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LILY LAKE TARGETED MONITORING SUMMARY

Prepared for: Middle Saint Croix WMO
Prepared by: Washington Conservation District

Introduction and Methods

The 2015 Middle St. Croix Watershed Management Organization (MSCWMO) Watershed Management Plan prioritized targeted monitoring protocols to more accurately identify sources of nutrients impairing Lily Lake. The goal of targeted protocol is improved placement and design of best management practices to reduce the nutrient load to the lake.

The MSCWMO worked closely with the Washington Conservation District to develop the following monitoring plan to achieve this goal:

- Year One-Identify all outfalls that directly discharge into Lily Lake. Install flow meters at all these locations and collect continuous discharge data for one season. Additionally, collect grab samples at each location during storm events to allow for a loading estimate to be generated.
- Year Two-Using data collected in year one, prioritize monitoring to the four catchments contributing the majority of the nutrient load to the lake. Increase sampling frequency at those sites where it is feasible to develop a more accurate loading estimate. Use data collected in year two to confirm trends observed in year one and more accurately identify nutrient sources

This plan was successfully implemented during the 2015 and 2016 growing seasons. In 2015, flow loggers were installed at seven outfalls to Lily Lake (see attached site map). An eighth outfall was identified after the initial location selection process, but no logger was installed at this site due to constraints for access of a logger. Observations of the flow occurring at this location were made while the other seven were visited during storm events and it was determined that negligible flow to the lake came from that catchment. Data collected in 2015 indicated that ~95% of the discharge to Lily Lake comes from four of the eight identified catchments.

In 2016 monitoring was focused on just these four catchments, with increased sampling frequency also occurring at the Greeley Street location to better characterize the variety of flow regimes present at that site. Discharge was calculated using an area velocity relationship at each location. Site installation and water quality sampling were conducted per WCD standard operating procedures, which can be found on the WCD website https://www.mnwcd.org/water-quality-water-monitoring/. The period of record for each site can be found in the table to the left.

Measurement Period of Record

Site	Stage, Velocity, Discharge, Total Phosphorus and Total Suspended Solids
Greeley Street	4/18/2015 - 5/23/2015, 6/4/2015 - 6/10/2015, 7/1/2015 - 10/1/2015, 4/18/2016 - 5/6/2016, 6/23/2016 - 9/2/2016, 9/12/2016 - 11/1/2016
Lake Street	4/20/2015 - 10/29/2015, 4/18/2016 - 10/31/2016
Willard Street	5/6/2015 - 10/29/2015
Grove Street	4/22/2015 - 10/12/2015
Pump Station	4/20/2015 - 10/29/2015, 4/18/2016 - 5/24/2016, 6/23/2016 - 10/31/2016
Pine Tree	4/22/2015 - 10/29/2015, 4/18/2016 - 10/31/2016
Lily Beach	4/20/2016 - 10/26/2015

Data

In 2015, 15-minute continuous stage, velocity and discharge measurements were collected at seven outfalls to Lily Lake. Storm event based grab sampling was conducted at six of the seven outfalls, the exception being the Lily Beach site due to no discharge being recorded during the monitoring season. In 2016, these same parameters were collected at four of the previous seven sites. Discharge and loading estimates by site for 2015 and 2016 can be found in Table 1 and Table 2 respectively. Water quality sample results by site from each year can be found in Table 3 and Table 4.

Table 1: 2015 Discharge and Loading Estimates

Site	Date range	Total Estimated Flow (CF)	Total Estimated Flow (ac-ft)	Proportion of Total Flow	Proportion of Storm Flow	Average Phosphorus Concentration (mg/L)	Phophorus Range (mg/L)	Average TSS Concentration (mg/L)	TSS Range (mg/L)	TP Load (lbs.)	TSS Load (lbs.)
Greeley Street Base	4/23 - 10/1*	4,641,079	106.60	0.6456	N/A	0.091	0.028 - 0.21	3.6	1 - 9	26.36	1043.01
Greeley Street Storm	4/23 - 10/1*	1,194,990	27.45	0.1662	0.4690	0.219	0.063 - 0.382	48	2 - 132	16.34	3580.73
Lake Street	4/20 - 10/29	429,834	9.87	0.0598	0.1687	0.213	0.124 - 0.329	12	8 - 16	5.72	321.99
Willard Street	5/6 - 10/29	29,965	0.69	0.0042	0.0118	0.201	0.14 - 0.315	11	4 - 24	0.38	20.58
Grove Street	4/22 - 10/12	34,733	0.80	0.0048	0.0136	0.449	0.074 - 2	36	4 - 91	0.97	78.06
Pump Station	4/20 - 10/29	497,872	11.44	0.0693	0.1954	0.274	0.183 - 0.376	24	8 - 45	8.52	745.93
Pine Tree	4/22 - 10/29	360,335	8.28	0.0501	0.1414	0.231	0.081 - 0.408	14	5 - 41	5.20	314.92
Lily Beach	4/20 - 10/26	0	0	0	0	0	0	0	0	0	0

*Indicates that estimations of flow occur during period using similar logged flow conditions

Table 2: 2016 Discharge and Loading Estimates

Site	Date range	Total Estimated Flow (CF)	Total Estimated Flow (ac-ft)	Proportion of Total Flow	Proportion of Storm Flow	Average Phosphorus Concentration (mg/L)	Phophorus Range (mg/L)	Average TSS Concentration (mg/L)	TSS Range (mg/L)	TP Load (lbs.)	TSS Load (lbs.)
Greeley Street Base	4/18 - 11/1*	5,504,990	126.44	0.6476	N/A	0.07	0.029 - 0.122	2	1 - 6	24.06	687.31
Greeley Street Storm	4/18 - 11/1*	1,401,207	32.18	0.1648	0.4678	0.437	0.059 - 0.744	233	10 - 616	38.23	20380.96
Lake Street	4/18 - 10/31	576,466	13.24	0.0678	0.1925	0.615	0.107 - 1.91	83	7 - 259	22.13	2986.88
Pump Station	4/18 - 10/31*	603,613	13.86	0.0710	0.2015	0.422	<0.020 - 1.02	51	11 - 99	15.90	1921.74
Pine Tree	4/18 - 10/31	414,015	9.51	0.0487	0.1382	0.334	0.072 - 0.676	53	5 - 148	8.63	1369.80

*Indicates that estimations of flow occur during period using similar logged flow conditions

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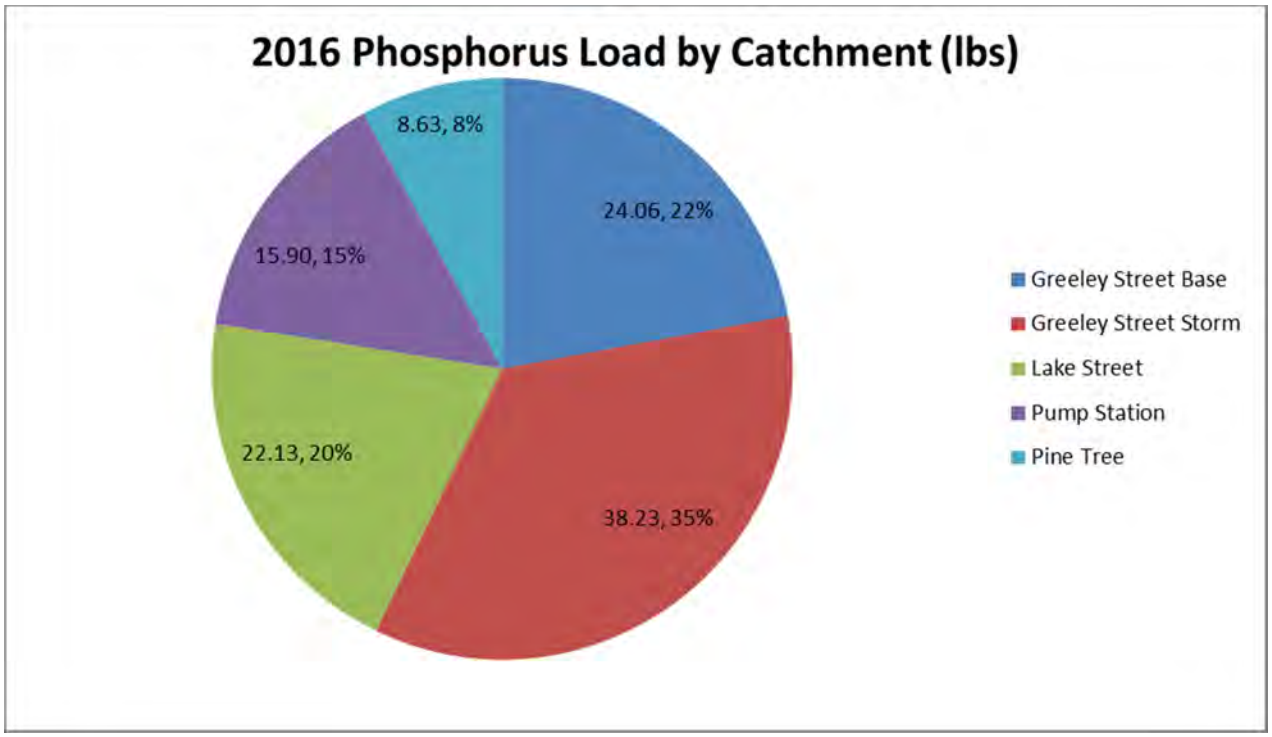
Table 3: 2015 Sample Results

	Greeley Street		Lake Street		Willard Street		Grove Street		Pump Station		Pine Tree		Lily Beach	
	TP (mg/L)	TSS (mg/L)	TP (mg/L)	TSS (mg/L)	TP (mg/L)	TSS (mg/L)	TP (mg/L)	TSS (mg/L)	TP (mg/L)	TSS (mg/L)	TP (mg/L)	TSS (mg/L)	TP (mg/L)	TSS (mg/L)
6/17/2015	0.382	84	0.329	8	0.196	4	0.092	4	0.376	29	0.188	7	N/A	N/A
6/22/2015	0.18	13	0.157	16	0.145	8	2	17	0.304	16	0.408	9	N/A	N/A
7/6/2015	0.063	~2			0.209	4	0.079	9	0.299	8	0.262	9	N/A	N/A
7/22/2015	0.21	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/28/2015	0.221	11	0.247	13	N/A	N/A	0.13	91	0.219	19	0.228	5	N/A	N/A
8/18/2015	0.27	132	0.21	14	0.315	24	0.318	90	0.265	45	0.218	41	N/A	N/A
8/25/2015	~0.035	~1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/17/2015	0.196	46	0.124	8	0.14	14	0.074	7	0.183	26	0.081	12	N/A	N/A
9/22/2015	~0.028	~1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 4: 2016 Sample Results

	Greeley Street		Lake Street		Pump Station		Pine Tree	
	TP (mg/L)	TSS (mg/L)	TP (mg/L)	TSS (mg/L)	TP (mg/L)	TSS (mg/L)	TP (mg/L)	TSS (mg/L)
4/27/2016	~0.039	~1	N/A	N/A	N/A	N/A	N/A	N/A
5/13/2016	0.059	10	0.173	7	0.168	25	0.141	23
5/18/2016	~0.036	~1	N/A	N/A	N/A	N/A	N/A	N/A
5/25/2016	0.744	383	1.910	259	1.020	99	0.676	148
5/31/2016	0.285	141	0.745	105	0.748	64	0.563	26
6/22/2016	0.122	3	N/A	N/A	N/A	N/A	N/A	N/A
7/21/2016	0.115	6	N/A	N/A	N/A	N/A	N/A	N/A
8/4/2016	0.366	616	0.142	36	<0.020	55	0.219	62
9/6/2016	0.732	14	0.107	9	0.163	11	0.072	5
9/28/2016	~0.029	~1	N/A	N/A	N/A	N/A	N/A	N/A
10/17/2016	0.076	~1	N/A	N/A	N/A	N/A	N/A	N/A

Figure 1: Load Allocation



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Results and Conclusions

The targeted monitoring approach implemented in this investigation of Lily Lake had the goal of more accurately identifying the major sources of nutrients to the lake and to help steer targeting and design of stormwater management practices. Short term monitoring limits the number of conclusions that can be drawn. With only two years of monitoring data and relatively limited sample results seasonal variations have a greater impact on observed differences. However uncertainty can be reduced through the comparison of the proportion of flow observed at each site year over year. Proportional flow values presented in Table 1 and Table 2 demonstrate consistency between 2015 and 2016, indicating that relative discharge contribution by catchment to Lily Lake has been accurately assessed. This consistency supports the approach of focusing on the four sites monitored in 2016 as the primary contributors to Lily Lake. The following discussion of results will focus on 2016 data to reflect this fact. See Table 1 and Figure 1 for reference in the discussion following.

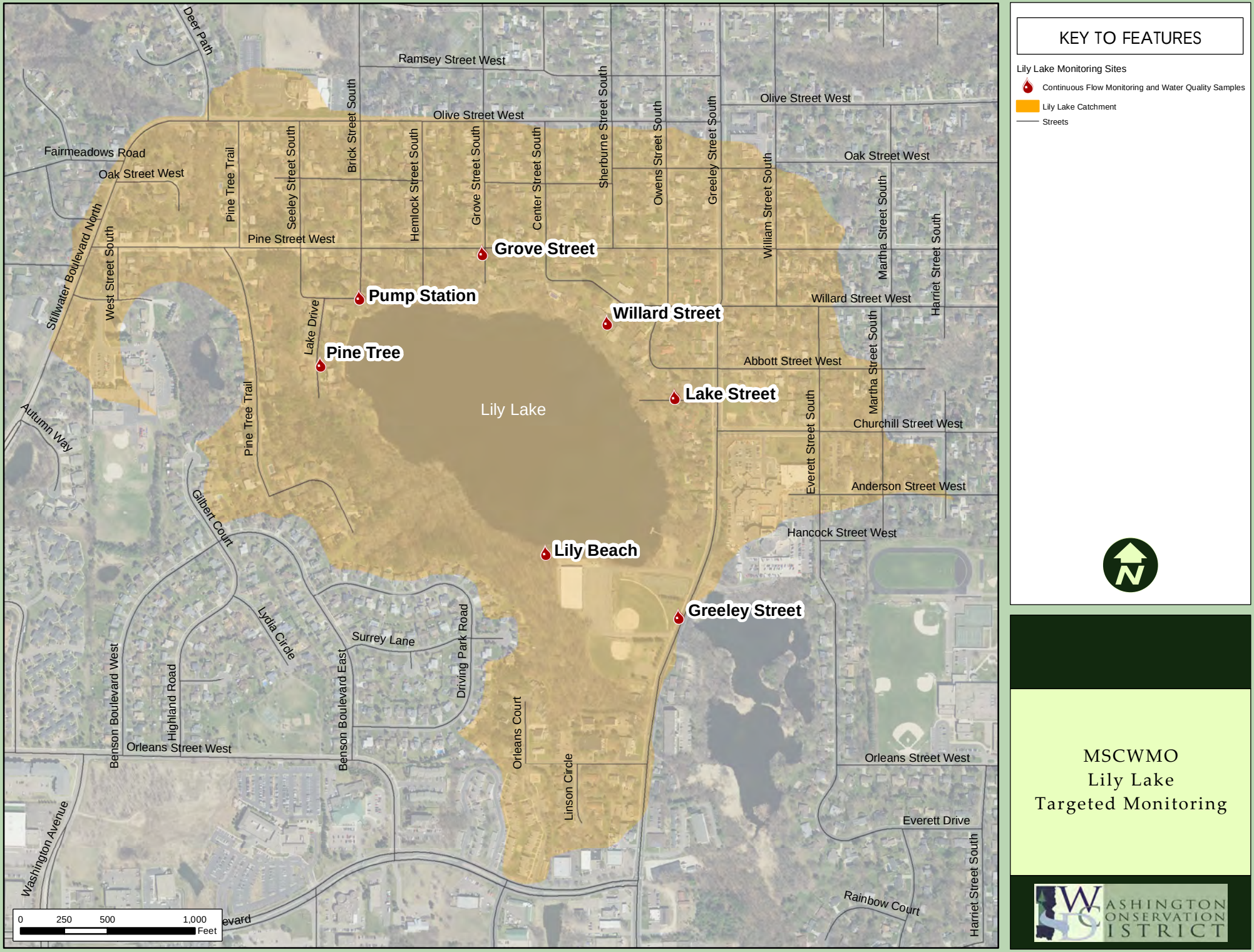
The average phosphorus concentration observed during storm events was 0.615 mg/L at Lake Street, 0.437 mg/L at Greeley Street, 0.422 mg/L at Pump Station and 0.334 mg/L at Pine Tree. The highest observed phosphorus value of 1.91 mg/L was recorded on 05/25/2016 at Lake Street. For comparison purposes, three similar stormwater sites located in South Washington Watershed District had phosphorus concentration averages between 0.124 – 0.254 mg/L in 2016, with a peak observed value of 0.347 mg/L.

By using these average concentrations and recorded flow data, an estimate of phosphorus loading to the lake was developed. Results indicate 78% of the total phosphorus load to Lily Lake is occurring during storm runoff events. The remaining 22% of the phosphorus load is from base flow periods from Brick pond to Lily Lake, as indicated by the monitoring station at Greeley Street. However, base flow from Brick Pond accounts for 65% of the total discharge to the lake. This low phosphorus load from the majority of the discharge to Lily Lake can be explained by the very low concentrations observed during base conditions. For the majority of the 2016 monitoring period, phosphorus concentrations coming out of Brick Pond were below 0.07 mg/L, and peaked just above 0.1 mg/L during the height of the growing season. While further reducing the phosphorus concentration discharging from Brick Pond is possible, it is not recommended due to the comparatively small reduction in phosphorus load to Lily Lake.

As stated above, 78% of the phosphorus load to Lily Lake is occurring during storm events. The highest contributing catchments during these events are Greeley Street and Lake Street, which combined account for 55% of the load. The phosphorus load from Greeley Street appears to be discharge driven, as the average phosphorus concentration during storm events was on the lower end of those observed yet the total flow was roughly triple that of the other sites. Also of note is that it appears the majority of this flow is coming from direct street runoff and not through Brick Pond. During the August 4th storm event a set of samples were collected at Greeley Street, one in the normal sampling location that combines all the street runoff and discharge from Brick Pond and one comprised of just street runoff. Table 4 shows the results from the combined sample of 0.366 mg/L for total phosphorus, the result for the street runoff only sample was 0.479 mg/L. Although this is only a single result and no definitive conclusions can be made, it does indicate that the water coming out of Brick Pond is actually serving to dilute the phosphorus entering the lake and supports field observations that street runoff is the primary component of storm discharge at this location. Therefore, it is recommended that steps be taken to implement best management practices in those areas of the Greeley Street catchment that are directly discharging to Lily Lake, with less of an emphasis being placed on water entering Brick Pond first.

Loading estimates indicate the next priority would be the Lake Street catchment, which showed the highest average and discrete phosphorus concentrations. However, reducing the discharge and/or the phosphorus concentration at any of the four catchments identified as high contributors should have a

significant impact on improving the water quality in Lily Lake. Therefore, it is recommended that these results be used in conjunction with implementation factors of stormwater management practices for targeting improvements to the catchments.


Deer Path
Ramsey Street West
Olive Street West
Fairmeadows Road
Oak Street West
Pine Tree Trail
Seeley Street South
Brick Street South
Hemlock Street South
Grove Street South
Center Street South
Sherburne Street South
Owens Street South
Greeley Street South
William Street South
Martha Street South
Harriet Street South
Pine Street West
Grove Street
Pump Station
Willard Street
Willard Street West
Stillwater Boulevard North
West Street South
Lake Drive
Pine Tree
Abbott Street West
Lake Street
Lily Lake
Churchill Street West
Everett Street South
Autumn Way
Anderson Street West
Gilbert Court
Hancock Street West
Lily Beach
Greeley Street
Lydia Circle
Surrey Lane
Driving Park Road
Benson Boulevard West
Highland Road
Benson Boulevard East
Orleans Court
Orleans Street West
Linson Circle
Everett Drive
Washington Avenue
Rainbow Court
0 250 500 1,000 Feet
KEY TO FEATURES
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Continuous Flow Monitoring and Water Quality Samples
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