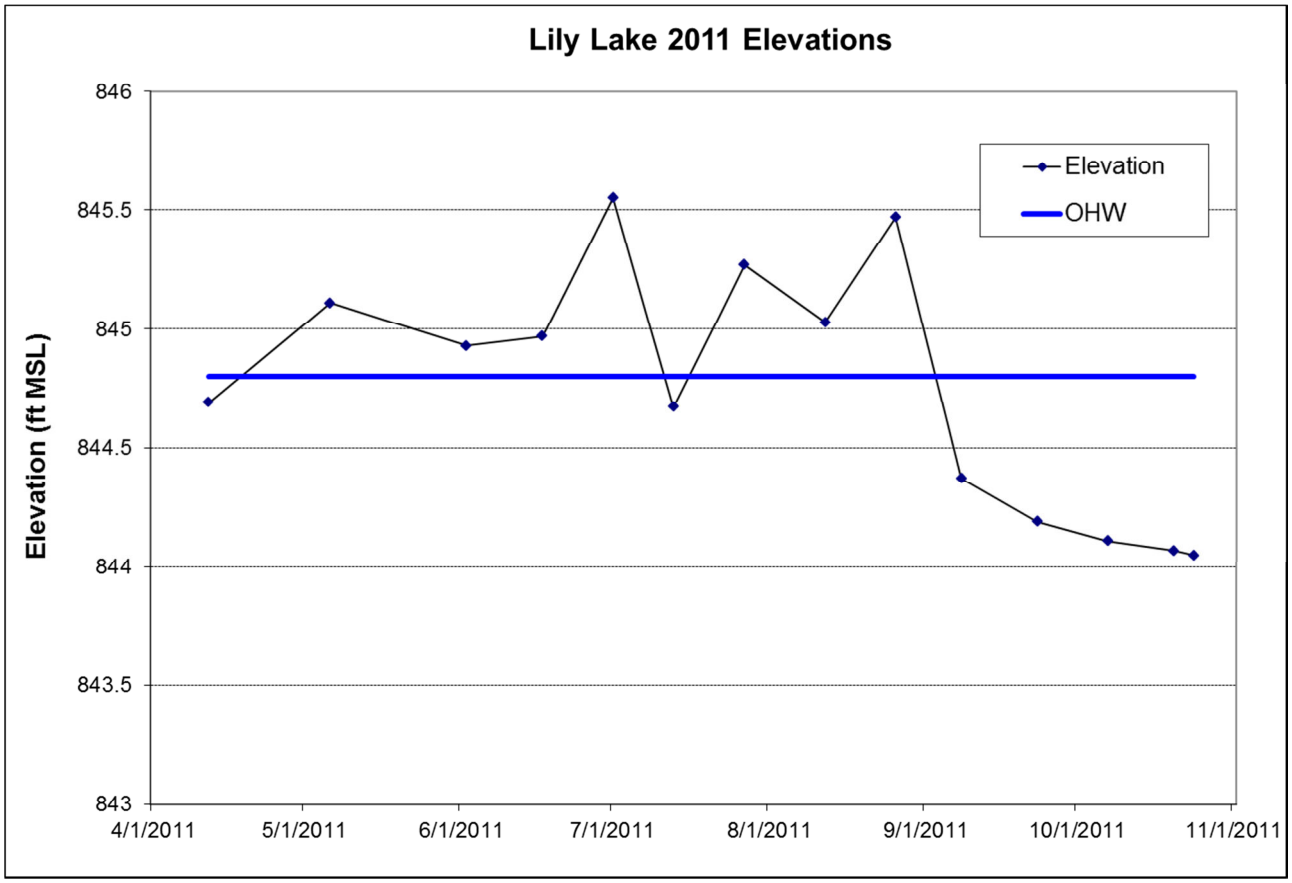

Figure 5 . Lily Lake 2011 Elevations

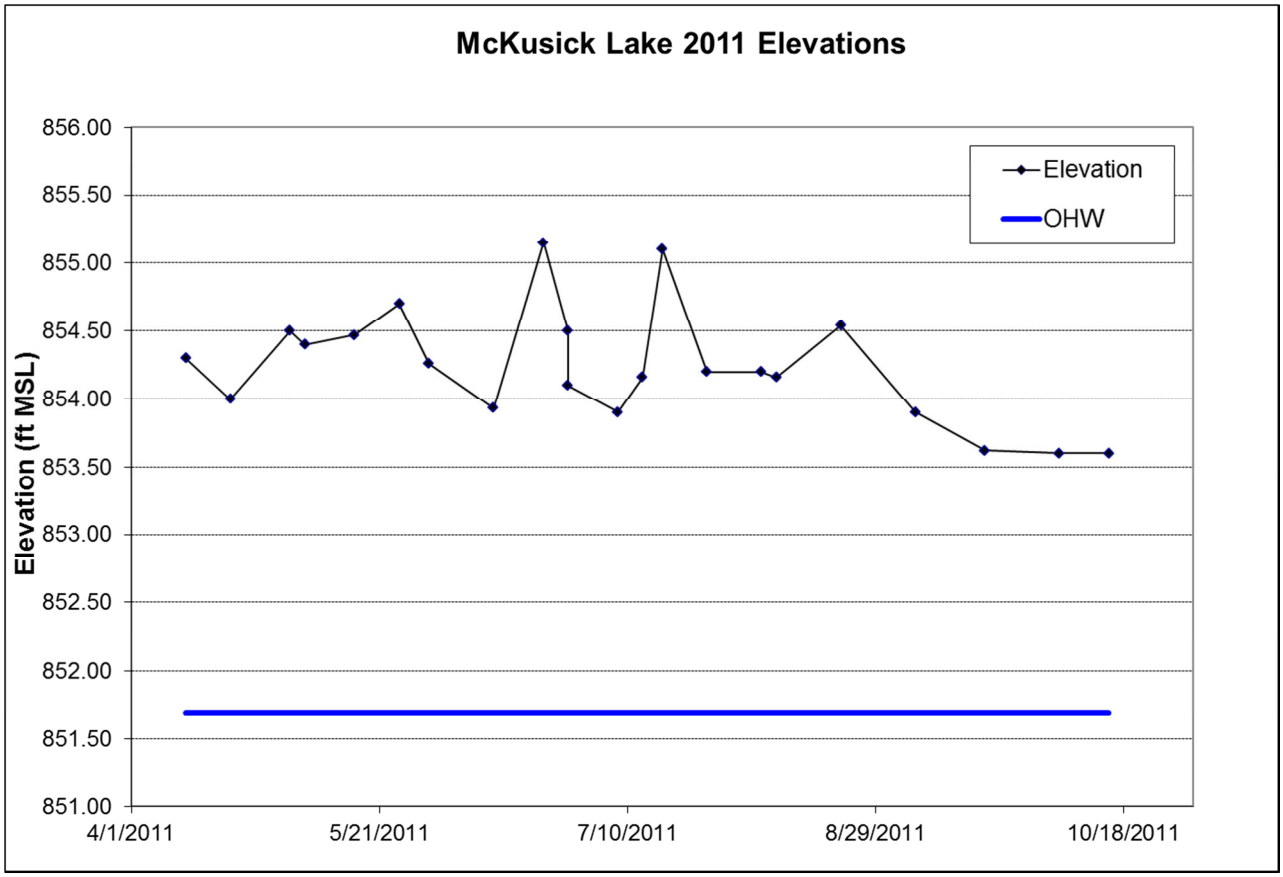

Figure 6. McKusick Lake 2011 Elevations

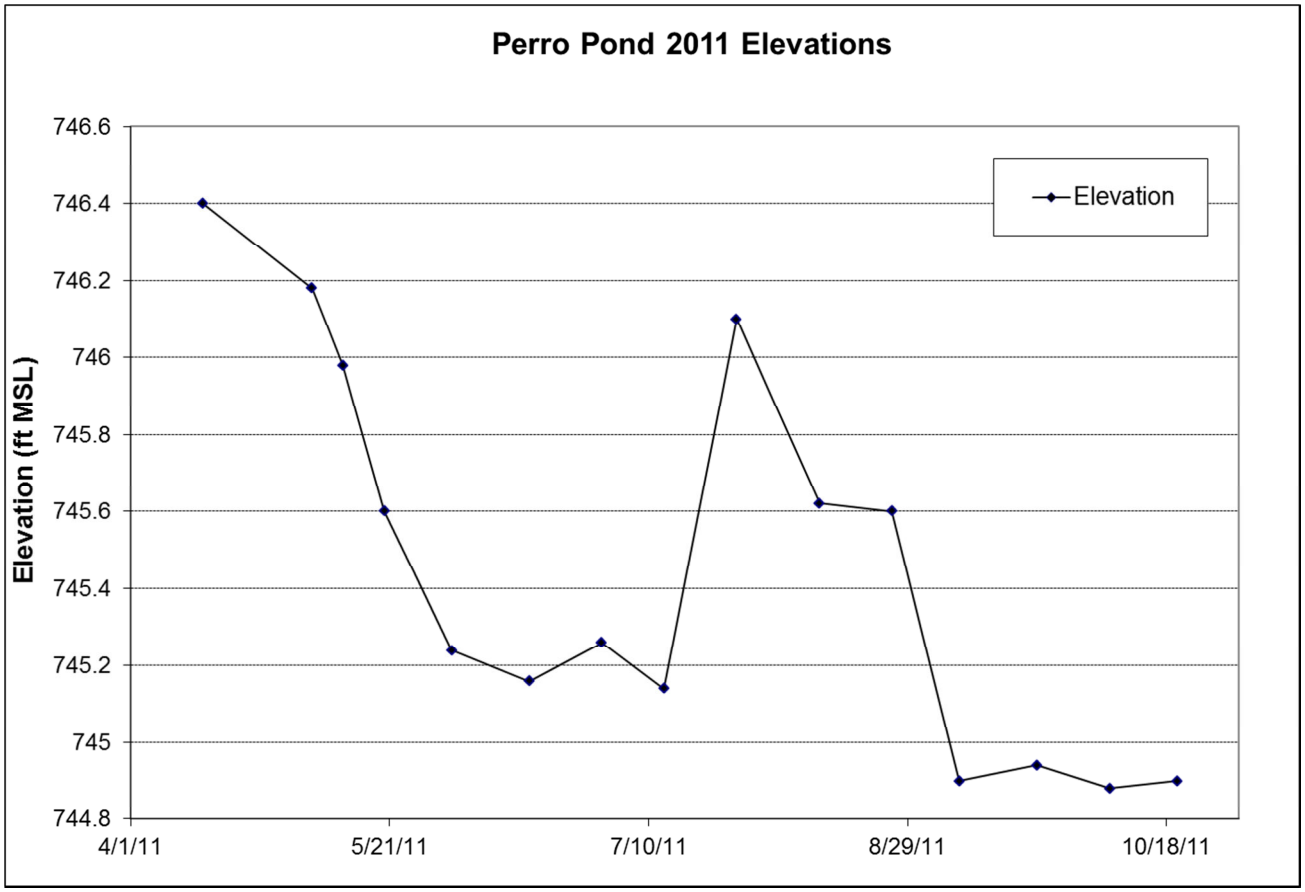

Figure 7. Perro Pond 2011 Elevations

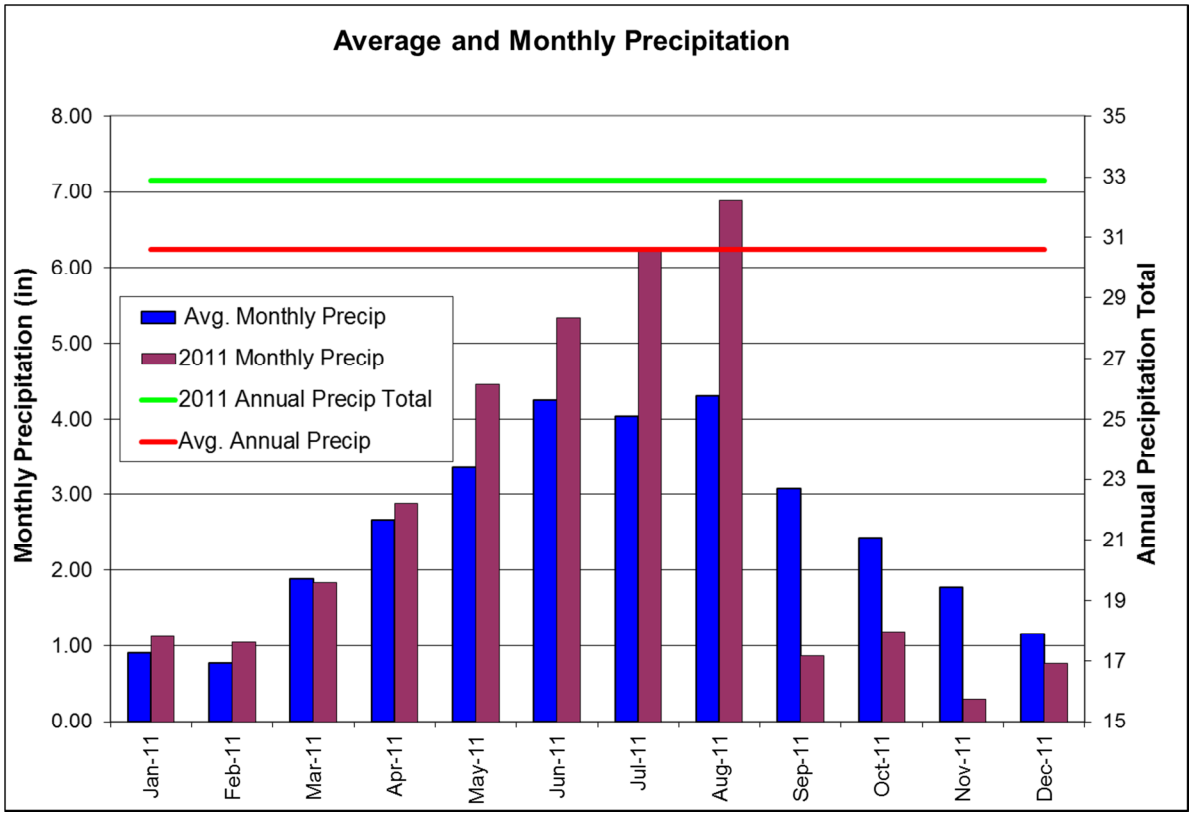

Figure 8. 2011 Annual Precipitation; Historical 30-Year* Average Annual Precipitation; Historical 30-Year* Average Monthly Precipitation; and 2011 Monthly Precipitation

2011 Data from WCD Precipitation Gage T 30N R 20W Sec 32

*Average monthly precipitation totals derived from historical 30-year (1981-2010) average for this region

B. MSCWMO LAKES: CONCLUSIONS AND RECOMMENDATIONS

Lake monitoring in MSCWMO will continue 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 with other lakes in the region.

In 2011 McKusick Lake and Brick Pond had average water quality ratings, with overall water quality grades of C- and a C, respectively. Both were also classified as eutrophic. When compared to historical data, McKusick Lake showed a decline in water quality in 2011, seeing its lowest grade since 1999 when it was a D. Brick Pond received its worst grade since monitoring began in 2008. With only four years of data on Brick Pond it should be noted that no statistically significant trend can be determined about the water quality at this time (whether it is improving or declining as a whole). Lily Lake was not monitored in 2011 and therefore was not assigned a letter grade for 2011.

McKusick Lake was within the NCHFE range only for Secchi disk transparency and was worse than the NCHFE range for TP and chl-*a* in 2011. Eight of the fourteen water quality samples collected from McKusick Lake exceeded the MPCA TP impairment threshold for shallow lakes of 0.06 mg/L. That is up from 2010 when no samples exceeded the threshold, and in 2009 when three exceeded the TP threshold values. Also four of the fourteen water quality samples exceeded the MPCA chl-*a* threshold value of 20 µg/L. DO data is useful in determining excessive production (algae/plants) in a lake. More production means more DO, for a time, but as plants and algae die off they turn from producers of DO into consumers, as they decay. McKusick Lake showed very low DO levels starting in early to mid-July, when daytime high temperatures ranged from 90 – 100 degrees Fahrenheit along with record dewpoints, and lasting until mid to late-September. Surface DO readings ranged from a low of 0.48 mg/L on 7/26/2011 to a high of 4.06 mg/L on 8/22/2011. Readings at a depths of greater than 1 m were lower, often times near zero. The low DO levels are likely due to the decomposition of algae and plants that had overtaken McKusick Lake earlier in the year. With DO levels remaining so low for so long (2 – 3 months) McKusick Lake went anoxic, ultimately resulting in a fish kill. The City of Stillwater completed the Trout Stream Mitigation Project (TSMP) in June 2003 that has been

functioning to divert stormwater from the 1,800-acre annexation area away from Brown's Creek, through McKusick Lake and ultimately to the St. Croix River. This diversion structure is designed to keep the warmer, urban stormwater from the southern tributary of Brown's Creek out of the temperature and nutrient sensitive Brown's Creek Ravine. Local residents' concerns about the amount of water and nutrients entering McKusick Lake are being investigated by the Brown's Creek Watershed District (BCWD) and the City of Stillwater. In 2006 the BCWD initiated stream flow monitoring and water quality sampling on the diversion structure drainage to assist in answering some of the water quality and quantity concerns. All associated data can be found in Figure 10, Table 12, Table 13, Table 14, Table 15 and Table 17. There was a sub-watershed assessment conducted on the McKusick Lake watershed in 2010. In 2011 six raingardens were constructed as a result of the sub-watershed assessment. The earliest the impacts of these raingardens could be seen is 2012, when they will have been on-line for the entire year. For more information on the McKusick Lake sub-watershed assessment see the McKusick Lake Stormwater Retrofit Assessment found at http://mscwmo.org/wp-content/subwatershed/McKUSICK-Assessment-Report-FINAL.pdf

2011 marked the fourth year that Brick Pond was monitored for water quality. TP showed an increase over the values seen in 2009 and 2010, and is still worse than the NCHFE range. Six of seven samples collected in 2011 were above the MPCA's Shallow Lake Nutrient Impairment Threshold of 0.06 mg/L (Figure 4). Chl-*a* showed an increase from 2010, and was the highest summer average concentration seen since monitoring began in 2008. Although it was the highest value seen, Brick Pond was still within the NCHFE range for 2011, and only one of seven samples exceeded the MPCA shallow lake impairment threshold of 20 µg/L (Figure **3**). Secchi disk transparency decreased once again in 2011 and was worse than the NCHFE range, with all measurements exceeding the MPCA shallow lake impairment threshold (Figure 2). It should be noted that it is difficult for transparency results to fall within the NCHFE range due to the shallowness of Brick Pond (the maximum depth of the pond is about 1.52 meters, just over the minimum NCHFE value).

In 2011 Lily Lake was scheduled to have a volunteer collect the water quality samples. Due to unforeseen circumstances, that volunteer was unable collect any water quality samples and

therefore there is no data for Lily Lake in 2011. 2010 data shows that Lily Lake was within the NCHFE range for TP and Secchi disk transparency with only one water quality sample exceeding the MPCA lake threshold for Secchi disk transparency impairment. Lily Lake exceeded the NCHFE range for chl-*a* in 2010, with three water quality samples exceeding the MPCA lake threshold for chl-*a* impairment. Summertime (June-September) Secchi disk transparency, TP, and chl-*a* averages have remained relatively consistent over the last ten years in Lily Lake with the exceptions of 2001 and 2009 where overall water quality dramatically improved for one year each time (Figure 2, Figure 3, Figure 4). In 2001 chl-*a* levels and the lake grade improved significantly and may indicate when a copper sulfate treatment began in Lily Lake. In 2006 and 2007, summer average TP, chl-*a*, and Secchi disk transparency all deteriorated when compared to the averages seen in 2001 to 2005. In 2009 Lily Lake improved over all previously recorded years and received a B+ lake grade, with 2010 sample results showing that Lily Lake returned back to the long term normal. The cause of these one-year increases (2009, 2001, and 1995) in water quality is presently unknown, and there could be many possible explanations which could be investigated further in the future. The summer average grade for chl-*a* should be interpreted with caution, as one of the sample values was undeterminable due to a recording error. Lake water quality management measures known to WCD staff are copper sulfate treatments, but the dates of those treatments are unknown, and the completion of a native buffer planting at the public access in mid-2010. The Lily Lake watershed underwent a sub-watershed assessment, which was conducted in 2010. In 2011 fifteen raingardens were constructed in the Lily Lake watershed as a result from the sub-watershed assessment. There are more raingardens planned for completion in 2012. The earliest the effects of these raingardens could be seen is the 2012 monitoring season, when the raingardens will have been on-line for the entire year. For more information about the Lily Lake sub-watershed assessment see the Lily Lake Stormwater Retrofit Assessment found on at http://mscwmo.org/wp-content/subwatershed/LILY-Assessment-Report-FINAL.pdf

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 the shallowness of the lake (McKusick Lake and Brick

Pond) or from long-term periods of urban runoff (Lily Lake). Shallow lakes typically will exist in a low algal production, clear-water state or a high-algal production, turbid water state, but not in between the two states. Shallow lakes may not completely stratify in the summer, such as Brick Pond; therefore, they have the capability to continually mix. That mixing causes TP to be distributed throughout the water column, causing more frequent and heavy algal blooms. This is unlike deeper, stratified lakes where TP below the thermocline is not available for primary production.

The MPCA has listed both Lily and McKusick Lake on the 303d impaired waters list for nutrient/eutrophication impairment, with McKusick Lake being considered for delisting from the 303d impaired waters list in 2012. If a water body is listed, it indicates that it is not currently meeting 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 lakes TMDL for Long Lake, Lily Lake, and McKusick Lake in 2010, but because of improving water quality trends in those lakes over recent years, the MPCA, along with the MSCWMO, BCWD, and City of Stillwater decided to postpone the TMDL. The MSCWMO, BCWD, and the City will utilize the City's exiting Lake Management Plan as well as the recently completed subwatershed assessments to guide project implementation in an effort to continue to improve the lakes water quality. The MPCA will consider the need for a TMDL again in the near future.

There were two lakes and one wetland monitored for water elevation from April to October 2011 (Figure 5, Figure 6, Figure 7). The highest recorded elevations in 2011 occurred around mid-summer for each water body. McKusick Lake recorded a high elevation of 855.15 ft. on June 23rd, and peaked again on July 17th with an elevation of 855.10 ft. The level of Lily Lake looked similar with a high reading of 845.55 ft. on July 1st and a second peak of 845.47 ft. on August 26th. Elevations on Perro Pond do not respond the same as the other two lakes because it is less dependent on precipitation and more dependent on the opening of a small dam that can allow water to discharge into Perro Creek. This dam was not opened until May 3rd of 2011, keeping the elevation of Perro Pond high up to that date. The high elevation for Perro Pond was 746.4 ft.

recorded on April 15th, with a second peak coming on July 27th with an elevation of 746.1 ft. The second peak could have been caused by precipitation, as well as the closing of the dam in the middle of the summer. Changes in lake/wetland elevation are attributed to the changes in monthly precipitation. As shown in Figure 8, precipitation was normal to above normal from January through August. Precipitation during the winter months of 2010 were also high, adding to a 2010 – 2011 extreme winter snowpack. Runoff from that snowmelt kept MSCWMO lakes higher than normal for the first part of the year. From September until the end of the year precipitation was well below normal and all MSCWMO lake/wetland elevations dropped during that time period. The low elevation on McKusick Lake was recorded on October 5th and October 17th with an elevation of 853.60 ft., and Lily Lake was at 844.05 ft. on October 24th. The low elevation recorded on Perro Pond was 744.88 ft. and that occurred on October 7th. Total annual precipitation for 2011 was 32.9 inches, with the majority of that occurring in the first half of the year. That is only 2.29 inches above the 30 year (1981-2010) historical annual average of 30.61 inches. It is recommended that water level monitoring of MSCWMO lakes and wetland continue.

STREAM MONITORING

A. METHODS, RESULTS, AND DISCUSSION

Perro Creek flows 1.8 miles from its source, Perro Pond, through an urban landscape and outlets into the St. Croix River. In the upper reach, much of the creek flows through the residential backyards of Bayport, MN. The lower reach of the creek has been substantially channelized through the use of pipes and concrete structures. The lower reach also flows through a more urban, industrial environment where it is prone to more runoff from the surrounding area.

The Myrtle Street monitoring site is located between Bayberry Avenue and Deer Path, on the south side of Myrtle Street in Stillwater, MN. It receives water from the urban area and wetland on the south side of Myrtle Street, and ultimately from Lily Lake. The purpose of this site is to quantify the loading to the Jaycee's Ballfield wetland from this southern area.

The Meadowlark Drive site is located downstream from the Myrtle Street site and the Jaycee's Ballfield wetland, where the tributary crosses the walking path extending from Meadowlark Drive on the southern side of McKusick Lake. The purpose of this site is monitored to quantify any additional loading that is entering into McKusick Lake from the Jaycee's Ballfield wetland.

Data from the Brown's Creek Diversion Structure is also included in this report for an evaluation of TP loading to McKusick Lake. Continued efforts at this location will allow for evaluation of water quality impacts to McKusick Lake. To eliminate confusion between watershed boundaries and political ownership, Perro Creek, Meadowlark Drive, and Myrtle Street are the only stream monitoring sites referenced as being within the MSCWMO.

A list of the WCD standard operating procedures can be found at http://www.mnwcd.org/water_monitoring_standards.php .

1. PERRO CREEK

In 2011, the WCD collected base flow grab samples, automated flow-weighted storm composite samples and duplicate samples according to WCD Standard Operating Procedures (SOP) over the course of the monitoring season at the Perro Creek site. An automated sampler, located about 1 mile upstream of the St. Croix River, (Figure 1) continuously monitored stream flow discharge and collected the event flow composite samples from April 5, 2011 until October 31, 2011. Data collected at this site by the WCD included total discharge, precipitation, and water quality analysis. All stream flow and chemistry data from 2011 can be found in Figure 9, Table 4, Table 5, Table 6, Table 7, and Table 8. Total flow during the 2011 monitoring season for Perro Creek was 24,764,482 cf, and total precipitation was 22.49 inches compared to 26.36 inches in 2010. Peak 15 minute average discharge for this site was 19.41 cubic feet per second (cfs), which occurred on July 16th. The highest values for TP, TSS, VSS and TKN were all from a composite sample collected from a large storm event on August 13th, with values of 0.312 mg/L for TP, 9,030 mg/L for TSS, 172 mg/L for VSS, and 1.3 mg/L for TKN. Of the eight samples collected throughout the year, all three storm event samples collected exceeded the water quality standard for turbidity.

The 2011 TP and TSS data were used to calculate the total load discharged to the St. Croix River from Perro Creek. In 2011, Perro Creek discharged an estimated load of 82 lbs of TP (a decrease of 97 lbs from 2010) and an estimated load of 379,634 lbs of TSS to the St. Croix River (Table 16). One cause for the high TSS loading in 2011 may have been due to the extreme precipitation observed. Thirteen storm events were identified in 2011, sampling only three, while in 2010 there were thirty two identified storm events with nine of them being sampled. Each of the three sampled storm events had very high TSS concentrations, which greatly increases the average storm event concentration. That average storm event concentration is used to estimate all storm event flows throughout the year, which would increase the total yearly estimated TSS load. Another possible cause for the load increase over the past five years could be the further degradation of the up-stream channel. At the location of the monitoring station, the banks have steadily degraded over the past four monitoring seasons, with large sections of bank sloughing

into the channel. It is likely that this degradation is also occurring along the entirety of the channel, and would certainly contribute to the increase in the TSS loading that has been observed.

Escherichia coli (E. coli) is a bacteria that can be characterized by its ability to grow at elevated temperatures. Perro Creek is impaired for *E. coli*, and data have shown numerous samples where values were above what the MPCA has set as a water quality standard. The following is the description for the *E. coli* standard:

> "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"[2].

Perro Creek exceeds this standard for the months of June, July, August, and September, where the geometric mean of at least five samples taken in these months exceeds the value of 126 #/100 mL. In 2011 there were five *E. coli* samples collected at the Perro Creek site. Of those five, four of them exceeded the water quality standard for *E. coli* (Table 4). Continued monitoring of *E. Coli* at this site will continue to help in determining if Perro Creek continues to exceed the water quality standards during the summer months.

[2] MPCA water quality standards for class 2B waters can be found at https://www.revisor.leg.state.mn.us/rules/?id=7050.0222

Table 4. Perro Creek *E. coli* Monthly Geometric Mean

Site	May	June	July	August	September	October
Monthly Geometric Mean	Insufficient Data	212.07	230.48	411.81	185.99	Insufficient Data
6/14/06 11:10		150				
7/25/06 8:45			249			
8/10/06 9:12				318		
9/6/06 9:50					291	
9/10/06 10:20					252	
5/2/07 12:00	276					
6/13/07 10:14		185				
7/16/07 9:51			488			
8/28/07 8:04				1986		
10/18/07 12:15						114
6/5/08 10:18		276				
6/26/08 9:43		153				
7/17/08 8:30			194			
8/27/08 10:20				1553		
7/29/2009 9:30			261			
8/27/2009 10:25				1120		
9/30/2009 8:50					163	
5/25/2010 9:00	99					
6/24/2010 9:15		225				
7/28/2010 11:25			93			
8/26/2010 9:49				111		
9/30/2010 9:51					95	
6/9/2011 10:24		345				
7/7/2011 8:32			262			
8/11/2011 8:53				40		
9/8/2011 8:07					196	
10/5/2011 9:03						133

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

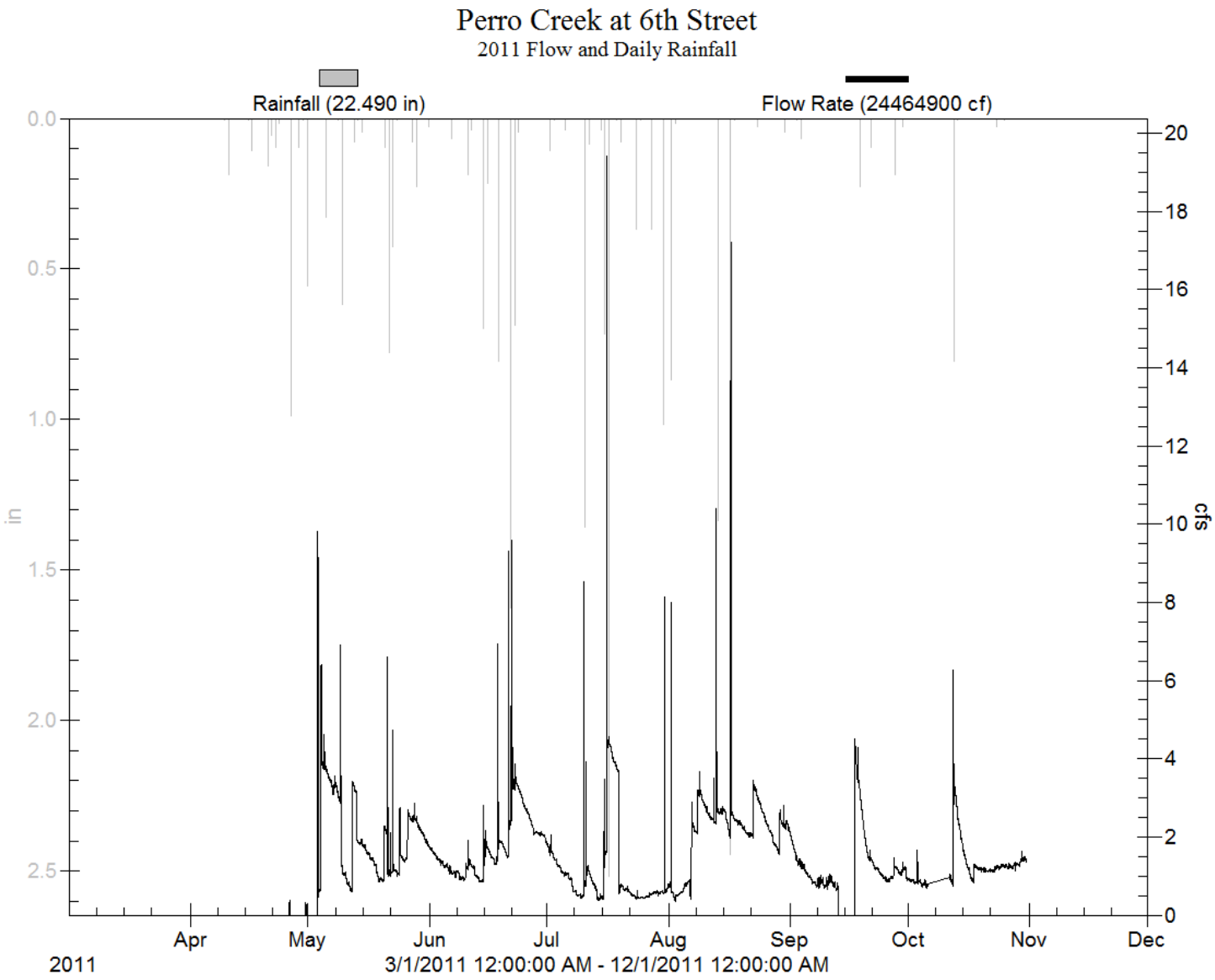

Figure 9. Perro Creek 2011 Discharge and Daily Rainfall

Table 5. Perro Creek 2011 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)
Intermittent flow			*3*	*0.037*	*1/1/2011 0:00*	*5/3/2011 12:00*	*9,966*	*0.23*	*2*	*0.02*
Base			*3*	*0.037*	*5/3/2011 12:00*	*5/9/2011 6:45*	*1,599,262*	*36.71*	*300*	*3.69*
Storm			*6260*	*0.260*	*5/9/2011 6:45*	*5/9/2011 9:30*	*41,823*	*0.96*	*16,344*	*0.68*
Base			*3*	*0.037*	*5/9/2011 9:30*	*5/21/2011 4:45*	*1,547,060*	*35.52*	*290*	*3.57*
Storm			*6260*	*0.260*	*5/21/2011 4:45*	*5/21/2011 7:15*	*30,804*	*0.71*	*12,038*	*0.50*
Base			*3*	*0.037*	*5/21/2011 7:15*	*5/22/2011 11:30*	*115,776*	*2.66*	*22*	*0.27*
Storm			*6260*	*0.260*	*5/22/2011 11:30*	*5/22/2011 12:45*	*11,408*	*0.26*	*4,458*	*0.19*
Base			*3*	*0.037*	*5/22/2011 12:45*	*5/25/2011 0:00*	*274,862*	*6.31*	*51*	*0.63*
Base Grab	5/25/11 9:33	5/25/11 9:33	3	0.041	5/25/2011 0:00	5/26/2011 0:00	122,282	2.81	23	0.31
Base			*3*	*0.037*	*5/26/2011 0:00*	*6/14/2011 18:15*	*2,556,131*	*58.68*	*479*	*5.90*
Storm			*6260*	*0.260*	*6/14/2011 18:15*	*6/14/2011 22:45*	*14,867*	*0.34*	*5,810*	*0.24*
Base			*3*	*0.037*	*6/14/2011 22:45*	*6/18/2011 6:00*	*448,198*	*10.29*	*84*	*1.04*
Storm			*6260*	*0.260*	*6/18/2011 6:00*	*6/18/2011 8:45*	*32,778*	*0.75*	*12,809*	*0.53*
Base			*3*	*0.037*	*6/18/2011 8:45*	*6/21/2011 3:30*	*417,615*	*9.59*	*78*	*0.96*
Storm Composite	6/21/11 4:15	6/22/11 4:57	1500	0.209	6/21/2011 3:30	6/22/2011 5:30	297,624	6.83	27,869	3.88
Base			*3*	*0.037*	*6/22/2011 5:30*	*6/30/2011 0:00*	*1,776,085*	*40.77*	*333*	*4.10*
Base Grab	6/30/11 10:55	6/30/11 10:55	4	0.029	6/30/2011 0:00	7/1/2011 0:00	168,103	3.86	42	0.30
Base			*3*	*0.037*	*7/1/2011 0:00*	*7/10/2011 6:00*	*837,656*	*19.23*	*157*	*1.93*
Storm			*6260*	*0.260*	*7/10/2011 6:00*	*7/10/2011 7:00*	*19,886*	*0.46*	*7,771*	*0.32*
Base			*3*	*0.037*	*7/10/2011 7:00*	*7/16/2011 5:30*	*446,905*	*10.26*	*84*	*1.03*
Storm Composite	7/16/11 5:57	7/16/11 10:57	8250	0.260	7/16/2011 5:30	7/16/2011 11:30	164,910	3.79	84,931	2.68
Base			*3*	*0.037*	*7/16/2011 11:30*	*7/30/2011 22:30*	*1,551,611*	*35.62*	*291*	*3.58*
Storm			*6260*	*0.260*	*7/30/2011 22:30*	*7/30/2011 23:45*	*17,827*	*0.41*	*6,967*	*0.29*
Base			*3*	*0.037*	*7/30/2011 23:45*	*8/1/2011 14:00*	*94,899*	*2.18*	*18*	*0.22*
Storm			*6260*	*0.260*	*8/1/2011 14:00*	*8/1/2011 18:45*	*35,375*	*0.81*	*13,824*	*0.57*
Base			*3*	*0.037*	*8/1/2011 18:45*	*8/13/2011 3:15*	*1,702,171*	*39.08*	*319*	*3.93*
Storm			*6260*	*0.260*	*8/13/2011 3:15*	*8/13/2011 6:15*	*59,493*	*1.37*	*23,249*	*0.97*
Base			*3*	*0.037*	*8/13/2011 6:15*	*8/16/2011 19:15*	*770,194*	*17.68*	*144*	*1.78*
Storm Composite	8/16/11 19:40	8/16/11 21:39	9030	0.312	8/16/2011 19:15	8/16/2011 22:00	104,160	2.39	58,716	2.03
Base			*3*	*0.037*	*8/16/2011 22:00*	*8/24/2011 0:00*	*1,490,640*	*34.22*	*279*	*3.44*
Base Grab	8/24/11 15:02	8/24/11 15:02	6	0.074	8/24/2011 0:00	8/25/2011 0:00	241,082	5.53	90	1.11
Base			*3*	*0.037*	*8/25/2011 0:00*	*9/21/2011 0:00*	*3,293,606*	*75.61*	*617*	*7.61*
Base Grab	9/21/11 9:37	9/21/11 9:37	1	0.022	9/21/2011 0:00	9/22/2011 0:00	123,468	2.83	8	0.17
Base			*3*	*0.037*	*9/22/2011 0:00*	*10/6/2011 1:15*	*1,208,456*	*27.74*	*226*	*2.79*
*Base**			*3*	*0.037*	*10/6/2011 1:15*	*10/11/2011 14:15*	*764,004*	*17.54*	*143*	*1.76*
Base			*3*	*0.037*	*10/11/2011 14:15*	*10/12/2011 13:15*	*74,801*	*1.72*	*14*	*0.17*
Storm			*6260*	*0.260*	*10/12/2011 13:15*	*10/13/2011 11:30*	*254,840*	*5.85*	*99,588*	*4.14*
Base			*3*	*0.037*	*10/13/2011 11:30*	*10/20/2011 0:00*	*817,647*	*18.77*	*153*	*1.89*
Base Grab	10/20/11 10:35	10/20/11 10:35	2	0.020	10/20/2011 0:00	10/21/2011 0:00	100,004	2.30	12	0.12
Base			*3*	*0.037*	*10/21/2011 0:00*	*10/31/2011 9:00*	*1,126,203*	*25.85*	*211*	*2.60*
*Base**			*3*	*0.037*	*10/31/2011 9:00*	*12/1/2011 0:00*	*4,222,128*	*96.93*	*791*	*9.75*
No Flow			*0*	*0.000*	*12/1/2011 0:00*	*1/1/2012 0:00*	*0*	*0.00*	*0*	*0.00*
Storm Average			6260	0.260						
Base Average			3	0.037						
All Average			2350	0.121						
Total							**28,986,610**	**665**	**379,634**	**82**
Perro Creek Major Subwatershed Total Acres							1,063			
Total TSS/TP (lb/ac/yr)									357.29	0.08
Total TSS/TP (kg/ha/yr)									400.47	0.09

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

*Interval volume from 10/06/2011 01:15 to 10/11/2011 14:15 and 10/31/11 to 12/1/11 were estimated based upon baseflow conditions.

Table 6. Perro Creek 2011 Water Quality Chemistry 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)	Nitrite N (mg/L)	Nitrate N (mg/L)	Ammonia Nitrogen (mg/L)
Base Grab	5/25/2011 9:33	5/25/2011 9:33	3	~2	0.41	~0.041	<0.010		<0.03	0.09	<0.02
Base Grab	6/30/2011 10:55	6/30/2011 10:55	4	~2	0.32	~0.029	~0.030		<0.03	<0.05	<0.02
Base Grab	8/24/2011 15:02	8/24/2011 15:02	6	3	0.38	0.074	~0.022		0.03	0.15	0.09
Base Grab	9/21/2011 9:37	9/21/2011 9:37	~1	~1	0.36	~0.022	~0.021		<0.03	23.00	~0.04
Base Grab	10/20/2011 10:35	10/20/2011 10:35	~2	~1	0.23	~0.020	<0.010		<0.03	0.39	<0.02
Storm Composite	6/21/2011 4:15	6/22/2011 4:57	1500	~56	1.20	0.209	~0.021		<0.03	0.13	~0.03
Storm Composite	7/16/2011 5:57	7/16/2011 10:57	8250	133	1.30	0.260	~0.047		<0.03	0.18	~0.03
Storm Composite	8/16/2011 19:40	8/16/2011 21:39	9030	172	1.30	0.312	0.052		<0.03	0.18	0.13
E. Coli Grab	6/9/2011 10:24	6/9/2011 10:24						345			
E. Coli Grab	7/7/2011 8:32	7/7/2011 8:32						262			
E. Coli Grab	8/11/2011 8:53	8/11/2011 8:53						40			
E. Coli Grab	9/8/2011 8:07	9/8/2011 8:07						196			
E. Coli Grab	10/5/2011 9:03	10/5/2011 9:03						133			

Water Quality Standard Exceedance

Exceeds Water Quality Standard for Turbidity (TSS value used to calculate)

Table 7. Perro Creek 2011 Sample Metal Chemistry Results

Sample Type	Start Date	End Date	Copper (mg/L)	Lead (mg/L)	Nickel (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Hardness (mg/L_CaCO3)
Base Grab	5/25/2011 9:33	5/25/2011 9:33	~0.00052	~0.00036	~0.00034	~0.0011	<0.00020	0.00044	174
Base Grab	6/30/2011 10:55	6/30/2011 10:55	<0.00030	~0.00032	<0.00030	~0.0013	<0.00020	0.00032	190
Base Grab	8/24/2011 15:02	8/24/2011 15:02	~0.00041	~0.00023	<0.00030	0.0188	<0.00020	0.00027	178
Base Grab	9/21/2011 9:37	9/21/2011 9:37	<0.00030	<0.00010	<0.00030	~0.0009	<0.00020	0.00020	226
Base Grab	10/20/2011 10:35	10/20/2011 10:35	<0.00100	~0.00011	<0.00100	0.0016	<0.00020	0.00027	234
Storm Composite	6/21/2011 4:15	6/22/2011 4:57	0.00730	0.01420	0.00310	0.0293	<0.00020	0.00460	80
Storm Composite	7/16/2011 5:57	7/16/2011 10:57	0.02030	0.03760	0.00960	0.0833	0.00052	0.01010	80
Storm Composite	8/16/2011 19:40	8/16/2011 21:39	0.00690	0.01580	0.00310	0.0254	<0.00020	0.00470	66

Exceeds Chronic Standard

Exceeds Max Standard

Exceeds Final Acute Standard

Table 8. Perro Creek 2011 Field Measurement Results

Date	Transparency (cm)	Water Temperature (C)	Dissolved Oxygen (mg/L)	Conductivity (umhos/cm)	pH
5/23/2011 9:34	>100	18.4	9.08	358	7.8
5/25/2011 9:33	>120	17.7	10.22	361	8.3
6/7/2011 10:51	>120	26.8	6.85	458	7.9
6/9/2011 10:24	>120	21.0	8.88	340	8.2
6/13/2011 15:15	>120	19.1	9.53	3.84	8.1
6/30/2011 10:55	>120	24.3	8.12	332	8.1
8/24/2011 15:02	>120	23.8	6.79	362	7.7
9/1/2011 14:28	>120				
9/21/2011 9:37	>120	15.3	8.83	449	7.9
10/20/2011 10:35	>120	7.3	11.51	487	8.1

2. MYRTLE STREET AND MEADOWLARK DRIVE

To identify possible sources of nutrient loading entering McKusick Lake, the WCD monitored the tributary on the south end of the lake at Meadowlark Drive and at Myrtle Street through grab samples collected during or directly following storm events. Results from this monitoring in 2011 can be found in Table 9 and Table 10. This tributary drains the area south of McKusick Lake and includes the outlet of Lily Lake, wetlands, and residential areas.

Table 10 shows the difference in results at the Meadowlark Drive site (downstream location) compared to those collected at the Myrtle Street site (upstream location), in order to determine what nutrient concentrations are increasing or decreasing as a result of runoff into this tributary between these sites. All TSS, VSS, TKN, and TP sample results show a decrease from the Myrtle Street to the Meadowlark Drive site, while discharge generally increased between these locations. In other words, the concentrations are decreasing as the water moves downstream. This is likely due to the Jaycee's Ballfield wetland complex, located between the two sampling sites, filtering out and treating many of the pollutants going through it. Comparing 2011 TP and TSS loads to historical data is difficult, as the Myrtle Street and Meadowlark Drive sites were only sampled three times in 2011, and one sample was taken without a discharge measurement. The 2009 and 2010 data show a similar trend that was observed in 2011, where the results of the majority of the samples taken at the Myrtle Street site are greater than the samples collected from the Meadowlark Drive site (Table 11).

Table 9. Myrtle Street and Meadowlark Drive 2011 Sample Chemistry Results

Site	Date	Sample Type	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Flow (cfs)	TP lbs/day*	TSS lbs/day*
Myrtle St.	4/26/11 10:20	Storm Grab	27	~9	1.3	0.282	NA	**NA**	**NA**
Myrtle St.	6/22/11 8:30	Storm Grab	~3	~2	0.71	0.075	3.17	**1.28**	**51.26**
Myrtle St.	8/17/11 12:09	Storm Grab	9	~6	0.76	0.082	2.20	**0.97**	**106.76**
Meadowlark Dr.	4/26/11 10:30	Storm Grab	~2	~1	0.51	0.056	NA	**NA**	**NA**
Meadowlark Dr.	6/22/11 8:50	Storm Grab	~1	~1	0.68	0.068	1.94	**0.71**	**10.48**
Meadowlark Dr.	8/17/11 11:20	Storm Grab	~4	~3	0.65	0.054	2.29	**0.67**	**49.48**

Table 10. Myrtle Street and Meadowlark Drive 2011 Sample Comparison

Site	Date	Sample Type	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Flow (cfs)	TP lbs/day*	TSS lbs/day*
Meadowlark Dr.	April 26, 2011	Storm Grab	(25)	(8)	(0.79)	(0.226)	NA	**NA**	**NA**
Meadowlark Dr.	June 22, 2011	Storm Grab	(2)	(1)	(0.03)	(0.007)	(1.22550)	**(0.57)**	**(40.79)**
Meadowlark Dr.	August 17, 2011	Storm Grab	(5)	(3)	(0.11)	(0.028)	0.09400	**(0.30)**	**(57.28)**
* Loadings are based on instantaneous flow measurement and values should be used with caution									
(Values in parentheses equate to a decrease in values from Myrtle to Meadowlark)									
Values in red equate to an increased value from Myrtle to Meadowlark									

Table 11. Myrtle Street and Meadowlark Drive Historic Sample Chemistry Results

Site	Date	Sample Type	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Flow (cfs)	TP lbs/day*	TSS lbs/day*
Myrtle St.	3/18/09 14:15	Snowmelt Grab	7	5	3.10	0.326	0.34	**0.59**	**12.68**
Myrtle St.	7/24/09 12:24	Storm Grab	16	3	7.70	0.230	0.11	**0.13**	**9.21**
Myrtle St.	8/20/09 8:18	Storm Grab	4	2	0.92	0.264	0.76	**1.08**	**16.40**
Myrtle St.	10/2/09 9:32	Storm Grab	2	1	0.47	0.038	0.9	**0.19**	**9.76**
Myrtle St.	10/7/09 9:00	Storm Grab	1	1	0.74	0.117	N/A	**N/A**	**N/A**
Myrtle St.	3/12/10 12:00	Snowmelt Grab	13	6	1.90	0.210	0.49	**0.56**	**34.47**
Myrtle St.	5/11/10 13:50	Storm Grab	19	~5	0.96	0.186	0.24	**0.24**	**24.85**
Myrtle St.	5/26/10 10:12	Storm Grab	16	~8	0.90	0.249	0.22	**0.30**	**19.35**
Myrtle St.	6/11/10 9:52	Storm Grab	7	3	0.75	0.084	3.33	**1.51**	**125.74**
Myrtle St.	8/2/10 10:46	Storm Grab	~5	~6	1.20	0.166	0.11	**0.10**	**2.89**
Myrtle St.	8/11/10 10:32	Storm Grab	7	~4	0.71	0.081	1.63	**0.71**	**61.59**
Myrtle St.	9/2/10 8:56	Storm Grab	5	~3	0.77	0.136	0.45	**0.33**	**12.21**
Myrtle St.	9/16/10 8:32	Storm Grab	8	5	0.80	0.116	0.24	**0.15**	**10.40**
Myrtle St.	9/23/10 14:07	Storm Grab	17	3	0.78	0.169	1.89	**1.72**	**173.18**
Myrtle St.	4/26/11 10:20	Storm Grab	27	~9	1.30	0.282	N/A	**N/A**	**N/A**
Myrtle St.	6/22/11 8:30	Storm Grab	~3	~2	0.71	0.075	3.17	**1.28**	**51.26**
Myrtle St.	8/17/11 12:09	Storm Grab	9	~6	0.76	0.082	2.20	**0.97**	**106.76**
Meadowlark Dr.	3/18/09 14:30	Snowmelt Grab	8	5	2.60	0.145	0.6	**0.47**	**25.93**
Meadowlark Dr.	8/20/09 7:58	Storm Grab	4	3	1.30	0.036	0.74	**0.14**	**16.01**
Meadowlark Dr.	10/2/09 9:18	Storm Grab	1	1	0.61	0.033	0.45	**0.08**	**2.42**
Meadowlark Dr.	10/7/09 8:00	Storm Grab	1	1	0.64	0.010	1.71	**0.09**	**9.22**
Meadowlark Dr.	3/12/10 11:55	Snowmelt Grab	4	3	2.30	0.163	0.17	**0.15**	**3.58**
Meadowlark Dr.	5/11/10 13:30	Storm Grab	~1	~1	0.58	~0.039	0.28	**0.06**	**1.52**
Meadowlark Dr.	5/26/10 9:55	Storm Grab	3	~2	0.67	0.060	0.61	**0.20**	**9.84**
Meadowlark Dr.	6/11/10 9:33	Storm Grab	3	~2	1.30	~0.049	1.64	**0.43**	**26.51**
Meadowlark Dr.	8/2/10 10:56	Storm Grab	~4	~4	0.66	0.053	0.18	**0.05**	**3.99**
Meadowlark Dr.	8/11/10 10:19	Storm Grab	~5	~4	0.58	0.061	1.74	**0.57**	**46.88**
Meadowlark Dr.	9/2/10 8:51	Storm Grab	~2	<1	0.52	~0.022	0.99	**0.12**	**10.70**
Meadowlark Dr.	9/16/10 8:20	Storm Grab	~1	~1	0.43	<0.010	0.32	**0.01**	**1.71**
Meadowlark Dr.	9/23/10 13:50	Storm Grab	~2	~1	0.42	<0.010	2.27	**0.06**	**24.45**
Meadowlark Dr.	4/26/11 10:30	Storm Grab	~2	~1	0.51	0.056	N/A	**N/A**	**N/A**
Meadowlark Dr.	6/22/11 8:50	Storm Grab	~1	~1	0.68	0.068	1.94	**0.71**	**10.48**
Meadowlark Dr.	8/17/11 11:20	Storm Grab	~4	~3	0.65	0.054	2.29	**0.67**	**49.48**

* Loadings are based on instantaneous flow measurement and values should be used with caution

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 2011. The City of Stillwater constructed the diversion structure in June of 2003, as part of the completion of the 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 from the southern tributary of the creek out of the temperature and nutrient sensitive Brown's Creek Ravine, it will mean that this water will be entering McKusick Lake, and could affect the lake water quality. Data collected at this site by the WCD includes total discharge and water quality sample analysis. All stream flow and chemistry data from 2011 can be found in Figure 10, Table 12, Table 13, Table 14, and Table 15.

Using a combination of composite and grab samples, TP and TSS loads were calculated at the Brown's Creek diversion structure site. TP increased by 1,491 lbs, from 608 lbs in 2010, to 2,099 lbs of TP exported in 2011. TSS also showed an increase of 125,635 lbs between 2009 and 2010, and 1,033,973 lbs between 2010 and 2011, making TSS exported to McKusick Lake 1,387,050 lbs in 2011 (Table 12, Table 17).

Water quality results showed all but one of the storm samples, including the snowmelt grab sample, exceeded the standard for TSS, but only showed water quality standard exceedances in two out of the five *E. coli* samples (Table 13). There were nine event flow samples that were tested for metals in 2011. All nine exceeded the chronic standard for lead, including one that exceeded the maximum standard. Seven samples exceeded the chronic standard for copper, including five that exceeded the maximum standard, and the 4/26-4/27 sample exceeded the final acute standard. The chronic standard for zinc was exceeded five out of the nine events sampled, with four exceeding the maximum standard and the 4/26-4/27 sample exceeded the final acute standard. The storm composite on 4/26-4/27 was the only sample that exceeded the chronic standard for cadmium as well. No base flow grabs exceeded any standards for metals (Table 14). No field data measurements exceeded any standards (Table 15).

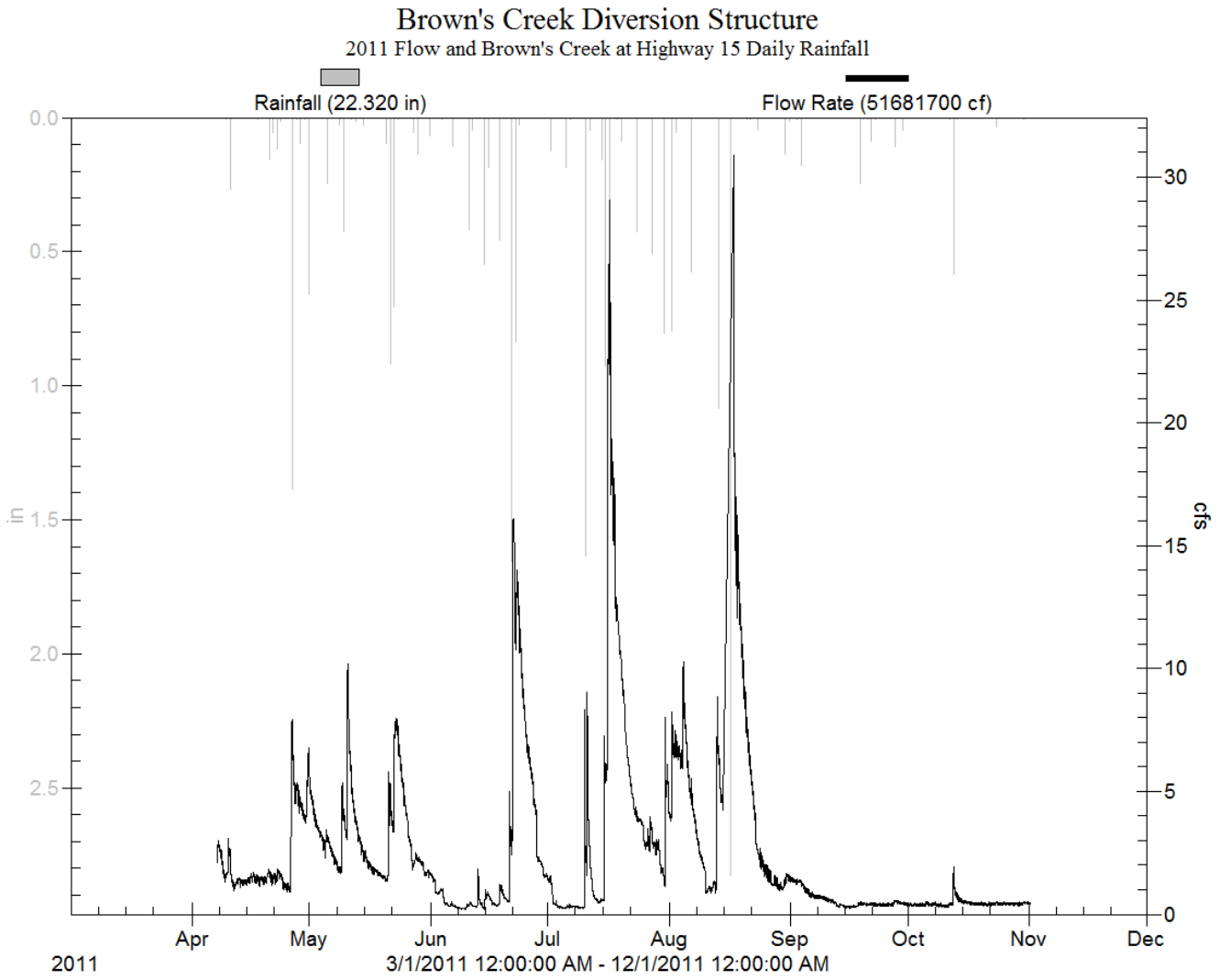

Figure 10. Brown's Creek Diversion Structure Drainage 2011 Flow and Brown's Creek at Highway 15 Rainfall

Table 12. Brown's Creek Diversion Structure Drainage 2011 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***			*13*	*0.102*	*1/1/2011 0:00*	*3/22/2011 7:00*	*2,705,508*	*62.14*	*2,196*	*17.23*
Snowmelt Grab**	3/22/2011 15:01	3/22/2011 15:01	228	0.304	3/22/2011 7:00	3/22/2011 18:00	257,400	5.91	3,664	4.88
*Base***			*13*	*0.102*	*3/22/2011 18:00*	*4/7/2011 10:30*	*1,016,550*	*23.35*	*825*	*6.47*
Base			*13*	*0.102*	*4/7/2011 10:30*	*4/10/2011 2:30*	*494,082*	*11.35*	*401*	*3.15*
Storm			*2794*	*3.541*	*4/10/2011 2:30*	*4/10/2011 14:30*	*110,188*	*2.53*	*19,219*	*24.36*
Base			*13*	*0.102*	*4/10/2011 14:30*	*4/26/2011 3:30*	*1,926,970*	*44.26*	*1,564*	*12.27*
Storm Composite	4/26/2011 6:53	4/27/2011 9:35	4040	5.360	4/26/2011 3:30	4/27/2011 10:30	625,666	14.37	157,794	209.35
Base			*13*	*0.102*	*4/27/2011 10:30*	*4/30/2011 3:30*	*1,050,800*	*24.14*	*853*	*6.69*
Storm Composite	4/30/2011 9:23	5/1/2011 3:24	1930	5.160	4/30/2011 3:30	5/1/2011 3:30	476,391	10.94	57,397	153.45
Base			*13*	*0.102*	*5/1/2011 3:30*	*5/9/2011 6:30*	*2,128,770*	*48.90*	*1,728*	*13.55*
Storm			*2794*	*3.541*	*5/9/2011 6:30*	*5/9/2011 11:30*	*74,396*	*1.71*	*12,976*	*16.45*
Base			*13*	*0.102*	*5/9/2011 11:30*	*5/10/2011 14:30*	*357,946*	*8.22*	*290*	*2.28*
Storm Composite	5/10/2011 16:07	5/11/2011 4:54	8100	4.640	5/10/2011 14:30	5/11/2011 5:30	435,169	10.00	220,044	126.05
Base			*13*	*0.102*	*5/11/2011 5:30*	*5/21/2011 3:30*	*2,211,390*	*50.79*	*1,795*	*14.08*
Storm			*2794*	*3.541*	*5/21/2011 3:30*	*5/21/2011 17:30*	*213,304*	*4.90*	*37,204*	*47.15*
Base			*13*	*0.102*	*5/21/2011 17:30*	*5/22/2011 11:30*	*252,479*	*5.80*	*205*	*1.61*
Storm			*2794*	*3.541*	*5/22/2011 11:30*	*5/23/2011 16:30*	*765,396*	*17.58*	*133,499*	*169.19*
Base Grab	5/25/2011 8:41	5/25/2011 8:41	18	0.093	5/23/2011 16:30	5/25/2011 16:30	960,320	22.06	1,079	5.58
Base			*13*	*0.102*	*5/25/2011 16:30*	*6/14/2011 17:30*	*1,917,450*	*44.04*	*1,556*	*12.21*
Storm			*2794*	*3.541*	*6/14/2011 17:30*	*6/15/2011 1:30*	*17,750*	*0.41*	*3,096*	*3.92*
Base Grab	6/15/2011 13:59	6/15/2011 13:59	29	0.178	6/15/2011 1:30	6/18/2011 12:30	163,885	3.76	297	1.82
Storm			*2794*	*3.541*	*6/18/2011 12:30*	*6/19/2011 3:30*	*55,496*	*1.27*	*9,680*	*12.27*
Base			*13*	*0.102*	*6/19/2011 3:30*	*6/21/2011 3:30*	*119,185*	*2.74*	*97*	*0.76*
Storm Composite	6/21/2011 22:20	6/22/2011 13:18	3080	5.920	6/21/2011 3:30	6/22/2011 13:30	987,201	22.67	189,812	364.83
Base			*13*	*0.102*	*6/22/2011 13:30*	*7/10/2011 5:30*	*4,770,700*	*109.58*	*3,872*	*30.38*
Storm			*2794*	*3.541*	*7/10/2011 5:30*	*7/10/2011 8:30*	*48,113*	*1.11*	*8,392*	*10.64*
Base			*13*	*0.102*	*7/10/2011 8:30*	*7/10/2011 22:30*	*124,092*	*2.85*	*101*	*0.79*
Storm Composite	7/11/2011 0:32	7/11/2011 5:18	2140	1.360	7/10/2011 22:30	7/11/2011 5:30	160,603	3.69	21,455	13.64
Base			*13*	*0.102*	*7/11/2011 5:30*	*7/15/2011 9:30*	*393,616*	*9.04*	*319*	*2.51*
Storm			*2794*	*3.541*	*7/15/2011 9:30*	*7/15/2011 14:30*	*91,297*	*2.10*	*15,924*	*20.18*
Base			*13*	*0.102*	*7/15/2011 14:30*	*7/16/2011 4:30*	*291,571*	*6.70*	*237*	*1.86*
Storm Composite	7/16/2011 4:27	7/16/2011 13:27	1840	3.220	7/16/2011 4:30	7/16/2011 15:30	785,076	18.03	90,177	157.81
Base			*13*	*0.102*	*7/16/2011 15:30*	*7/20/2011 15:30*	*4,880,180*	*112.09*	*3,960*	*31.07*
Base Grab	7/21/2011 11:00	7/21/2011 11:00	18	0.101	7/20/2011 15:30	7/22/2011 15:30	1,057,100	24.28	1,188	6.67
Base			*13*	*0.102*	*7/22/2011 15:30*	*7/30/2011 22:30*	*2,218,170*	*50.95*	*1,800*	*14.12*
Storm			*2794*	*3.541*	*7/30/2011 22:30*	*7/31/2011 1:30*	*69,401*	*1.59*	*12,105*	*15.34*
Base			*13*	*0.102*	*7/31/2011 1:30*	*8/1/2011 16:30*	*654,309*	*15.03*	*531*	*4.17*
Storm Composite	8/1/2011 18:02	8/2/2011 9:36	752	1.410	8/1/2011 16:30	8/2/2011 10:30	447,898	10.29	21,026	39.42
Base			*13*	*0.102*	*8/2/2011 10:30*	*8/4/2011 11:30*	*1,159,270*	*26.63*	*941*	*7.38*
Storm			*2794*	*3.541*	*8/4/2011 11:30*	*8/4/2011 17:30*	*198,211*	*4.55*	*34,572*	*43.81*
Base			*13*	*0.102*	*8/4/2011 17:30*	*8/13/2011 3:30*	*2,272,100*	*52.19*	*1,844*	*14.47*
Storm Composite	8/13/2011 5:13	8/14/2011 20:23	468	0.538	8/13/2011 3:30	8/14/2011 20:30	818,963	18.81	23,926	27.51
*Base***			*13*	*0.102*	*8/14/2011 20:30*	*8/16/2011 21:15*	*789,750*	*18.14*	*641*	*5.03*
*Storm***			*2794*	*3.541*	*8/16/2011 21:15*	*8/17/2011 11:15*	*1,562,400*	*35.89*	*272,512*	*345.37*
Base Grab**	8/17/2011 11:40	8/17/2011 11:40	5	0.136	8/17/2011 11:15	8/17/2011 14:15	237,600	5.46	74	2.02
Base			*13*	*0.102*	*8/17/2011 14:15*	*8/17/2011 18:15*	*294,093*	*6.75*	*239*	*1.87*
Base Grab	8/18/2011 8:21	8/18/2011 8:21	15	0.110	8/17/2011 18:15	8/19/2011 18:15	2,334,470	53.62	2,186	16.03
Base			*13*	*0.102*	*8/19/2011 18:15*	*8/23/2011 18:15*	*2,104,070*	*48.33*	*1,708*	*13.40*
Base Grab	8/24/2011 14:59	8/24/2011 14:59	11	0.099	8/23/2011 18:15	8/25/2011 18:15	368,110	8.46	253	2.27
Base			*13*	*0.102*	*8/25/2011 18:15*	*9/13/2011 18:15*	*1,671,810*	*38.40*	*1,357*	*10.65*
Base Grab	9/14/2011 13:54	9/14/2011 13:54	3	0.042	9/13/2011 18:15	9/15/2011 18:15	57,492	1.32	11	0.15
Base			*13*	*0.102*	*9/15/2011 18:15*	*10/12/2011 11:15*	*921,761*	*21.17*	*748*	*5.87*
Storm			*2794*	*3.541*	*10/12/2011 11:15*	*10/12/2011 19:15*	*31,101*	*0.71*	*5,425*	*6.87*
Base			*13*	*0.102*	*10/12/2011 19:15*	*10/19/2011 19:15*	*328,911*	*7.55*	*267*	*2.09*
Base Grab	10/20/2011 11:38	10/20/2011 11:38	2	0.058	10/19/2011 19:15	10/21/2011 19:15	70,460	1.62	9	0.26
Base			*13*	*0.102*	*10/21/2011 19:15*	*11/1/2011 10:15*	*404,098*	*9.28*	*328*	*2.57*
*Base***			*13*	*0.102*	*11/1/2011 10:15*	*1/1/2012 0:00*	*2,041,065*	*46.88*	*1,656*	*13.00*
Storm Average			2794	3.451						
Base Average			13	0.102						
All Average			1335	1.688						
Total							**52,981,553**	**1,217**	**1,387,050**	**2,099**
Brown's Creek Major Subwatershed Total Acres							3,837			
Total TSS/TP(lb/ac/yr)									361.49	0.55
Total TSS/TP (kg/ha/yr)									405.17	0.61

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

**Interval volumes from 01/01/11 to 04/07/11; 08/14/2011 to 08/17/2011; and 11/01/11 to 1/1/12 were estimated using recorded base flow

Table 13. Brown's Creek Diversion Structure Drainage 2011 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/100mL)
Snowmelt Grab	3/22/2011 15:01	3/22/2011 15:01	228	48	1.70	0.304	0.073	
Base Grab	5/25/2011 8:41	5/25/2011 8:41	18	6	0.71	0.093	~0.023	
Base Grab	6/15/2011 13:59	6/15/2011 13:59	29			0.178	0.045	
Base Grab	7/21/2011 11:00	7/21/2011 11:00	18	7	0.84	0.101	~0.037	
Base Grab	8/17/2011 11:40	8/17/2011 11:40	5	~2	0.81	0.136	0.087	
Base Grab	8/18/2011 8:21	8/18/2011 8:21	15			0.11	0.01	
Base Grab	8/24/2011 14:59	8/24/2011 14:59	11	5	0.74	0.099	<0.010	
Base Grab	9/14/2011 13:54	9/14/2011 13:54	3	~1	0.32	~0.042	~0.021	
Base Grab	10/20/2011 11:38	10/20/2011 11:38	~2	~1	0.25	0.058	~0.034	
Storm Composite	4/26/2011 6:53	4/27/2011 9:35	4040	980	13.00	5.36	0.061	
Storm Grab	4/26/2011 13:25	4/26/2011 13:25	132			~0.345		
Storm Composite	4/30/2011 9:23	5/1/2011 3:24	1930	500	22.00	5.160	~0.039	
Storm Composite	5/10/2011 16:07	5/11/2011 4:54	8100	~2800	16.00	4.64	~0.033	
Storm Composite	6/21/2011 22:20	6/22/2011 13:18	3080	~840	24.00	5.920	0.092	
Storm Grab	6/22/2011 8:31	6/22/2011 8:31	37			~0.251	0.061	
Storm Composite	7/11/2011 0:32	7/11/2011 5:18	2140	443	6.60	1.36	0.084	
Storm Composite	7/16/2011 4:27	7/16/2011 13:27	1840	544	15.00	3.22	0.119	
Storm Composite	8/1/2011 18:02	8/2/2011 9:36	752	288	8.10	1.41	0.093	
Storm Composite	8/13/2011 5:13	8/14/2011 20:23	468	156	2.80	0.538	0.067	
E. Coli Grab	6/9/2011 9:08	6/9/2011 9:08						2420
E. Coli Grab	7/7/2011 9:00	7/7/2011 9:00						276
E. Coli Grab	8/11/2011 9:20	8/11/2011 9:20						106
E. Coli Grab	9/8/2011 8:13	9/8/2011 8:13						114
E. Coli Grab	10/5/2011 10:30	10/5/2011 10:30						78

Table 14. Brown's Creek Diversion Structure Drainage 2011 Secondary Water Quality Results

Sample Type	Start Date	End Time	Copper (mg/L)	Nickel (mg/L)	Lead (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Chloride (mg/L)	Nitrite (mg/L)	Nitrate mg/L)	Ammonia Nitrogen (mg/L)	Hardness (mg/L _CaCO3)
Snowmelt Grab	3/22/2011 15:01	3/22/2011 15:01	0.00400	0.00310	0.00240	0.0110	<0.0002	0.00290	34	<0.03	0.88	0.17	70
Base Grab	5/25/2011 8:41	5/25/2011 8:41	0.00092	0.00077	~0.00029	0.0042	<0.0002	0.00057	84	<0.03	0.12	~0.03	78
Base Grab	6/15/2011 13:59	6/15/2011 13:59											
Base Grab	7/21/2011 11:00	7/21/2011 11:00	0.00078	~0.00059	~0.00023	<0.005	<0.0002	0.00043	98	<0.03	<0.05	<0.02	60
Base Grab	8/17/2011 11:40	8/17/2011 11:40	0.00095	0.00078	~0.00012	0.0024	<0.0002	0.00042	50	<0.03	0.07	~0.05	58
Base Grab	8/18/2011 8:21	8/18/2011 8:21											
Base Grab	8/24/2011 14:59	8/24/2011 14:59	~0.00052	~0.00054	<0.0001	~0.0015	<0.0002	0.00029	73	<0.03	0.11	~0.04	74
Base Grab	9/14/2011 13:54	9/14/2011 13:54	0.00200	0.00063	<0.0001	0.0024	<0.0002	0.00049	59	<0.03	0.89	<0.02	252
Base Grab	10/20/2011 11:38	10/20/2011 11:38	<0.0010	<0.0010	<0.0001	0.0022	<0.0002	0.00031	56	<0.03	0.94	0.02	258
Storm Composite	4/26/2011 6:53	4/27/2011 9:35	0.06490	0.06930	0.09150	0.2810	0.00200	0.07770	52	0.03	0.45	~0.05	100
Storm Grab	4/26/2011 13:25	4/26/2011 13:25											
Storm Composite	4/30/2011 9:23	5/1/2011 3:24	0.04240	0.04790	0.06060	0.1710	0.00130	0.05140	57	0.04	0.29	<0.02	144
Storm Composite	5/10/2011 16:07	5/11/2011 4:54	0.03570	0.04190	0.05290	0.1600	0.00100	0.04890	80	<0.05	0.38	0.08	104
Storm Composite	6/21/2011 22:20	6/22/2011 13:18	0.04020	0.04270	0.05180	0.1530	0.00110	0.04710	52	0.03	0.12	0.09	120
Storm Grab	6/22/2011 8:31	6/22/2011 8:31											
Storm Composite	7/11/2011 0:32	7/11/2011 5:18	0.01510	0.01300	0.01190	0.0480	~0.00041	0.01130	27	0.04	0.31	~0.06	108
Storm Composite	7/16/2011 4:27	7/16/2011 13:27	0.02600	0.02760	0.02890	0.0969	0.00074	0.03030	48	<0.03	0.18	0.13	84
Storm Composite	8/1/2011 18:02	8/2/2011 9:36	0.01070	0.01150	0.01090	0.0440	~0.00032	0.01290	68	<0.03	0.14	~0.04	108
Storm Composite	8/13/2011 5:13	8/14/2011 20:23	0.00540	0.00540	0.00390	0.0193	~0.00024	0.00510	64	<0.03	0.21	~0.03	78
E. Coli Grab	6/9/2011 9:08	6/9/2011 9:08											
E. Coli Grab	7/7/2011 9:00	7/7/2011 9:00											
E. Coli Grab	8/11/2011 9:20	8/11/2011 9:20											
E. Coli Grab	9/8/2011 8:13	9/8/2011 8:13											
E. Coli Grab	10/5/2011 10:30	10/5/2011 10:30											
	Exceeds Chronic Standard												
	Exceeds Max Standard												
	Exceeds Final Acute Standard												

Table 15. Brown's Creek Diversion Structure Drainage 2011 Field Measurement Results

Date/Time	Transparency (cm)	Water Temperature (C)	Dissolved Oxygen (mg/L)	Conductivity (umhos/cm)	pH
3/22/2011 15:01	25	0.6	10.77		
4/27/2011 9:47		6.8	10.71	296	8.0
5/25/2011 8:41	90	16.6	8.13	379	7.4
6/9/2011 9:08	68	12.4	9.58	577	8.1
6/13/2011 10:25	56	15.7	8.73	466	7.8
6/15/2011 13:59	38				
7/21/2011 11:00	62	27.5	5.89	440	7.2
8/24/2011 14:59		25.3	7.25	4.25	7.8
8/29/2011 11:24		19.7	7.61	391	7.3
10/5/2011 10:30	>100	11.4	10.8	563	8.0
10/20/2011 11:38	110	7.5	11.08	578	8.0

B. MSCWMO STREAMS: CONCLUSIONS AND RECOMMENDATIONS

While Perro Creek had a decrease in discharge and total pounds of TP exported to the St. Croix River in 2011 as compared to 2010, almost double the total pounds of suspended sediment were exported. When looking at the historical loading data, there is no increasing or decreasing trend in TP, whereas TSS has been increasing exponentially since 2007, after a large decrease from 2006 (Table 16). Monitoring of Perro Creek started at the end of the monitoring season in 2005 and there was not enough data to calculate loading values for that year.

Table 16 Perro Creek Historical Annual Discharge and Loading Amounts

	2011	2010	2009	2008	2007	2006
Discharge (cf)	28,986,610	38,802,342	16,272,950	25,428,457	16,703,958	39,748,331
Subwatershed Total Acres	1,063	1,063	1,063	1,063	1,063	1,063
Total pounds of Phosphorus exported	82	179	242	87	212	241
TP (lb/ac/yr)	0.08	0.17	0.23	0.08	0.20	0.23
Total pounds of TSS exported	379,634	191,200	51,874	29,343	13,023	162,938
TSS (lb/ac/yr)	357.29	179.95	48.82	27.62	12.26	153.35

Changes in discharge in Perro Creek are directly related to precipitation (Figure 8), but are also related to anthropogenic sources, such as the small dam that holds back Perro Pond and releases water into Perro Creek. This dam was not opened until May 3rd, 2011 and Perro Creek did not flow continuously until the dam was opened. In previous years WCD staff has observed artificial blockages in the channel and dumping of yard waste into the creek. The changes in discharge caused by artificial means (such as channel blocking) can and has caused deterioration in the stability of the stream bank and has created difficulty in monitoring. Additional waste dumped into the stream causes larger loads observed in the stream, and more nutrients and waste products discharged to the St. Croix River.

When examining TP and TSS in lbs/day for the Myrtle Street and Meadowlark Drive sites, the majority of samples showed a decrease between these two sites in amount of loading, with only one sample over the past three years for TSS showing an increase (Table 11). The Meadowlark Drive site (located downstream of the Myrtle Street site) is monitored to assess whether any additional loading is entering the tributary from the Jaycee's Ballfield wetland between Myrtle Street and Meadowlark Drive. It can be seen from the results that this wetland is actually acting as a sink for nutrients rather than a source, since only one sample for TSS has showed an

increase. All other TP and TSS values have shown a decrease in values between these sites, which could be a result of particulates settling out in the wetland. Based on these results it is recommended to discontinue the monitoring of these sites. If better insight to this system and the effect of this tributary on the water quality of McKusick Lake is needed, it is recommended that continuous monitoring equipment be placed at the Meadowlark Drive site so a total yearly load entering McKusick Lake can be estimated.

The Brown's Creek Diversion Structure Drainage data is extremely valuable for determining current and future impacts to McKusick Lake. The large load observed coming from this site is likely one of the major impacts on the water quality of the lake. 2011 has resulted in the highest discharge seen since monitoring began, as well as the largest load of total phosphorus and total suspended solids exported to McKusick Lake (Table 17). Brown's Creek Watershed District has implemented more intense monitoring of the entire diversion area drainage to identify potential load sources. This monitoring also includes components to determine which types of best management practices will be most effective in reducing the loads entering McKusick Lake. For more information on this monitoring see the Brown's Creek Watershed District 2011 Water Monitoring Report. Goals have been established through the City of Stillwater's Lake Management Plan for McKusick Lake. Accurately monitored loading data will continue to provide evidence of reductions in the total phosphorus load to McKusick Lake from water quality improvement projects.

Table 17. Brown's Creek Diversion Structure Drainage Historical Annual Discharge and Loading Amounts

Brown's Creek Diversion Structure Drainage	2011	2010	2009	2008	2007	2006
Discharge (cf)	52,981,553	38,197,468	31,166,264	29,397,219	49,768,967	33,916,362
Total pounds of Phosphorus exported	2,099	608	544	206	653	676
TP (lb/ac/yr)	0.550	0.160	0.140	0.050	0.170	0.176
Total pounds of TSS exported	1,387,050	353,007	227,372	59,313	232,190	455,793
TSS (lb/ac/yr)	361.49	92.00	59.26	15.46	60.51	118.79

The following are WCD recommendations to the MSCWMO:

- Continue to monitor Perro Creek for any potential water quality trends and water quality standard exceedances.
- Work with Perro Creek's neighboring landowners to improve stewardship along the creek to prevent future channel blockage and excess waste dumping.
- Establish a record keeping protocol for the opening and closing of the Perro Pond Outlet, to enhance future monitoring data interpretation
- Continue to evaluate loading estimates at the Brown's Creek Diversion Structure Drainage site to determine if future water quality improvement projects are helping to reduce loading to McKusick Lake.
- Discontinue monitoring the Myrtle Street and Meadowlark Drive sites
- Monitor Lily Lake

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Appendix A

Water Quality Data– McKusick Lake, Lily Lake, and Brick Pond

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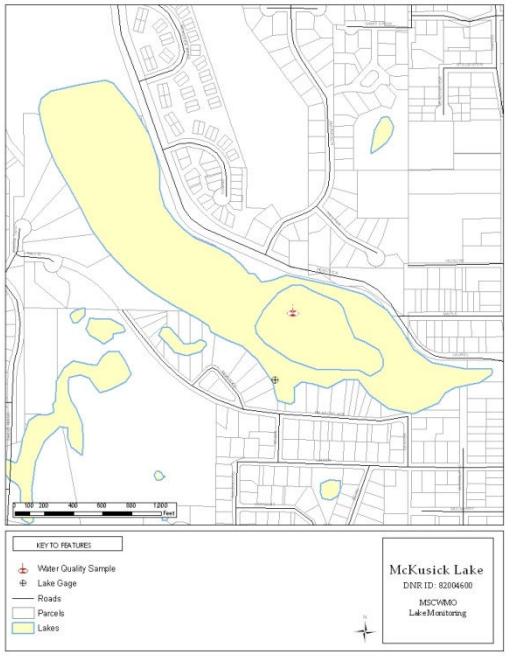
McKusick Lake

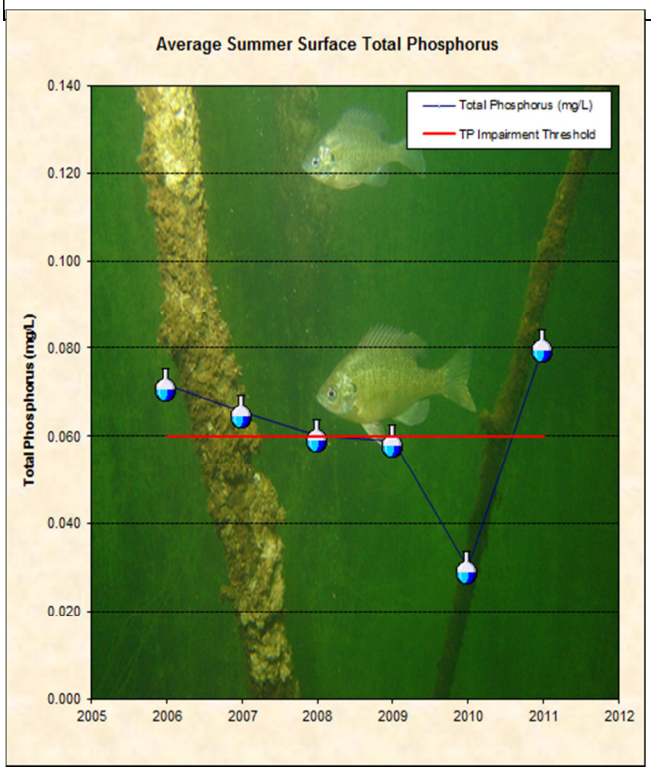
2011 Lake Grade: C-

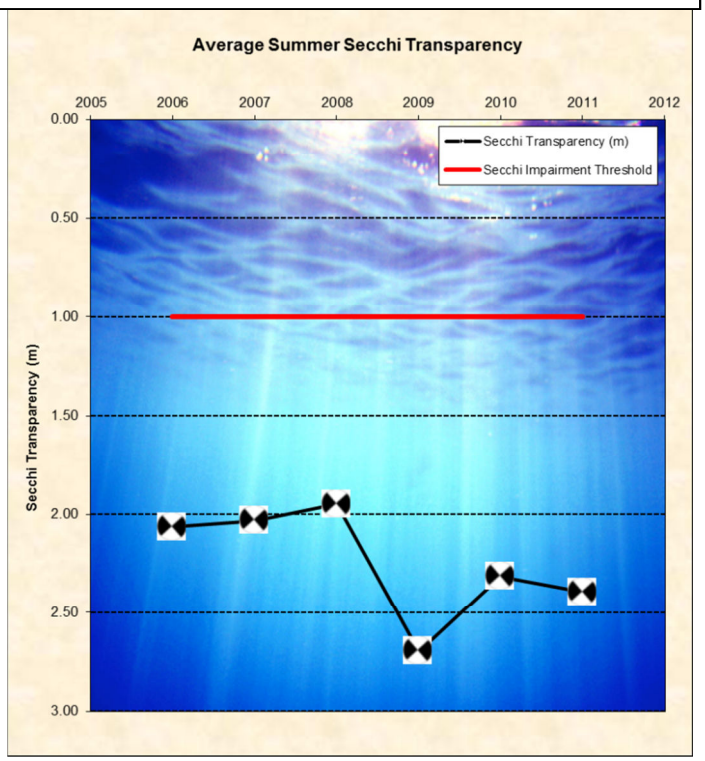
- DNR ID #: 820020
- Municipality: City of Stillwater
- Location: NE ¼ Section 29, T30N-R20W
- Lake Size: 46 Acres
- Maximum Depth (2011): 16 ft
- Ordinary High Water Mark: 853 ft
- 100%Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- McKusick Lake was considered eutrophic in 2011, based on the Carlson Trophic State Index.
- Using a Kendal Tau correlation test ($p<0.01$), 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 did stratify in 2011 with the thermocline around 3 meters.
- McKusick Lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List, but is scheduled to be de-listed



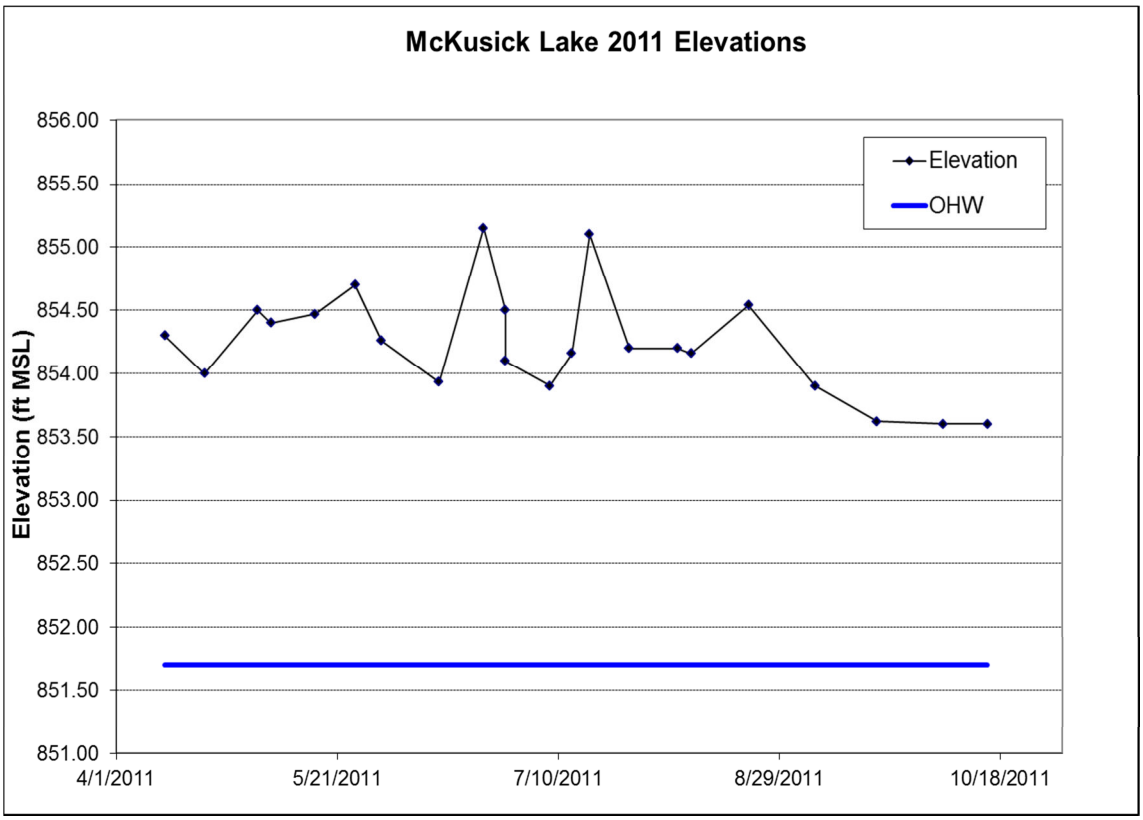


Date	Total Phosphorus (mg/l)	Chlorophyll-*a* (ug/l)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depths (m)	Surface Dissolved Oxygen Levels (mg/l)	Surface Temperature Levels (Celsius)
4/21/2011	0.04	7.7	0.59	2.5908	10.96	7.6
5/3/2011	0.031	7.1	0.52	2.8956	11.07	7.4
5/16/2011	0.032	5.8	0.6	2.1336	9.46	14.6
5/31/2011	0.036	6.8	0.72	3.3528	7.52	19.8
6/13/2011	0.04	7.8	0.94	2.8956	7.91	19.7
6/27/2011	0.071	4.2	1	3.048	14.33	22.2
7/13/2011	0.046	5.9	0.94	2.1336	3.01	24.3
7/26/2011	0.081	16	1.2	2.1336	0.48	25.7
8/9/2011	0.115	87	1.4	0.9144	1.02	23.6
8/22/2011	0.109	29	1.1	1.9812	4.06	23.4
9/6/2011	0.107	50	1.1	1.2192	2.98	21.1
9/20/2011	0.075	12	1	2.286	2.85	15.7
10/5/2011	0.067	22	1	1.9812	10.12	15.7
10/17/2011	0.06	5.6	1.3	3.9624	8.14	11.1
2011 Average	0.065	19	1.0	2.4	6.71	18.0
2011 Summer Average	0.081	26.488	1.085	2.076	4.580	21.963

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
2011 Elevation (ft)	855.15	6/23/2011	853.60	10/15/2011	854.22

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

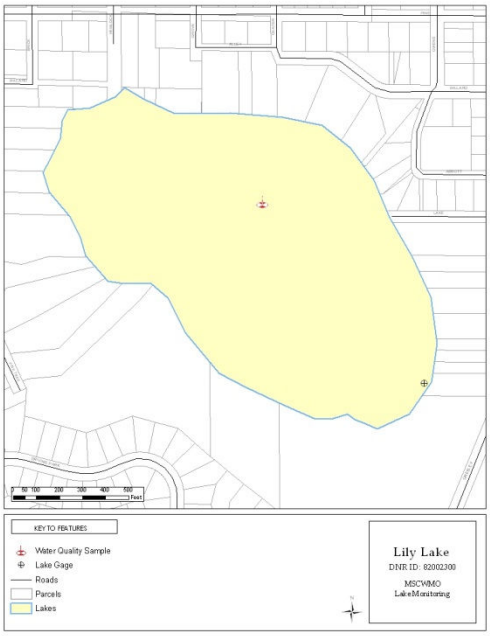


Lake Water Quality Summary											
	Trophic Status	Summertime Lake Grades									
	2011	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002
Total Phosphorus (mg/L)	Hypereutrophic	D	B	C	C	C	D	C	C	C	C
Chlorophyll-*a* (ug/L)	Eutrophic	C	A	A	B	B	B	B	A	B	C
Secchi depth (ft)	Mesotrophic	C	B	B	C	C	C	C	B	C	D
Overall	Eutrophic	C-	B+	B	C+	C+	C	C+	B	C+	C+

Lily Lake

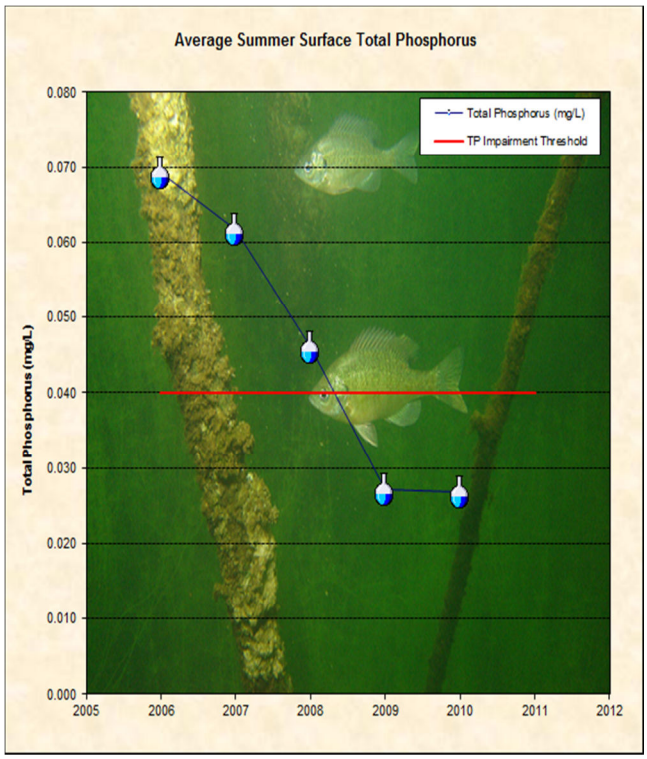
2011 Lake Grade: N/A

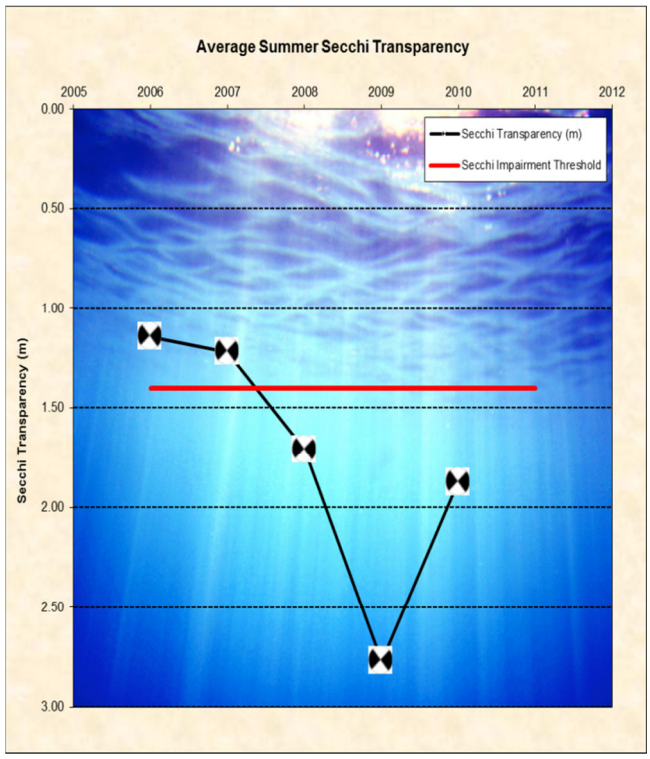
- DNR ID #: 820023
- Municipality: City of Stillwater
- Location: NE ¼ Section 32, T30N-R20W
- Lake Size: 35.90 Acres
- Maximum Depth: 51 ft
- Ordinary High Water Mark: 844.8 ft
- 55%Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.
- Public access and public beach present



Summary Points

- Lily Lake was scheduled to be monitored by a volunteer in 2011, however the volunteer was unable to monitor once the season started. Therefore, no conclusions can be drawn for 2011.
- Lily Lake was considered mesotrophic in **2010**, based on the Carlson Trophic State Index.
- At this time no statistically significant trend can be determined for water quality.
- The major land use is urban/residential.
- Lily Lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.



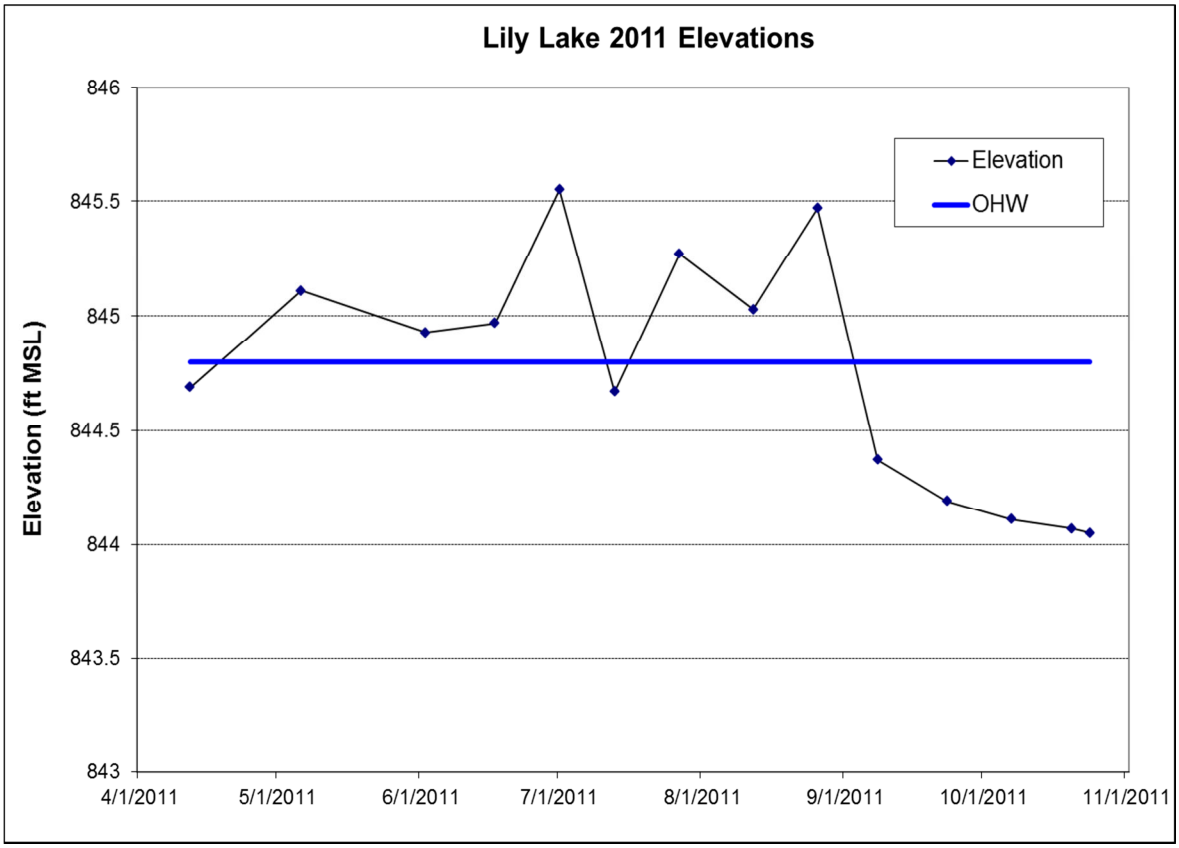


Date	Total Phosphorus (mg/l)	Chlorophyll-*a* (ug/l)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depths (m)	Surface Dissolved Oxygen Levels (mg/l)	Surface Temperature Levels (Celsius)
Sample I	N/A	N/A	N/A	N/A	N/A	N/A
Sample II	N/A	N/A	N/A	N/A	N/A	N/A
Sample III	N/A	N/A	N/A	N/A	N/A	N/A
Sample IV	N/A	N/A	N/A	N/A	N/A	N/A
Sample V	N/A	N/A	N/A	N/A	N/A	N/A
Sample VI	N/A	N/A	N/A	N/A	N/A	N/A
Sample VII	N/A	N/A	N/A	N/A	N/A	N/A
2011 Average	N/A	N/A	N/A	N/A	N/A	N/A
2011 Summer Average	N/A	N/A	N/A	N/A	N/A	N/A

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

	High	High Date	Low	Low Date	Average
2011 Elevation (ft)	845.55	7/1/2011	844.05	10/24/2011	844.75

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

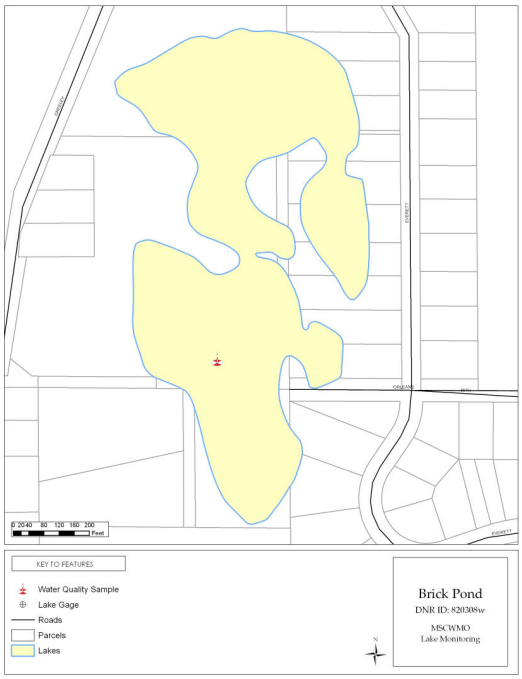


Lake Water Quality Summary											
	Trophic Status	Summertime Lake Grades									
	2011	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002
Total Phosphorus (mg/L)	**NA**	**NA**	B	B	C	C	D	C	C	C	C
Chlorophyll-*a* (ug/L)	**NA**	**NA**	C	A	C	C	C	B	B	B	B
Secchi depth (ft)	**NA**	**NA**	C	B	C	C	D	C	C	C	C
Overall	**NA**	**NA**	C+	B+	C	C	D+	C+	C+	C+	C+

Brick Pond

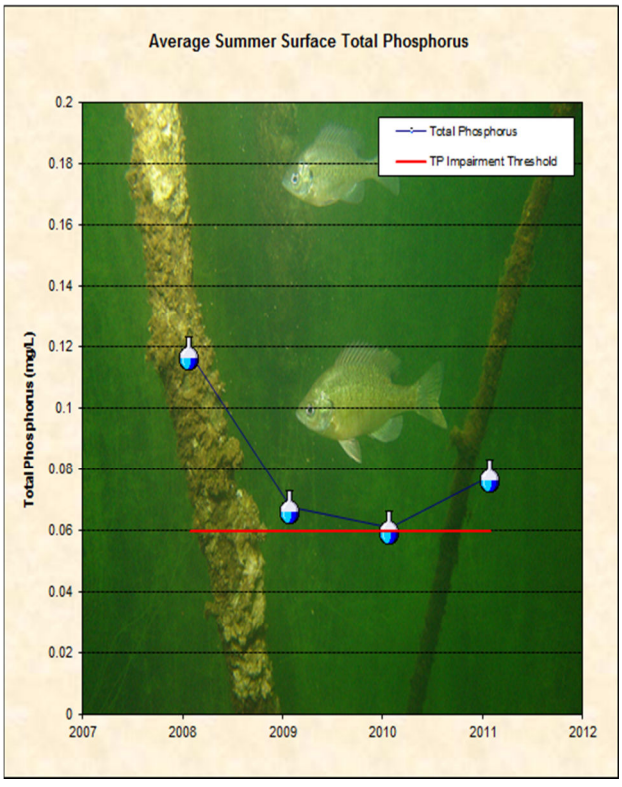
2011 Lake Grade: C

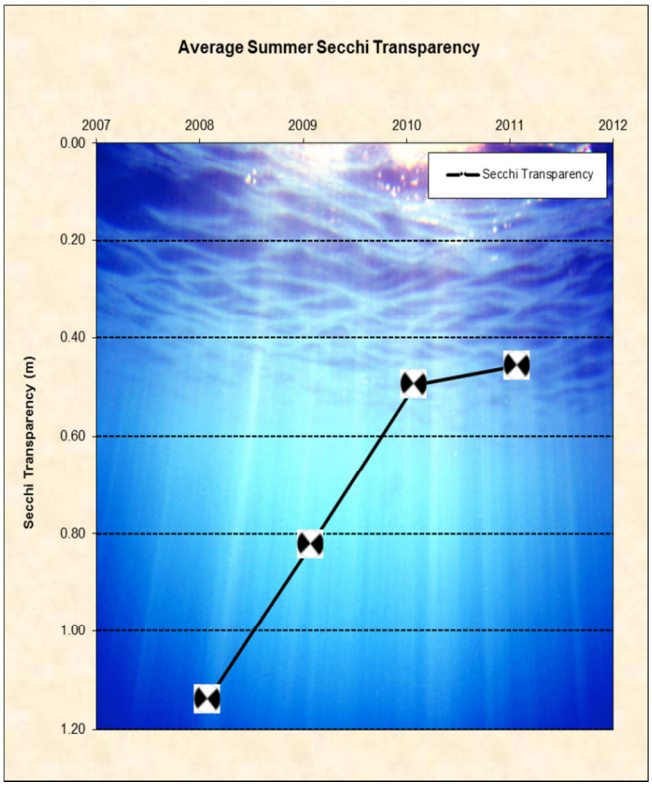
- DNR ID #: 820308
- Municipality: City of Stillwater
- Location: NW ¼ Section 33, T30N-R20W
- Lake Size: 12 Acres
- Maximum Depth (2010): 2 ft
- Ordinary High Water Mark: N/A
- 100%Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Brick Pond was considered eutrophic in 2011, based on the Carlson Trophic State Index.
- At this time there are not enough years of data to determine a statistically significant overall water quality trend.
- The major land use is urban/residential.
- The pond did not stratify in 2011.





Date	Total Phosphorus (mg/L)	Chlorophyll-a (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depths (m)	Surface Dissolved Oxygen Levels (mg/L)	Surface Temperature Levels (Celsius)
5/3/2011	0.049	8.2	0.61	0.61	16.3	16.7
5/31/2011	0.149	2.6	1.1	0.76	14.98	21.5
6/16/2011	0.086	9.1	0.86	0.61	10.96	25.5
7/13/2011	0.064	12	0.79	0.46	9.65	24.7
8/9/2011	0.095	17	0.68	0.46	12.02	22.8
9/8/2011	0.066	14	0.88	0.30	9.26	20.9
10/5/2011	0.113	37	1.1	0.46	13.21	7.9
2011 Average	0.089	14.3	0.86	0.52	12.34	20.00
2011 Summer Average	0.078	13.0	0.80	0.46	10.47	23.48

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
2011 Elevation (ft)	N/A	N/A	N/A	N/A	N/A

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

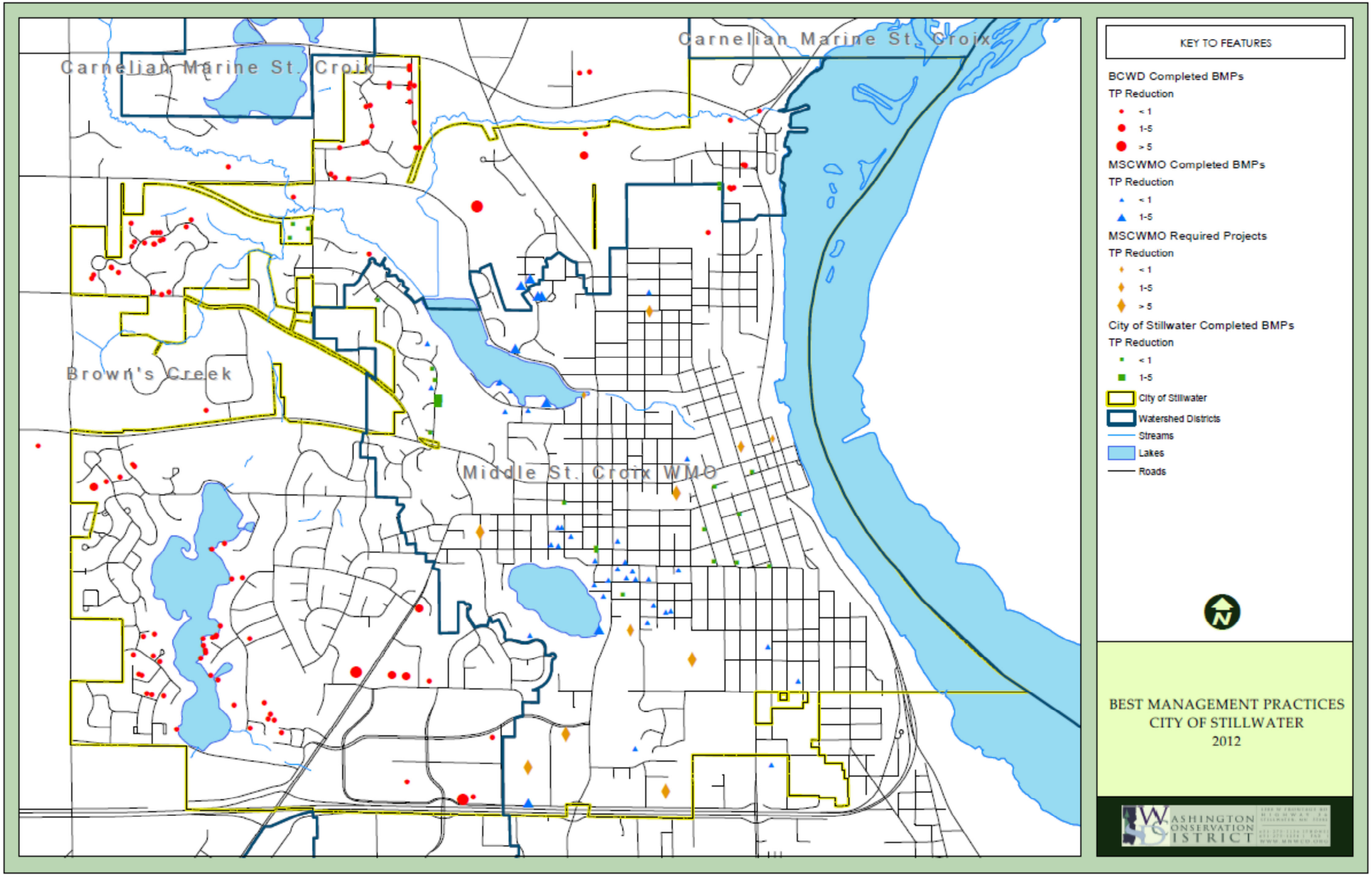
Lake Water Quality Summary

	Trophic Status	Summertime Lake Grades									
	2011	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002
Total Phosphorus (mg/L)	Hypereutrophic	D	C*	C	D	NA	NA	NA	NA	NA	NA
Chlorophyll-*a* (ug/L)	Eutrophic	B	A	A	A	NA	NA	NA	NA	NA	NA
Secchi depth (ft)	Mesotrophic	C*	C*	C	C	NA	NA	NA	NA	NA	NA
Overall	Eutrophic	C	B-	B-	C+	NA	NA	NA	NA	NA	NA

*Adjusted for shallow lake

Appendix B

City Of Stillwater BMP Map


Carnelian Marine St. Croix
Carnelian Marine St. Croix
Brown's Creek
Middle St. Croix WMO
KEY TO FEATURES
BCWD Completed BMPs
TP Reduction
< 1
1-5
> 5
MSCWMO Completed BMPs
TP Reduction
< 1
1-5
MSCWMO Required Projects
TP Reduction
< 1
1-5
> 5
City of Stillwater Completed BMPs
TP Reduction
< 1
1-5
City of Stillwater
Watershed Districts
Streams
Lakes
Roads
N
BEST MANAGEMENT PRACTICES
CITY OF STILLWATER
2012
WASHINGTON CONSERVATION DISTRICT