Prepared by Middle St. Croix Watershed Management Organization

With Emmons & Olivier Resources, Inc.

Lily Lake Impaired Waters Delisting Roadmap

CLEAN WATER LAND & LEGACY AMENDMENT

Cover Image: Lily Lake Fall 2017

by Emmons & Olivier Resources, Inc.

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August, 2018

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

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
mg/L	milligram per liter
MN DNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
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
TSS	Total Suspended Solids
µg/L	micrograms per liter
µmhos/cm	micromhos per centimeter

1. EXECUTIVE SUMMARY

This document is a summary of past studies, installed water quality improvement practices, in-lake and stormsewer outfall water quality monitoring data, and current requirements for delisting impaired waters. Based on these and previous studies the report concludes the installation of two stormwater BMPs and application of two alum treatments will achieve state water quality thresholds of 0.04 mg/L TP, 14 µg/L Chl-a, 1.4 m Secchi depth resulting in the delisting of Lily Lake.

Lily Lake is a deep lake located in Stillwater, Minnesota. It has served as a recreational resource for the residents of Stillwater for over 100 years. Due to the presence of excess nutrients which impact its aquatic recreation use, Lily Lake was added to the State Impaired Waters List in 2002. From 2002-2007 the City and watershed conducted multiple studies leading to the 2007 Lily Lake Management Plan that identified a 145.0 pound annual reduction in total phosphorus was needed to achieve in lake phosphorus goals.

To date, the City and watershed have installed 41 retrofit water quality projects that models have predicted address 100.0 pounds per year of the annual phosphorous load to Lily Lake. Additionally, Lily Lake annual condition monitoring demonstrates a long-term statistical improvement in the in-lake concentration of phosphorous.

Based on this data, the Middle St. Croix Watershed Management Organization and the City of Stillwater have formulated a goal to complete the load reductions to Lily Lake by 2021, conduct in-lake treatment in 2021 and 2022, monitor the in-lake condition response, and request removal from the impaired waters list by 2024.

To accomplish this, the City and watershed conducted targeted monitoring of all the outfalls directly discharging to Lily Lake in 2015 and 2016. This data demonstrated that a large portion (55% in 2016) of the phosphorus to Lily Lake was contributed by two stormsewer subwatersheds. The 2010 Lily Lake Subwatershed Analysis was then updated through a civic engagement and stormwater quality retrofit feasibility study to evaluate potential BMPs to reduce annual phosphorous from the stormsewer subwatersheds by 45.0 lbs. The results of the engagement process and feasibility study was the recommendation to install two stormwater management practices that will reduce 51.2 lbs. total phosphorus discharging directly to Lily Lake from 47.7 acres of urban residential and institutional land uses. Modeling predicts the two practices, one large bioretention basin and one underground infiltration gallery, will reduce annual phosphorous by more than 80% for the two stormsewer watersheds that monitoring indicated contributed 55% in 2016.

Additional factors that may influence chlorophyll a (Chl-a), secchi disk, or in lake phosphorus were also studied. A literature review on the effects of in-lake herbicide and algaecide on Chl-a and secchi disk depths was completed in 2018. Results of the literature review indicated herbicide and algaecide treatments may increase Chl-a and decrease secchi depths. The Lake Association and City decided to halt lake-wide treatments in 2018 based on these findings. Also in 2018, sediment cores were collected and the internal load and the probable effectiveness and cost of alum treatment were studied. Results indicated two alum treatments to Lily Lake will reduce annual internal loading by 120 lbs. pear year.

2. LILY LAKE EXISTING CONDITIONS

2.1. Introduction

Lily Lake is a deep lake located within the City of Stillwater, Minnesota. It has a surface area of 35.9 acres, an average depth of 18 feet, and an ordinary high water level of 844.8 feet. The Lily Lake, Brick Pond, and their watershed encompass approximately 567 acres. Major land uses include 60% residential and 10% institutional. The lake is naturally landlocked and is pumped to Lake McKusick. Water discharging to McKusick Lake then flows east through the Mulberry Ravine to Lake St. Croix.

Lily Lake does not meet State water quality standards and is included on the State's Impaired Waters List or 303(d) list due to excess nutrients which impacts its aquatic recreation use. Lily Lake was added to the Impaired Waters List in 2002. The Minnesota Pollution Control Agency (MPCA) lists a 2021 start date for a Total Maximum Daily Load study (TMDL) for Lily Lake.

2.2. Previous Studies and Recommendations

Prior to, and in the 1960s Lily Lake was known for its depth and clarity (Metropolitan Study of Metropolitan Area Lakes, 1995). A photograph from the 1960's shows the public beach on Lily Lake occupied by over one hundred swimmers (Figure 1). This number was significantly smaller by the 1990's due to decreased water quality (Save Lily Lake, 1998 and Gazette Editorial, 1998). A 1996 feasibility study by Short Elliot Hendrickson, Inc. (SEH) identified that in the 1970's stormwater was diverted into Lily Lake's 3 drainages: Brick Pond (306 acres, 94 lbs P), Churchill Street (34 acres, 30 lbs. P), and the Northwest Drainage area (130 acres, 88 lbs P). The report identified stormwater drainage from these three drainage areas as the causes for total phosphorous concentrations in 1995 of 0.05 mg/L in 1995. The study was the first report to identify Lily Lake's total watershed area at 567 acres. In 2000 a pump station was installed on the north side of Lily Lake that pumps water from Lily Lake into Lake McKusick and eventually discharges through the McKusick outlet to Lake St. Croix.

Figure 1. Swimmers at Lily Lake Beach, circa 1960's (photo)

Between 1996 and 2013 seven studies, management plans, and feasibility reports were completed to evaluate the Lily Lake watershed, phosphorous loading, vegetation management, and identify implementation actions to improve conditions in Lily Lake. After each report, implementation actions have been completed. This section and Appendix B identify the goals, findings, and actions associated with each study.

In 1996 the Lily Lake Stormwater Treatment Feasibility Report conducted by SEH studied the contributing watershed and potential stormwater treatment measures to improve the water quality of Lily Lake. The report identified an annual total loading of 265 lbs. of phosphorus per year. The report noted the MPCA required an annual reduction 66 lbs. per year of phosphorus to achieve a swimmable condition for 75% of the swimming season. In order to achieve swimmable conditions, a reduction of 107 lbs. of phosphorus was required. The report also notes sediment build up had reduced Lily Lake's depth by 12 ft since the 50's to a total depth of 45 feet. A major contributor to the sedimentation was identified as the NW and Churchill Drainage areas which had both caused erosion. Multiple stormwater treatment measures were identified and are listed as implementation actions 1 to 6 in Appendix B. Finally, the report noted herbicide applications would not treat the underlying nutrient issue in Lily Lake and would only serve to address the symptoms of the problem.

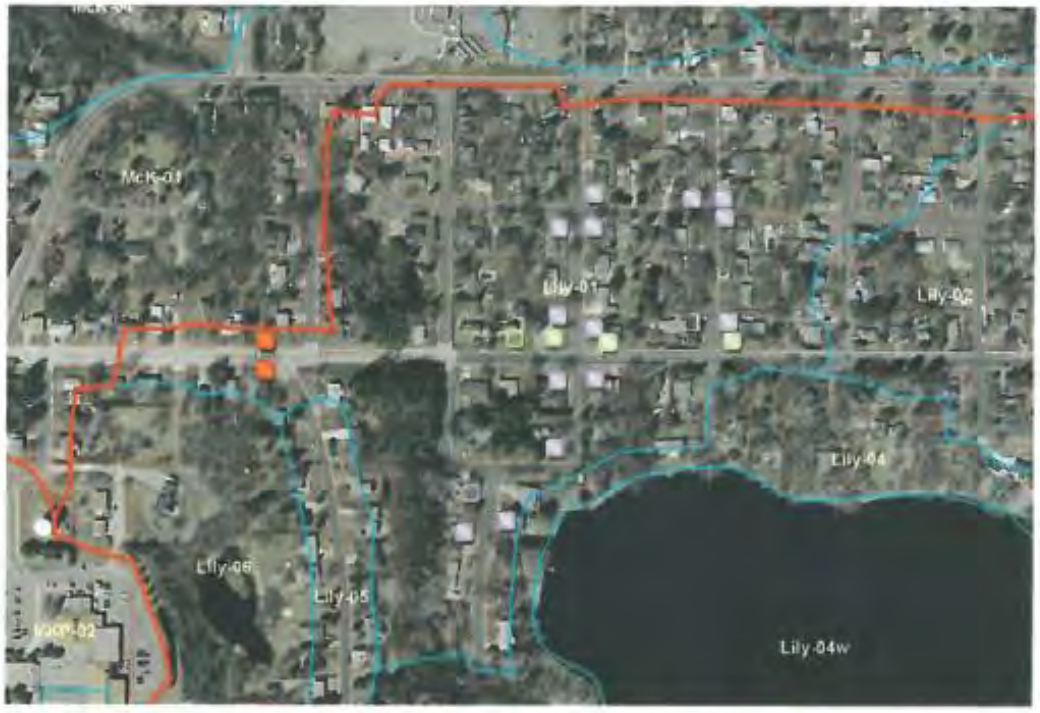
In 1997 a Feasibility Study conducted by SEH further investigated stormwater treatment options from the 1996 study. The report identified three recommended actions described as actions 7 to 10 in Appendix B.

In 1999 the Lily Lake Water Quality Improvement Review conducted by consulting firm Bonestroo Inc. (now Stantec) summarized the findings of monitoring from 1995 to 1998 and recommended stormwater treatment measures. At the time of this study Lily Lake had been above the state threshold for phosphorus (0.04 mg/L) since 1995. The load reduction recommendation from this study was 66 lbs. of TP annually, and the main finding was that the highest phosphorus concentration entered Lily Lake through the Brick Pond system. Many projects were identified and recommended from this study. They are described in the listed implementation actions 15-27 in Appendix B.

In 2007 the City of Stillwater Lily Lake Management Plan conducted by Wenck Engineering outlined basic lake information as well as water quality findings. The study found Total Phosphorus loading to Lily Lake in 2007 was 285 pounds. A 145 pound reduction goal was identified to meet State water quality standards. In 2007 Lily Lake was receiving stormwater runoff from a 587 acre fully-developed urban watershed. This inflow volume from the drainage area is 521 acre-feet. The report found the Lily Lake subwatershed contributed 100% of the hydraulic load and 93% of the phosphorus load to Lily Lake. Between 1995 and 2006 the TP ranged from 36-69 ug/l, and in only 3 of those years was the concentration at or below the 40 ug/l standard. Vegetation surveys showed an increase in Robbins and Largeleaf pondweeds and filamentous algae. The filamentous algae increase suggested increased nutrient loads to the lake which is enriching the lake sediment. In 2007 Lily Lake had an anoxic zone (less than 2mg/l of DO) as shallow as 2m in depth which the report purported could result in large release rates of phosphorus from the sediments. This can also stress fish that need at least 5mg/l of DO. Chlorophyll-a (Chl-a) concentrations had only exceeded the state standard (15 ug/l) in the past two years which could be a shift in the algal community from filamentous to blue-green algae or a loss of zooplankton grazing with an increase in the panfish population. The study recommended these signs of eutrophication be addressed. Secchi depth had been at or above the standard secchi depth of 1.2 meters. Prioritized projects added up to $869,500 to reduce the load by 120 lbs per year at a cost of $6,840 per pound. These projects are described in items 28-33 in Appendix B.

In 2010 the Lily Lake Subwatershed Assessment was conducted by the Washington Conservation District. The report more precisely mapped the drainage areas for Lily Lake and conducted P8 water quality modeling to simulate pollutant generation and treatment of the urban areas. Potential water quality best management practices were identified, prioritized and ranked. In this plan, 22 catchments were analyzed for their loading. Catchments around Lily Lake are shown in Figure 2. Potential practices to reduce phosphors loading to Lily Lake were identified in each catchment. Twelve of these were identified as having the best cost/benefit ratio for potential implementation. Each catchment has a map and summary chart in this report like the one shown in Figure 3. In-lake Alum Treatments were also explored in this study as recommended management practices. The recommendations from this report are detailed in items 34 in Appendix B.

Figure 2. Lily Lake Catchments



	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	13.1	8.7	4.4
	TSS Reduction (lb/yr)	7,217	5,794	3,952
	TSS Reduction (%)	53%	42%	29%
	Volume Reduction (acre-feet/yr)	10.9	7.3	3.6
	Volume Reduction (%)	29%	20%	9%
	Live Storage Volume (cubic feet)	4,080	2,450	1,100
Costs	Materials/Labor/Design	$61,200	$36,750	$16,500
	Promotion & Admin Costs	$122	$177	$318
	Total Project Cost	$61,322	$36,927	$16,818
	Annual O&M	$3,060	$1,838	$825
	Term Cost/lb/yr (30 yr)	$390	$353	$315

Figure 3. Example Catchment Map and Cost/Benefit Analysis

In 2013 the Lily Lake Aquatic Management Plan was conducted by Wenck Engineering. The goal of this study was to create an aquatic management plan for Lily Lake for the first time. Lily Lake didn't yet have an aquatic management plan, just sporadic herbicide application thus far for access paths, which was cost shared by the city and lakeshore owners. An example of such treatments was July 14th, 2005 when the Lake Management company applied for a Department of Natural Resources (DNR) permit for herbicide treatments for plankton algae on Lily Lake. Three main issues were identified in this plan. The first was overabundant submerged vegetation leading to minimal access by non-powered boats to open water areas, nuisance levels of dead plant biomass, and limited bird

and waterfowl habitat. The second was overabundance of submerged aquatic vegetation leading to limited swimming opportunities including the beach areas. The third was that overabundant plant communities reduce the aesthetic value of the lake leading to nuisance levels of dead plant biomass and odor issues. Several recommendations were identified and described in items 35-40 in Appendix B.

Curlyleaf pondweed was present in Lily Lake which is an invasive aquatic plant. There was an abundance of Robbins pondweed, Coontail, and Largeleaf pondweed. Water lilies were also found to be abundant later in the growing season. The DNR issues Aquatic Plant Management permits to provide riparian access, enhance recreational use, control invasive aquatic plants, manage water levels, and protect or improve habitat. There are also activities that do not require a permit. Harvesting and herbicide are two management strategies that could benefit Lily Lake. Limitations to both of these practices are quantified to minimize impact and are detailed in the report. Potential impacts on water quality were discussed in the plan. Harvesting can suspend sediment, but in Lily Lake this would be minimized because of the limited amount of cutting in shallow areas (less than 3-4 feet deep). Although removal of plant tissue occurs during harvesting it is likely it will not contribute more than 2-3% of the annual phosphorus loading. However, harvesting can also interrupt the life cycle of aquatic plants to indirectly aid in phosphorus loading.

2.3. Existing Water Quality Best Management Practices

Since the late 1990s the City of Stillwater and MSCWMO have installed stormwater water quality best management practices through targeted retrofitting, redevelopment standards, and voluntary conservation projects with private landowners. Stormwater best management practices improve the quality of water in Lily Lake by reducing total suspended solids (TSS), total phosphorus (TP), and nitrogen (N).

Multiple additional structural and non-structural practices have been implemented in the watershed that reduce annual TP discharging to Lily Lake but are not quantified in this report. For example, structural residential scale raingardens, native slope stabilization and native shorelines have been installed by individual landowners. As well, non-structural street sweeping zones, municipal curbside yard waste pick up, and catch basin sump cleaning are managed by the City and play a significant role in reducing annual phosphorus discharges to Lily Lake.

2.3.1. Water Quality BMPs Installed Between 2007-2017

Since 2007 the City of Stillwater and MSCWMO have installed 40 water quality BMPs during redevelopment, through targeted retrofitting, capital improvement projects, and voluntary landowner conservation practices. These practices have addressed 100 lbs. or 69% of the total load reduction of the 145 pounds load reduction identified in the 2007 Lily Lake Management Plan by Wenck Engineering. In this summary, the MSCWMO has credited structural infrastructure scale stormwater practices. To date, these stormwater practices account for 100.0 pounds of annual phosphorus reduction in the watershed.

The estimated load reductions to date are as follows:

Water Quality BMP	Year(s) Installed	Load Reduction Estimation Model	Estimated Annual Load Reduction of Phosphorus (lbs. /yr.)
32 Bioretention Basins, 4 Isolator Rows, 1 Infiltration Gallery	2010-2018	WinSLAMM	14.7
Greeley Gully Stabilization	2018	WinSLAMM and BWSR Water Pollution Reduction Estimator	40.0
Lakeview Hospital Gully Stabilization	2017	BWSR Water Pollution Reduction Estimator	4.7
MnDOT Hwy 36 Reconstruction Stormwater Wet Ponds (2)	2016	P8	8.0
Diasorin Bioretention Basin and Stormwater Reuse	2015	WinSLAMM	14.0
Lake Street Gully Stabilization	2010	BWSR Water Pollution Reduction Estimator	6.1
Driving Park Road Gully Stabilization	2008	BWSR Water Pollution Reduction Estimator	7.9
Curve Crest Cry Pond	2007	P8	4.7

Figure 4. Water quality improvement practices installed since 2007.

2.3.2. Water Quality BMP Inspection and Annual Maintenance

Existing water quality best management practices receive annual inspections and maintenance through multiple sources. The MSCWMO tracks and inspects all water quality BMPs annually. The results of the inspections are transmitted to parties responsible for maintenance. Many BMPs are maintained by residents through existing agreement or through the voluntary Adopt A Raingarden program and annual community raingarden clean up events. The remaining BMPs are maintained by the City of Stillwater either with their public works and park staff or through an agreement with the Washington Conservation District Maintenance Program. In 2018 over half of the raingardens were cleaned out by volunteers during the Spring Raingarden Clean Up event organized through the Adopt A Raingarden Program and the Lily Lake Association. In addition, many of the older curb cut bioretention basins that were frequently found to be partially, or nonfunctional due to clogged rock inlets, received new paver stone inlets in 2018. The MSCWMO inspections and maintenance

program was highlighted by the EPA in 2016. A complete summary of the program is located in Appendix C.

2.4. In-Lake Water Quality Monitoring

Lily Lake monitoring began in 1985 for TP, Chl-a, Secchi depth. The MSCWMO has reliable data starting in 1995 for Secchi depth and TP, and 1999 for corrected Chl-a.

Current monitoring efforts of Lily Lake consist of paired TP, corrected Chl-a, and Secchi measurements along with several other water quality parameters such as total Kjeldahl nitrogen (Figure), surface dissolved oxygen, and surface water temperature. The lake monitoring field season varies but can start as early as April and continue through October. A season long average (April-October) and summer average (June-September) is calculated for each monitoring season. The MPCA's water quality requirements are in reference to the summer season (June-September).

In 2017, 14 total samples were collected from Lily Lake, 9 of which were during the summer season. Lily Lake's TP levels have met the state standard since 2013 (Graph 1). Lily Lake's Chl-a levels have been above state standard since 2015, and the Secchi depth standard has not been met since 2016 (Graph 2, Graph 3).

Using a Kendall's Tau correlation test ($p<0.05$) Lily Lake has maintained a statistically significant improving trend for average total phosphorus since 2015, but there is currently no trend present for average Secchi transparency or average Chl-a corrected for pheophytin.

Based on the Chl-a results Lily Lake was considered eutrophic in 2017, according to the Carlson Trophic State Index. Summertime (June-September) TP, Chl-a and Secchi disk transparency averages for 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. See Appendix D for the 2017 MSCWMO Water Quality Monitoring Report. Current reports are also available on the MSCWMO Website http://www.mscwmo.org/water-monitoring

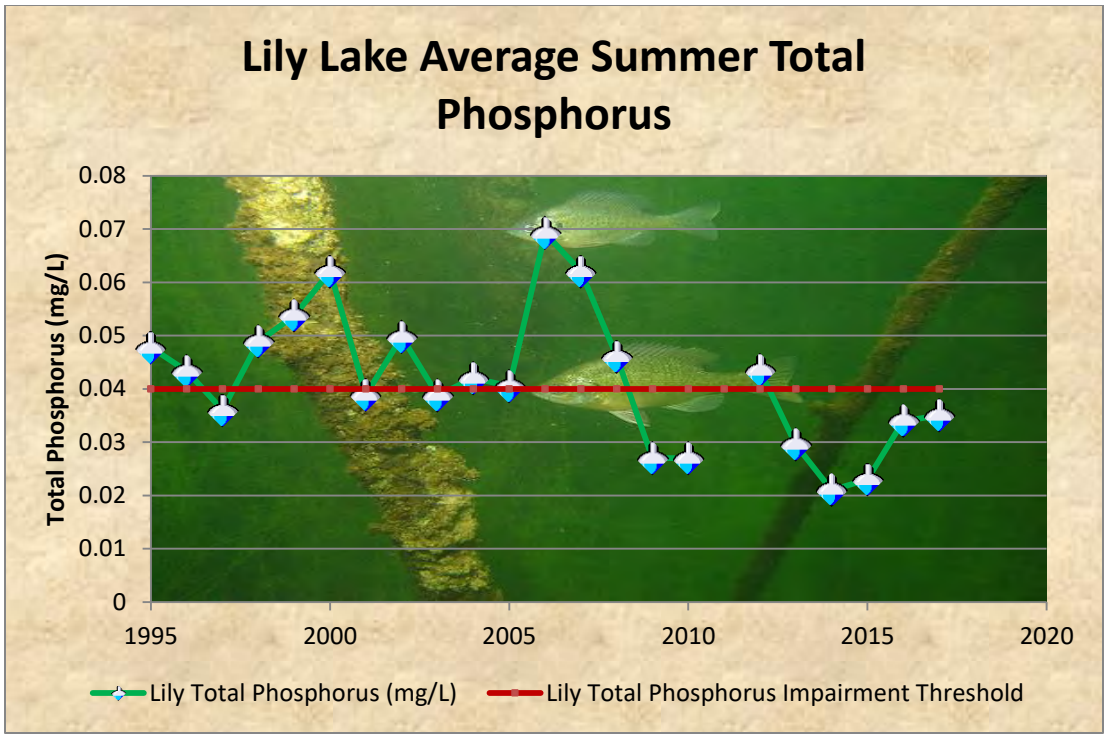


Figure 5. Lily Lake Average Summer Total Phosphorus measures from 1995 to 2017 (except 2011).

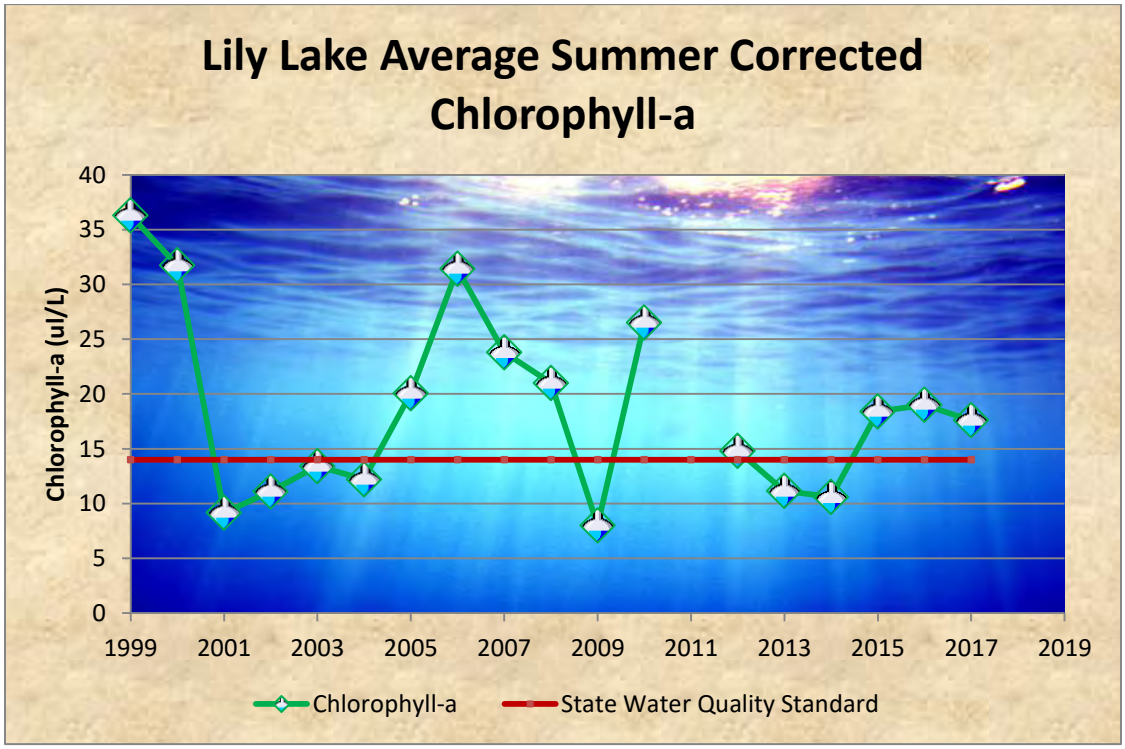


Figure 6. Lily Lake Average Summer Corrected Chlorophyll-a measures from 1999 to 2017 (except 2011).

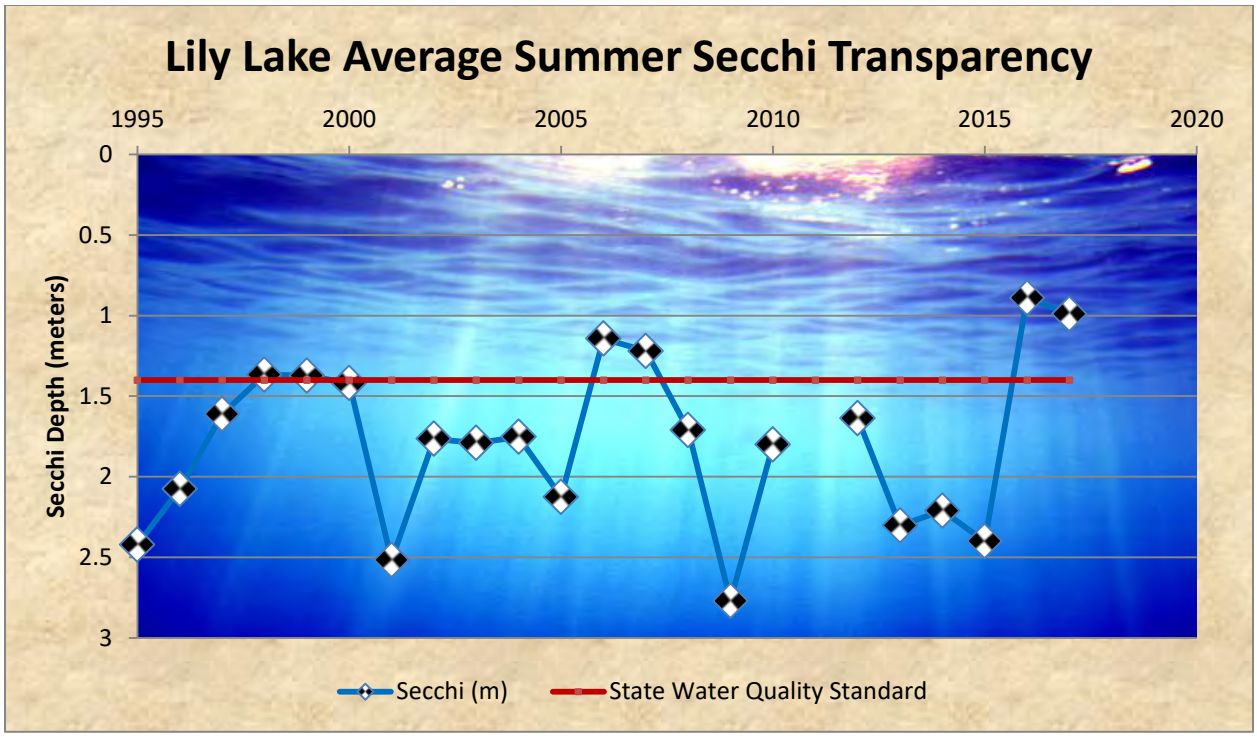


Figure 7. Lily Lake Average Summer Secchi depth from 1995 to 2017 (except 2011).

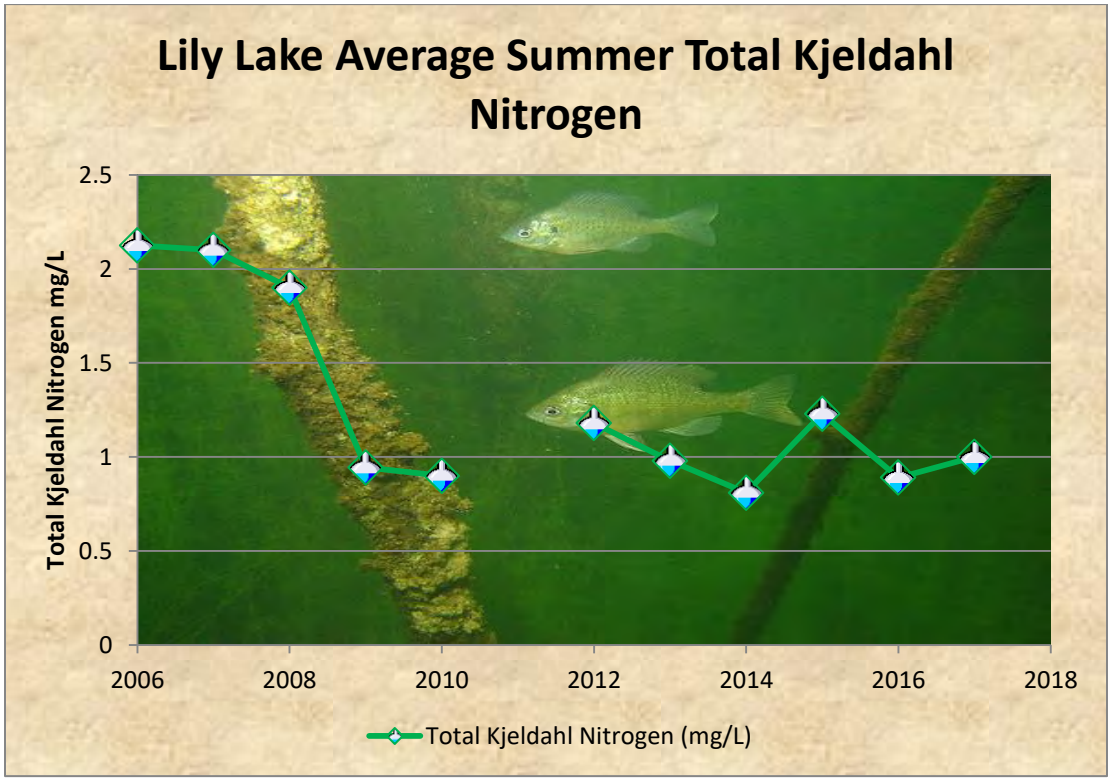


Figure 8. Lily Lake Average Summer Total Kjeldahl Nitrogen from 2006 to 2017 (except 2011).

3. CURRENT STUDY RESULTS AND GOALS FOR LILY LAKE

3.1. Delisting Lily Lake

The Minnesota Pollution Control Agency (MPCA) *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment*, indicates Lily Lake can be removed from the impaired waters list while avoiding a full TDML study if "during subsequent monitoring or the development of the TMDL study, new and reliable data or information indicates that the water body is no longer impaired and is meeting water quality standards. Such a water body would be delisted before a TMDL plan was completed" (Anderson, P. et al, 2016). Continued monitoring and use of monitoring data for Lily Lake would need to meet the MPCA's requirements of at least 8 paired TP, corrected Chl-a, and Secchi measurements (June to September) over a minimum of 2 years for the most recent 10 years. The state water quality thresholds for Lily Lake are 0.04 mg/L TP, 14 µg/L Chl-a, 1.4 m Secchi depth. By meeting the state standard in one of the ways stated below, Lily Lake could be removed from the impaired waters list:

• If TP meets the standard, and either Chl-a or Secchi meet the standard, the lake will be removed from the TMDL List.

• If TP exceeds the standard and corrected Chl-a AND Secchi meet the standard, and an improving trend in TP is observed or management activities are in place to maintain improved chl-a or Secchi observations, the lake may be delisted. This will require the local entity to provide information that details how the response conditions will be met over time (Anderson, P. et al, 2010).

3.2. Current Studies and Planned Water Quality BMP Projects

During the goal setting of 2015-2025 Middle St. Croix Watershed Management Plan the watershed and the City of Stillwater set the goal of completing the annual phosphorous stormwater load reduction goal of 145 pounds identified in the 2007 Lily Lake Management Plan. By completing the recommendations of that study and addressing the internal load, the data suggests Lily Lake will meet State water quality standard for in-lake total phosphorous of 0.04 mg/L and either Chl-a of less than 14 µg/L or a Secchi depth of greater than 1.4 m. As discussed above, previous efforts to reduce 100.0 pounds annual TP and control sources of phosphorus in the watershed have resulted in a long-term improving statistical trend for in lake phosphorous concentrations. To improve prioritization and targeting of practices five studies were conducted from 2015-2018. See Appendices D through H for the full study reports.

3.2.1. 2015-2016 Lily Lake Stormwater Outfall Monitoring

Targeted monitoring of stormsewer outfalls discharging into Lily Lake was conducted in 2015 and 2016 to more accurately identify the sources of nutrients impairing the lake. The ultimate goal of this effort was to more effectively target and design future stormwater management practices to treat stormwater prior to discharging into the lake.

In 2015 flow meters were installed at all outfalls that directly discharge to Lily Lake, and grab samples were taken at each location during storm events. Data was then collected at seven of eight outfalls to the lake. Analysis of this data indicated that only four of the eight identified outfalls contributed 95% of the discharge to Lily Lake. Monitoring in 2016 focused on these four major outfalls, with increased sampling frequency.

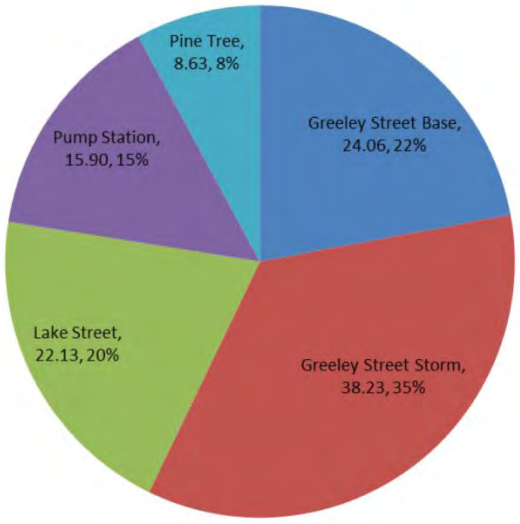


Figure 9. 2016 Phosphorus Load by Catchment (lbs.)

Results indicated that street runoff is the primary source of storm discharge at Greeley Street, although these findings were not definitive. Based on data collected and analyzed it was recommended that steps be taken to implement stormwater BMPs in areas of the Greeley Street and Lake Street catchments that directly discharge to Lily Lake, with less emphasis placed on water coming from Brick Pond.

The outfall from Brick Pond, a type 5 wetland located to the east of Lily Lake and connected to the by a stormwater pipe, continued to be monitored beyond 2015-2016. Sample results in 2017 were similar to results in prior years. The Greeley Street catchment base flow grab samples had low levels of TP and TSS. The 2017 average TP was 0.06 mg/L; similar to the 0.07 mg/L seen in 2016. The 2017 average TSS concentration was 3 mg/L; similar to the 2 mg/L seen in 2016. Monitoring at Brick Pond is currently planned to continue until 2025.

See the Appendix E for the MSCWMO Annual Monitoring Summary or visit the website for current water quality monitoring reports: http://www.mscwmo.org/water-monitoring

3.2.2. 2018 Lily Lake Subwatershed Analysis

2015-2016 Lily Lake outfall monitoring and Brick Pond outfall monitoring in 2015, 2016, and 2017 exhibited lower concentrations and load contributions from Brick Pond than the storm sewers discharging to Lily Lake. Based on this information, the subwatershed analysis did not evaluate contributing catchments to Brick Pond. Instead, modeling focused only on the catchments directly discharging to Lily Lake. The catchments were more closely examined for drainage area, impervious surface coverage, type, connectivity, and existing BMPs. Catchments were modeled using WinSLAMM and potential BMPs were identified by evaluating drainage areas, feasible BMP locations, and cost estimated based on complexity of BMPs.

The analysis incorporated modeling of 32 small scale BMPs installed since 2007 that infiltrate, filtrate, or reduce gross solids and TSS. WinSLAMM modeling indicates these BMPs reduce annual total phosphorus by 14.6 pounds within the catchments discharging directly to Lily Lake through storm sewer outfalls. Two additional gully stabilization projects occurred within the direct discharge watershed but were not incorporated into model because WinSLAMM does not accurately estimate loads and reductions for gully stabilization projects. Instead, gully stabilization project load reductions were estimated utilizing the Board of Water and Soil Resources Pollution Reduction Estimator (Version Sept, 2009) and are documented in Section 2.3.1.

Retrofit analysis identified four small scale bioretention basins (0.78 -1.6 acre drainage areas), one catchment scale bioretention basin (17.3 acre drainage area), and one catchment scale underground infiltration gallery (33.1 acre drainage area). The small scale bioretention opportunities were evaluated by seeking sufficiently contributing catchments and sufficient right-of-way area to reduce annual total phosphorus by at least 0.75 pounds per year without the need for a retaining wall greater than 3.0'. Larger scale BMPs were evaluated based on the potential to intercept and treat large drainage area without major utility conflicts and with suitable soils. See Appendix F for the complete 2018 Lily Lake Stormwater Retrofit Analysis.

Figure 10. Water quality BMPs and their catchment boundaries within the direct drainage area of Lily Lake

3.2.3. Final 45 Feasibility Study and Civic Engagement

Concurrent with the subwatershed analysis, the MSCWMO, East Metro Water Resource Education Program and EOR Inc. conducted a civic engagement process and a feasibility analysis for a variety of water quality BMPs to be installed in the Lily Lake watershed to meet the "Final 45" reduction goal to get Lily Lake delisted from the impaired waters list.

The restoration of Lily Lake's water quality and subsequent removal from the impaired waters list is a high priority for residents and local decision makers. Engaging the community and gathering input from citizen stakeholders, city staff and local elected officials was central to the targeting of the two large proposed infrastructure scale practices. At the writing of this report, the following engagement activities have taken place: open houses on July 11, 2017 and March 28, 2018, an article published in the Stillwater Gazette on February 16, 2018, City Council, City Parks and

Washington County Commissioners meetings between January and May 2018, Lily Lake Association meetings on June 7, 2017, September 12, 2017, and July 16, 2017. Additionally, the MSCWMO and East Metro Water Resource Education program started an Adopt A Raingarden Program in the Lily Lake watershed and coordination of the annual spring raingarden cleanup in coordination with the Lily Lake Association.

Based on results from the civic engagement processes and targeted monitoring in 2015 and 2016 two projects were chosen in the Greeley Street (Lily-09) and Lake Street (Lily-03) catchment areas for further refinement and cost estimating. The BMPs were chosen because of their ability to provide substantial phosphorus load reductions to the lake due to the high volume of stormwater contributed from these catchment areas. They were also chosen because of the availability of land, support from the City of Stillwater, and support from local residents. See Appendix G for 60% plans.

3.2.3.1. Lily Lake Park Infiltration Basin

The proposed BMP is a large bioinfiltration basin located in Lily Lake Park. The BMP would collect low flows of stormwater running off of Greeley Street from the south. The basin would provide 20,000 cubic feet of live storage and would infiltrate into the sandy soils on site. Overflow stormwater would return to the Greeley Street storm sewer. The BMP is sized to accommodate the volume from a 1.1" storm.

This BMP will be designed as an ecological landscape amenity. It will be planted with a wide variety of native, pollinator-friendly perennials, as well as native trees and shrubs that provide habitat for birds and wildlife. The basin would also feature a turf walking path at the perimeter and seating.

The contributing drainage area for this BMP consists of residential areas and park land with mature tree canopy cover totaling 15.2 acres. Impervious surfaces (rooftops, roadways, parking areas) make of 36% (5.5 acres) of the drainage area. In January, 2108 three soil borings were conducted by American Engineering Testing Inc. utilizing continuous split spoon sampling to a depth of 14.0'. The soil borings demonstrated predominately SP soils (poorly graded sand or poorly graded sand with gravel) with a 1.0' confining layer of ML soils (silt) at 10-12' feet below the surface.

Under current conditions, stormwater from this area is discharge directly to Lily Lake via storm sewer located along South Greeley Street. Under proposed conditions, flow will be diverted from the existing storm line to the BMP at Lily Park. See Appendix G for 60% Plans.

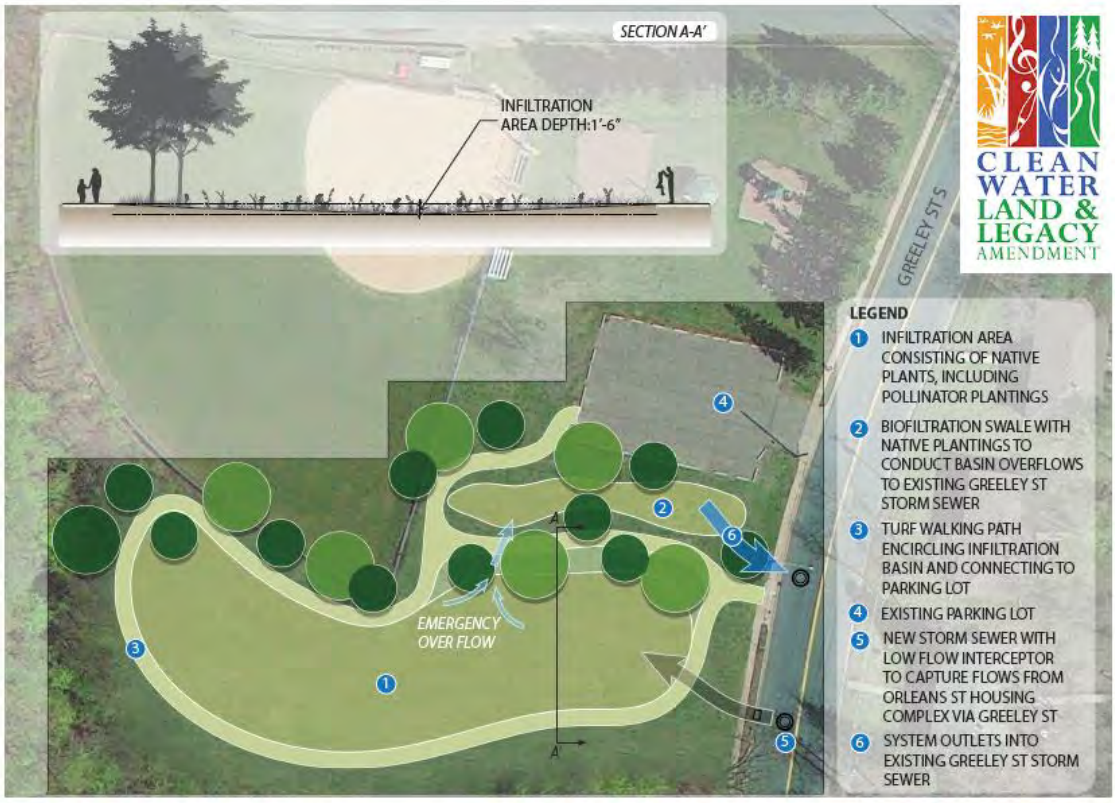


Figure 11.Lily Lake Park Infiltration basin landscape rendering used for public engagement.

3.2.3.2. Washington Park Infiltration Gallery

The proposed BMP at Washington Park is a large underground infiltration trench covering a 9,000 square foot area. The infiltration gallery consists of clear rock and four 6' diameter perforated steel pipes which combined provide 52,000 cubic feet of storage. Stormwater is piped into the trench underground from the manhole at the intersection of Lake and Greeley Street. The system is sized to nearly accommodate the volume from a 1.1" storm event (54,000 cubic feet). The proposed design replicates the infiltration gallery installed as part of the Arlington Hamline water quality improvement project by the Capitol Region Watershed District in 2007. The Arlington Hamline underground infiltration gallery's performance has been monitored for 11 years and it is currently performing as designed.

The contributing drainage area for this BMP consists largely of residential land use, but includes smaller areas of park land and institutional land use. The total drainage area is 34.3 acres with impervious surfaces making up 40% (13.7 acres) of the land cover. In January, 2108 two soil borings were conducted by American Engineering Testing Inc. utilizing continuous split spoon sampling to a depth of 26.0'. The soil borings identified 12.0'-14.0' of urban fill over 14.0' of SP soils (poorly graded sand or poorly graded sand with gravel).

Under current conditions all untreated stormwater is directed from the storm main along South Greeley Street to Lily Lake via a storm sewer line along Lake Street. There are a few existing BMPs located within the drainage area, but an estimated 91% of the runoff generated during a 1.1-inch

storm event reaches Lily Lake. Under proposed conditions, this untreated portion will be diverted to the proposed infiltration gallery. See Appendix G for 60% Plans.

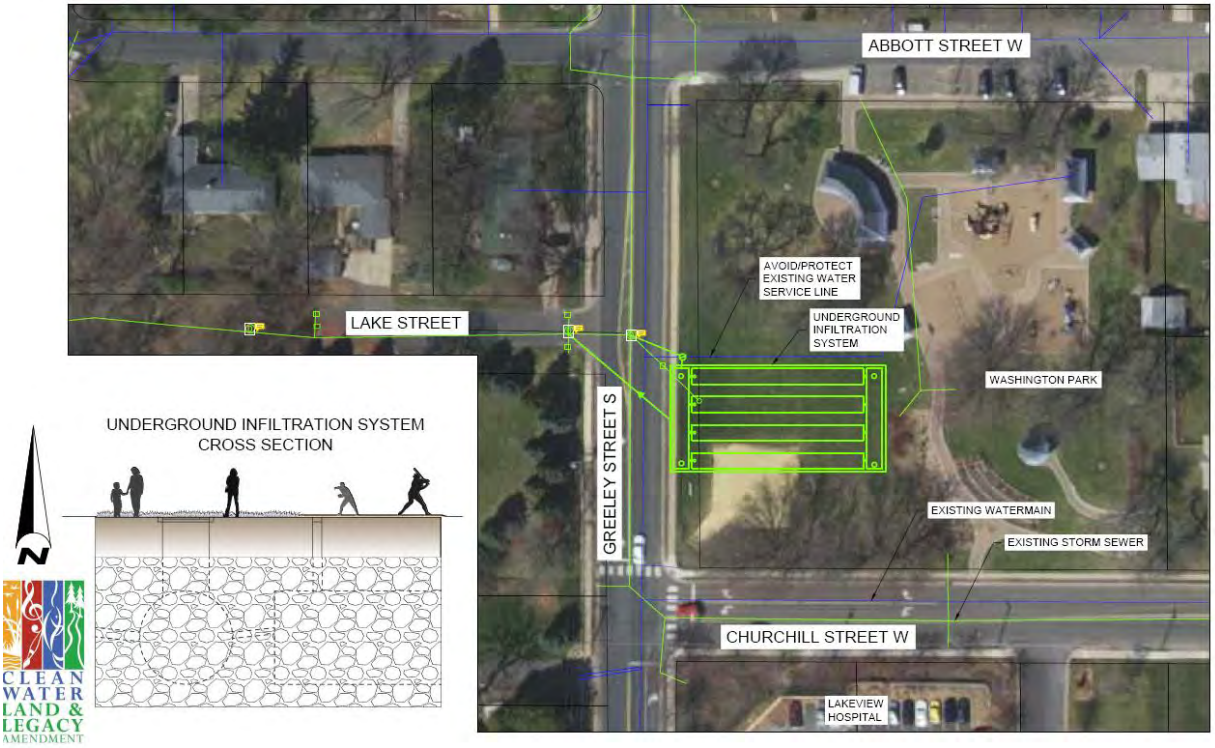


Figure 12. Washington Park Infiltration Gallery overview used for public engagement.

3.2.4. Lily Lake Internal Load Study

In 2018 Wenck collected sediment cores from Lily Lake and conducted an internal load analysis. The study found a moderately high anaerobic phosphorus release rate and the high levels of iron-bound P in Lily Lake's sediment and alum treatment will reduce internal phosphorous loading by up to 120lbs. per year. Specifically the report advises two alum treatments at areas of the lake with a depth of 30 feet. Internal loading treatments with alum are proposed for 2020 and 2021. See Appendix H for the final report.

3.2.5. Herbicide and Algaecide Treatment on Lily Lake

Herbicide and algaecide treatments have historically been coordinated by the Lily Lake Association and the City of Stillwater through a licensed commercial applicator in efforts to improve aquatic recreation. These treatments required a permit from the DNR and were implemented in 1993, 1995-2011, and in 2016-2017. In 2016, water quality monitoring staff documented a rapid decline in secchi disk readings after applications. While there are many factors that can affect annual secchi disk readings, the watershed conducted an evaluation of years herbicides and algaecides had been applied to Lily Lake based on limited data from the Minnesota Department of Natural Resources permits and conducted a review of current research. The evidence showed that algaecide and herbicide use can result in decreased water clarity.

Based on this information, the Lake Association and the City decided to not conduct large scale treatment (8 acres) of the Lake at meeting reviewing the data on July 18, 2018. However, individual landowners hired a licensed applicator to conduct smaller scale (8,000 square feet) applications. The Watershed will continue to work with the Lake Association and the City to continue to advocate for suspension of future herbicide and algaecide application on Lily Lake to negate the potential impacts to water quality. See Appendix I for the review of literature and citations.

4. RECOMMENDATIONS

Install the Lily Park Bioinfiltration Basin and the Washington Park Infiltration Gallery to reduce 51.0 lbs. total phosphorus discharging directly to Lily Lake from 47.7 acres of urban residential and institutional land uses.

Conduct two alum treatments to Lily Lake to reduce annual internal loading by 120 lbs. pear year.

Continued in-lake monitoring for Lily Lake to demonstrate when Lily Lake meet the MPCA's requirements of at least 8 paired TP, corrected Chl-a, and Secchi measurements (June to September) over a minimum of 2 years for the most recent 10 years.

Continue to monitor the flow and annual phosphorus concentration from Brick Pond into Lily Lake. There are currently no accurate methods of modeling phosphorus contributions from wetlands. To verify that the annual TP loads from Brick Pond remain low, it is recommended to continue outfall monitoring to Lily Lake.

Continue annual inspections and maintenance. To ensure installed BMPs continue to function as intended the MSCWMO needs to continue to inspect BMPs annually and the responsible parties need to continue to perform maintenance on the existing practices. To continue to ease the burden of maintenance, the MSCWMO should continue the Adopt A Raingarden program and annual community raingarden clean up events.

APPENDIX A. REFERENCES CITED

APPENDIX B. TABLE OF PREVIOUS STUDIES & RECOMMENDATIONS

APPENDIX C. MSCWMO INSPECTION AND MAINTENANCE PROGRAM

APPENDIX D. 2017 WATER MONITORING SUMMARY

APPENDIX E. 2015-2016 LILY LAKE TARGETED MONITORING SUMMARY

APPENDIX F. 2018 LILY LAKE SUBWATERSHED RETROFIT ANALYSIS

APPENDIX G. 60% PLANS LILY BIOINFILTRATION AND WASHINGTON GALLERY

APPENDIX H. LILY LAKE INTERNAL LOAD STUDY

APPENDIX I. HERBICIDE AND ALGICIDE USE ON LILY LAKE