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Half Moon Lake Watershed Management Plan

Nine Element (319) Watershed Plan

Prepared for
City of Eau Claire, Wisconsin

August, 2018

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Acronyms

Acronym	Description
ac	acre
AIS	aquatic invasive species
BMP	best management practice
CIP	capital improvements plan
CLP	curlyleaf pondweed
GIS	geographic information system
kg	kilograms
lbs	pounds
MEP	maximum extent practicable
µg/L	micrograms per liter
MS4	municipal separate storm sewer system
P	phosphorus
TMDL	Total Maximum Daily Load
TP	total phosphorus
TSS	total suspended solids
USACE	United States Army Corps of Engineers
WI DNR	Wisconsin Department of Natural Resources

1.0 Background and Purpose

Half Moon Lake is a small, shallow lake formed as an oxbow of the Chippewa River, located in the city of Eau Claire and the Lower Chippewa River Basin. This watershed management plan (Plan) has been developed for Half Moon Lake, consistent with the requirements of Section 319 of the Clean Water Act (i.e., a nine element plan). This Plan utilizes previous analyses of Half Moon Lake in developing the nine elements, while augmenting the results with additional analysis, where necessary.

Readily available information about watershed characteristics and lake data, GIS data, and information compiled by the city (public concerns, past reports, surveys) and other sources were brought together for the Plan. In addition, the Plan includes input from meetings and interviews of key staff and stakeholders to gain additional institutional knowledge of the lake (e.g., known pollutant sources and magnitudes), existing management measures, water quality goals and management measures that should be considered for future implementation.

1.1 Half Moon Lake Watershed and Lake Characteristics

Figure 1-1 shows the Half Moon Lake watershed, including storm sewer lines, subwatershed divides and existing best management practices (BMPs) for stormwater treatment. The figure shows that the eastern half of the watershed has higher density development, while the island and western half of the watershed primarily contains parkland and lower density development. Land use in the watershed is approximately 45% residential, 41% open land and 14% commercial. Table 1-1 lists the drainage areas for each subwatershed and the individual lake basins (Brauns bay, east arm, south arm, and west arm) that receive drainage from each subwatershed. The total watershed area is approximately 662 acres, including the lake surface area. Figure 1-2 shows the lake and storm sewer sampling station locations that have been utilized for water quality studies since 1999.

Half Moon Lake has a surface area of approximately 132 acres with a maximum depth of 9 feet and a mean depth of 6 feet. The Wisconsin Department of Natural Resources (WI DNR) considers Half Moon Lake a seepage lake. Most of the shoreline is publicly owned by the City of Eau Claire and the city has a policy of purchasing properties abutting the lake when they become available. There are only three parcels that remain in private ownership at this time. Currently, city ordinances prohibit motorboat operation on the lake (applies to boats powered by an internal combustion engine).

SS3
SS6
SS2
SS7
West Arm
SS4
South Arm
East Arm
SS5
SS1
Brauns Bay
Sherman Creek Outlet
Beccas Brook Seepage

Half Moon Lake Watershed
Subwatersheds
BMP
Overflow Storage
Storm Sewerlines
Outfalls/Lake Outflows

500 0 500
Feet

HALF MOON LAKE
WATERSHED MAP
Nine Element Plan
City of Eau Claire

FIGURE 1-1

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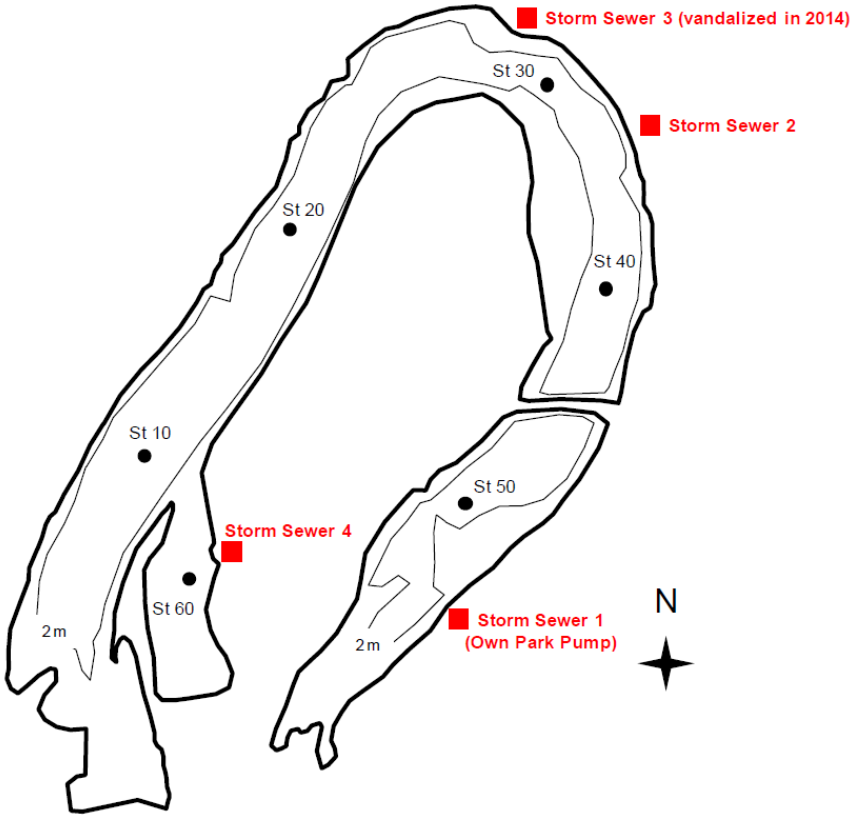
Table 1-1 Half Moon Lake Subwatersheds

Name	Area (acres)	Drains to
East Arm(1)	96.45	East Arm (St 30 and St 40)
SS5	37.61	East Arm (St 30 and St 40)
SS2	18.12	East Arm (St 30 and St 40)
SS3	50.74	East Arm (St 30 and St 40)
SS6	41.35	West Arm (St 10 and St 20)
West Arm(1)	153.94	West Arm (St 10 and St 20)
SS7	41.68	West Arm (St 10 and St 20)
Brauns Bay(1)	30.44	St 60
SS4	21.77	St 60
SS1	87.12	South Arm (St 50)
South Arm(1)	82.67	South Arm (St 50)

Note(s):
See Figure 1-1 for subwatershed delineations and Figure 1-2 for lake and storm sewer sampling station locations.
(1) Area includes lake surface area



(James, 2016)

Figure 1-2 Sampling station locations in Half Moon Lake

1.2 Synopsis of Previous Studies

The formation of the Advisory Task Force in 1998 led to a series of high-quality studies regarding the desired uses and the water quality of Half Moon Lake. Early diagnostic studies (e.g., USACE, 2001) conducted extensive analysis of the sources and sinks of phosphorus for Half Moon Lake. The USACE study identified high phosphorus concentrations as the primary cause of lake turbidity and phytoplankton growth. The phosphorus sources were shown to be 80-percent internal and 20-percent external. Most of the previous studies and implementation projects have been funded with grant assistance from WI DNR (as shown in Table 1-2).

Table 1-2 Wisconsin DNR grants awarded for Half Moon Lake

Grant Title	Date Awarded
CITY OF EAU CLAIRE: Half Moon Lake Water Quality Study	1992
CITY OF EAU CLAIRE: ACQ-Half Moon Lake Land Acquisition-Layton, Thompson Parcels	1995
CITY OF EAU CLAIRE: LMI-Half Moon Lake School Lakeshore Drainage Improvement	1995
CITY OF EAU CLAIRE: Half Moon Lake Water Quality Monitoring and Education	1996
CITY OF EAU CLAIRE: Half Moon Lake Assessment - Task Two	1999
CITY OF EAU CLAIRE: Half Moon Lake Assessment - Task One	1999
CITY OF EAU CLAIRE: Half Moon Lake Assessment - Task 5, Eau Claire	1999
CITY OF EAU CLAIRE: Half Moon Lake Assessment, Tasks 3 and 4, Eau Claire	1999
Half Moon Lake Education and Management	2004
CITY OF EAU CLAIRE: Half-Moon Map-Core	2005
CITY OF EAU CLAIRE: Half-Moon Alum Research	2005
EAU CLAIRE AREA SCHOOL DISTRICT: Half-Moon Curly Leaf Monitoring	2006
CITY OF EAU CLAIRE: Half-Moon CLP, Milfoil Research	2008
CITY OF EAU CLAIRE: LMI-Half-Moon Alum	2010
CITY OF EAU CLAIRE: Half Moon Lake CLP Treat, Assess	2011
CITY OF EAU CLAIRE: Half Moon Alum Evaluation	2011
CITY OF EAU CLAIRE: Half Moon Endothol 2	2013
CITY OF EAU CLAIRE: Half-Moon Endothol 3	2015
CITY OF EAU CLAIRE: LMI-Alum Treatment Half Moon Lake	2017

In 2003, the Eau Claire City Council approved the formation of the Half Moon Lake Implementation (Committee) Taskforce. Later, the City of Eau Claire (2010) worked with the Committee to provide an update on the Half Moon Lake water quality improvements and document progress made in

implementing recommendations. The updated document outlined numerous recent efforts to improve water quality that included:

- Curly-leaf pondweed (CLP) management
- Storm sewer diversion
- Construction of rain gardens and drainage swales to collect runoff from parking areas of Mayo Hospital and the Lakeshore School area
- Gasoline-powered motorboat ban
- Conservancy zoning around the entire lake
- Fisheries survey and installation of aeration equipment
- TMDL development

Since 2010, phosphorus (P) controls primarily targeted internal phosphorus loads with herbicide treatment of curly-leaf pondweed (ongoing), whole-lake alum treatment of lake sediment for phosphorus control (2011 and 2017), and restrictions on water skiing and power boating. These efforts were successful, with total phosphorus (TP) in 1999 commonly above 100 µg/L in midsummer, whereas in 2016 total phosphorus was more commonly between 30 and 60 µg/L in midsummer.

The City of Eau Claire community has been fully invested in management of Half Moon Lake to improve water quality (City of Eau Claire, 2017). A survey conducted indicated that over 80% of the community believed that the lake was a vital resource to the City and supported management to improve and maintain a healthy ecosystem. The outcome of on-going management on use has been multifaceted. Beach attendance has increased tremendously. Recreational canoeing, kayaking, and fishing have increased. The lake now supports the swimming leg of the Eau Claire triathlon. The Dragon Boat Festival, sponsored by Mayo Health Care Systems to promote wellness and support hospice services, has grown in popularity and was expected to have up to 52 teams paddling Hong Kong-style dragon boats along a 250-meter course on Half Moon Lake in August, 2018. Overall park attendance and usage has steadily increased in conjunction with management for improved water quality. The overall water quality goal was to maintain total phosphorus and chlorophyll below 30 and 20 µg/L, respectively (City of Eau Claire, 2017). From a fisheries perspective, Half Moon Lake had previously become overpopulated with largemouth bass, but the size limits have been removed, and the goal is to provide sustainable panfishing.

1.2.1 Half Moon Lake TMDL and Applicable Water Quality Standards

Total Maximum Daily Load (TMDL) is a maximum amount of a pollutant a water body can receive, above which it will be deemed impaired (not meeting water quality standards). Pollutant sources can be point sources such as a discharge pipe from permitted stormwater runoff, or nonpoint sources, such as atmospheric sources of phosphorus. Water bodies such as lakes can also have an internal load of pollutants that is occasionally released—because of wave action, disturbance, or changes in lake condition—from the sediment that is settled at the bottom of the lake. Once a water body exceeds its TMDL for a pollutant, activities should be chosen and put into practice to decrease pollutant inputs and bring the water quality up to the accepted standard.

The TMDL (WI DNR, 2004) for Half Moon Lake set a summer (June-August) lake mean epilimnetic phosphorus concentration of 52 µg/L as the numeric water quality goal, which resulted in an allowable seasonal load of 102 kg (225 lbs) to meet the standard. The TMDL report estimated that the city's stormwater runoff (considered a point source) was 15 kg during a summer season. In setting the TMDL wasteload allocation for the city's stormwater (MS4), it was expected that minimal additional reduction was likely to occur, since significant stormwater management activities (including stormwater diversion and street sweeping) had already occurred in the watershed. Increased frequency of street sweeping and implementation of other urban BMPs in the watershed were expected to decrease the seasonal stormwater phosphorus load by about 10%, resulting in a TMDL wasteload allocation of 13 kg for total phosphorus (i.e., a 2 kg total phosphorus load reduction). Stormwater management provisions of the TMDL were incorporated into the City of Eau Claire stormwater permit in 2003.

After the TMDL report was approved, the WI DNR changed water quality standards for lakes, which were adopted on December 1, 2010 (Chapter NR 102). As a result, the current water quality standards indicate that a total phosphorus criteria of 40 µg/L would now apply to Half Moon Lake.

1.2.2 Limnological, Sediment, and Aquatic Macrophyte Biomass Studies

Limnological studies have been conducted by University of Wisconsin—Stout annually on Half Moon Lake since 2011. These assessments and studies have highlighted some of the potential challenges in maintaining good water quality. The most recent reports (prior to 2017) show that late-summer phosphorus still spikes up in the water column, suggesting that internal phosphorus loading is an issue despite the 2011 whole-lake alum treatment. Prior to 2017, sediment cores taken in the lake also showed that mobile phosphorus (e.g., iron-bound phosphorus) is increasing in the surficial sediment layer. Incubated sediment cores also show internal phosphorus loading. Some of the available data also provide the capability to evaluate how the existing external (watershed) loads may be limiting the longevity of internal load controls (discussed in Section 2). Table 1-3 shows how the average summer TP concentrations varied for each lake station in Half Moon Lake during 2016. The 2016 results follow the recent pattern and the pattern before the 2011 alum treatment where water quality is significantly better in Braun's Bay and the south arm compared to the east arm stations, while the west arm stations have the highest TP concentrations.

Table 1-3 2016 mean summer phosphorus for each Half Moon Lake station

Station	Mean Summer (July—Sep) TP Conc. (µg/L)
10 – west arm	49
20 – west arm	46
30 – east arm	42
40 – east arm	40
50 – south arm	38
60 – Brauns bay	30

Sources: James (2016).

1.3 Additional Considerations for Plan Development

The city periodically pumps water into Half Moon Lake from nearby wells in Owens Park to help maintain the water level in the lake and to improve water quality through a flushing process. However, there is a concern that water pumped into Half Moon Lake may actually be short-circuiting and quickly flowing out of the Lake via Becca's Brook. This may explain why water quality samples from the south arm of the lake have typically been better than water quality samples from the east and west arms of the lake (as described in Section 1.2.2). Seepage from Becca's Brook discharges via groundwater to the Chippewa River (southwest of the South Arm shown in Figure 1-1) rather than flowing through the lake to the outlet structure that discharges to Sherman Creek, southwest of the west arm of Half Moon Lake. As a result, this Plan considers the importance of addressing the short-circuiting of flow out of the lake along with the water quality of the pumped water.

Since most of the designated land uses in the watershed are fully developed, the Plan considers cost-effective management measures for further reducing phosphorus in stormwater loadings as the watershed undergoes redevelopment and/or street reconstruction. Other questions that the Plan considers, and which may need to be evaluated in more detail, include:

- Is it necessary to control phosphorus loads from stormwater runoff and the Owen Park pump discharge to extend the life of internal load control measures?
- If dissolved phosphorus loading from these sources is significant, should the Plan include measure(s) or an approach that can remove dissolved phosphorus?

2.0 Pollutant Sources and Causes

As previously discussed, current water quality standards require that total phosphorus meet the 40 µg/L criteria, which is approximately 23% lower than the standard that had been used for the approved TMDL. This section identifies the sources and causes of impaired water quality conditions in Half Moon Lake that should be controlled to achieve updated load reductions based on previous estimates in the TMDL report.

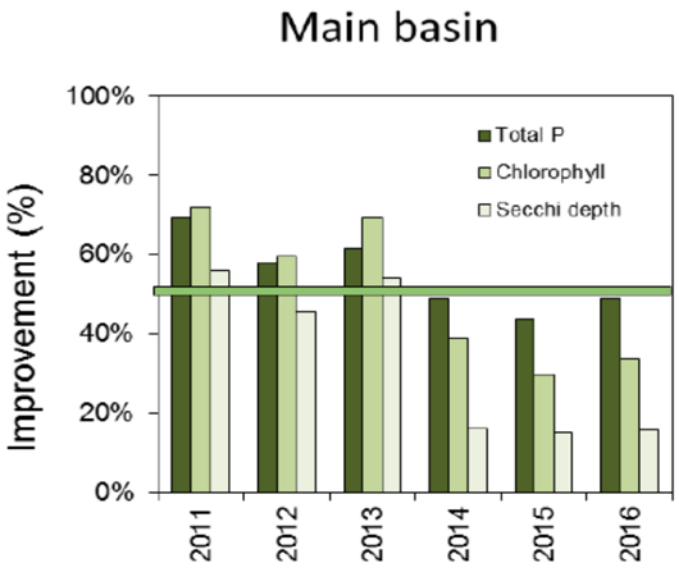
2.1 Lake Water Quality Response to Alum Treatment and Climate

For this analysis, lake water quality and precipitation data were compiled from the limnological studies and available monitoring data prior to the 2017 alum treatment. Table 2-1 shows how the average summer TP concentrations in the main basin (west and east arm) lake stations (10, 20, 30 and 40) of Half Moon Lake have varied since 2011, along with the summer precipitation totals measured for Eau Claire. Figure 2-1 shows how the main basin water quality has changed in comparison with the average water quality (1999-2010), before the 2011 alum treatment of Half Moon Lake. It shows that the percentage improvement in TP concentration was significantly better in the first three years following the alum treatment, but TP concentrations over the last three years have been between 30 and 50 percent higher than the average TP concentrations between 2011 and 2013. Some of the difference between the first three years and the last three years can be attributed to anaerobic phosphorus release (James, 2016), but it should be noted that the first three years' summer precipitation totals were between 8.3 and 11.4 inches, while the summer precipitation totals over the last three years were between 22.8 and 24.2 inches. As a result, it is expected that changes in stormwater runoff P loadings can explain part of the shift shown in Table 2-1 and Figure 2-1 over the last three years.

Table 2-1 Comparison of Half Moon Lake mean summer phosphorus and precipitation

Year	Mean Summer (July—Sep) TP Conc. (µg/L)	Summer Precipitation Totals (inches)
2011	27	11.4
2012	36	8.3
2013	32	9.3
2014	42	23.8
2015	47	24.2
2016	44	22.8

Sources: James (2016) and National Weather Service.



(James, 2016)

Figure 2-1 Percent improvement in mean summer (July-Sep) limnological response variables after 2011 alum application compared to 1999-2010 average

2.2 Analysis of Lake Phosphorus Loading Estimates

Phosphorus loading estimates from the 2015 limnological study (James, 2015) were compiled to calculate the net change in lake P mass (difference between late-summer and early-summer P mass), Owen Park pumping P mass, and internal loading sources of P mass (anaerobic sediment P flux), shown in Table 2-2. These P loads were used to estimate the stormwater P load, also shown in Table 2-2. The 2014 and 2015 results permit a low-end estimate of how much the summer stormwater P load could have contributed to the net increase in the lake-wide P mass, which corresponded to 35% (i.e., 10.6/30) and 40% (i.e., 20.3/51), respectively. The 2014 and 2015 net P mass increases and calculated stormwater P load contributions shown in Table 2-2 do not explicitly account for the in-lake settling or assimilation of the incoming P loads, nor do they account for any short-circuiting of the Owen Park pumping. As a result, it is likely that not only would the P load from stormwater runoff account for at least 40% of the TP budget for the whole lake during most years, but likely accounted for a majority of the P budgets for the east and west arms of Half Moon Lake during the past three years (2014 – 2016).

Table 2-2 Net changes in summer lake phosphorus mass (kg) compared with source loads

Variable	2014 (mid-June—Sep)	2015 (mid-July—Sep)
Lake-wide net change in P mass	30	51
Owen Park pumping (Jun-Sep)	17	23
Anaerobic sediment P flux	2.4	7.7
Estimated stormwater P load(1)	10.6	20.3

Source: James (2015), except where noted.

(1) Calculated based on the net change in lake-wide P mass minus the Owen Park pumping and anaerobic sediment P flux; would also include atmospheric deposition of P

2.3 Analysis of Stormwater Phosphorus Loadings

Table 2-3 shows that the phosphorus loadings, and estimated P loading rates, were significantly higher for the SS1 subwatershed than the other two monitored subwatersheds (SS2 and SS4) in 2016. The Carson Park bioswale is a structural BMP that provides extensive treatment for the drainage from the SS4 subwatershed. Our review of past drainage plan permit approvals indicates that the SS2 subwatershed has a bioretention area that treats most of the runoff from this drainage area and past redevelopment projects have also included disconnection of impervious surfaces and/or impervious surface reductions. Unlike the SS2 and SS4 subwatersheds, the SS1 subwatershed is larger with higher-density residential development, and has very few or no structural BMPs. While it is expected that street sweeping was occurring in this subwatershed during the summer months, the flow-weighted mean TP concentration (0.410 mg/L or 410 µg/L) is an order of magnitude higher than the water quality standard for Half Moon Lake (40 µg/L). A review of Figure 1-1 shows that very few of the remaining (unmonitored) subwatersheds in the Half Moon Lake watershed have structural BMPs and may also contribute higher phosphorus loadings rates to the lake during the summer months.

Table 2-3 Summer 2016 total phosphorus mass loading and flow-weighted mean concentrations for monitored storm flows

Sewer	TP Load (June—Sep), kg	Flow-Weighted Mean TP Conc. (mg/L)	Summer Stormwater TP Export Rate (lbs/ac)(1)
SS1	16.29	0.410	0.41
SS2	1.63	0.121	0.07
SS4	0.68	0.170	0.07

Source: James (2016), except where noted. See Figure 1-2 for storm sewer sampling station locations.
Note(s):
(1) Calculated based on respective drainage areas shown in Table 1-1

2.4 Suggested Changes to Stormwater Load Reduction Goals

Based on the review of existing monitoring data (discussed in this section) and comparison to water quality standards (updated since the TMDL was approved, as described in Section 1.2.1), it is expected that P load reductions from stormwater runoff BMPs will represent the primary means for achieving the required load reduction goals. As discussed in Section 1.2.1, the TMDL report estimated that the city's stormwater runoff was 15 kg during a summer season and that increased frequency of street sweeping and implementation of other urban BMPs in the watershed would decrease the seasonal stormwater phosphorus load to 13 kg. Combining the stormwater load estimates from Tables 2-2 and 2-3, it is estimated that the summer stormwater TP load to Half Moon Lake has been at least as high as the 11 to 20 kg range (shown in Table 2-2) between 2014 and 2015, but more likely higher than 30 kg during 2016 (based on an extrapolation of the SS1 TP export rate from Table 2-3 to the unmonitored subwatersheds).

While the change in the water quality standards would lower the summer mean TP criteria by 23% (from 52 µg/L in the TMDL study to 40 µg/L in Chapter NR 102), Table 2-1 shows that the highest summer mean lake P concentration since the 2011 alum treatment was 47 µg/L in 2015. A 15% load reduction (from 47

µg/L) would be required to meet the 40 µg/L standard, or approximately 8 kg of the 51 kg increase in lake P mass in 2015 (taken from Table 2-2). An 8 kg reduction from the estimated stormwater TP load (shown in Table 2-2) represents approximately a 40 percent reduction in the 2015 stormwater load that resulted in the observed P mass increase during 2015. However, this estimate does not explicitly account for the in-lake settling or assimilation of the incoming P loads nor does it account for any short-circuiting of the Owen Park pumping. As a result, it is recommended that future BMP implementation efforts target practices that can reliably remove 50 to 60 percent of the untreated stormwater TP load.

3.0 Recommended Management Measures

Based on the proposed updates to the water-quality target load reductions established in Section 2.4, this section describes management measures that will achieve the load reductions and targets critical areas for BMP implementation. Best management practices to achieve the target load reductions can include structural capital improvements, non-structural measures (e.g., street sweeping, BMP maintenance), policies, and/or standard operating procedures that could be implemented to improve water quality. Recommendations for potential solutions are based on concept-level estimates of load reduction potential, feasibility, and cost. Where possible, the available monitoring and model results were used to identify subwatersheds or locations with the greatest potential to provide water quality improvement and identify and quantify the phosphorus source loadings that can be targeted in each area.

3.1 Changes to BMP Design and Redevelopment Requirements

City ordinance 19.30 lists the following standards for TSS reduction:

Development Type	TSS Reduction
New Development	80 percent
In-fill Development ≥ 1 acre	80 percent
In-fill Development < 1 acre and Redevelopment	40 percent

Because the Half Moon Lake watershed is fully developed, only the redevelopment standard applies to the watershed (i.e., TSS reduction of 40%). The ordinance also requires that BMPs be designed to "infiltrate runoff to the MEP in accordance with NR 151.12(5)(c)." However, NR 151.12(5)(c) exempts redevelopment from this requirement.

Therefore, the current application of redevelopment post-construction stormwater management requirements (City ordinance 19.30) in the watershed will result in BMP effectiveness of approximately 40% TSS removal. This can be problematic in the Half Moon Lake watershed for a few reasons:

1. WI DNR, in their MS4/TMDL guidance, equates 40% TSS removal with a 27% total phosphorus removal rate. However, much of the BMP monitoring and guidance from other states indicate that these BMPs (sized for 40% TSS removal) are unlikely to reliably remove substantial amounts of phosphorus on an annual basis. Therefore, we expect phosphorus removals may be negligible for most BMPs that are sized for 40% TSS removal.
2. Many of the BMPs implemented over the past 15 years have emphasized gravel filtration, grass filter strips, grass swales and/or a CDS® unit that may be designed (modeled) to meet the TSS removal requirement, but are not likely to remove phosphorus at corresponding levels, as expected or intended (i.e., 27% TP removal). In a couple of instances, larger bioretention areas were installed without storage volume below the control elevation. Because of the lack of storage volume, these bioretention areas would need to infiltrate between 1 and 4 inches per hour to realize the expected TSS (and TP) reduction, which seems over-optimistic without field verification of infiltration rates and/or maintenance agreements to ensure continued performance.

3. The WI DNR determined, in the Half Moon Lake TMDL implementation plan, that street sweeping should be adequate to comply with the wasteload allocations for the lake. However, monitoring since 2011 (following the previous alum treatment) shows that the lake water quality goals have not been met. It is our expectation that greater levels of stormwater treatment (e.g., 50 – 60% phosphorus removals, infiltration of 1.0 inch of runoff off of impervious surfaces) will be needed throughout the watershed to reliably meet the lake water quality goals and reduce the reliance on frequent in-lake alum treatments.

It is recommended that the city amend the requirements (in City ordinance 19.30) to establish and enforce BMP design criteria for new development and redevelopment projects in the Half Moon Lake watershed that minimally achieve 80% TSS and 50% TP removals. In addition, the city will need to ensure that maintenance plans are required for each BMP that is implemented, and that BMP maintenance is documented, consistent with MS4 permit reporting requirements.

3.2 Feasibility Study to Improve Owen Park Pumping Water Quality

The limnological studies that published monitoring results collected between 2014 and 2016 indicate that the Owen Park pumping accounts for between 17 and 65 kg of the TP loading to Half Moon Lake during the respective summer seasons. While the flow-weighted mean TP concentration from this source (typically ranging from 70 µg/L to 110 µg/L) is lower than the other sources of stormwater runoff, the TP load from this source typically represents the largest component of the phosphorus budget for the lake in the recent past. As a result, it is recommended that a feasibility study be completed to consider options to filter the pumped flow before it is discharged to Half Moon Lake. One proven technology is the use of an iron-enhanced sand filter which could remove soluble phosphorus and dissolved organic phosphorus from the base flows of Owen Park pump water. Iron-enhanced sand filters use elemental iron and sand to filter and chemically bind phosphorus and can treat dissolved phosphorus to levels below 20 µg/L, which is between 70 and 80 percent lower than existing conditions.

3.3 Becca's Brook Feasibility Study

This recommended feasibility study would evaluate the extent to which water pumped into the lake is short-circuiting via Becca's Brook, and analyze the expected water quality benefit of eliminating the short-circuiting of flow to Becca's Brook. Components of this evaluation would include the following:

- Review of publically available existing information such as well records, groundwater elevation maps and data for the vicinity of Half Moon Lake, including topographic data, water elevation information for Half Moon Lake and the Chippewa River, flow data for the Half Moon Lake outfall to Sherman Creek, flow data for Becca's Brook, any existing estimates of stormwater runoff volume into Half Moon Lake, data on pumped inflow to Half Moon Lake, a desktop analysis of the Eau Claire County water table mapping and water quality data for groundwater in the vicinity of Half Moon Lake and for Half Moon Lake. Based on the available data, a preliminary assessment of lake inflows and outflows with and without the pumped input would be prepared to evaluate the impact and fate of the pumped input.

- If flow data for the Half Moon Lake outfall and Becca's Brook are not available, install flow monitoring stations if locations for the stations can be identified.
- If the evaluation of inflows and outflows is inconclusive or there is insufficient data available to perform the evaluation, it may be possible to use dye trace testing to evaluate if the pumped input to the lake is quickly exiting via Becca's Brook. Temporary monitoring points would be established at the south arm of Half Moon Lake. An environmentally safe dye would be introduced near the pumped water inlet pipe. Water samples would be collected over time and analyzed for evidence of the dye to determine if the dye is present and how long it takes to flow from the inlet pipe to the southeastern end of this portion of Half Moon Lake and also to the constructed outlet structure at the southwest end of the lake.
- Identification of management measures that could feasibly be implemented to eliminate short-circuiting of the flow to Becca's Brook, as well as the associated cost and water quality implications for each measure.

3.4 Improvements to Limit Bacteria and Minimize Beach Closings

Elevated bacteria concentrations measured by Eau Claire County Health Department at Half Moon Lake beach have resulted in beach closings to the public a few times each year, most noticeably after runoff events. A goose roundup in 2013 resulted in the capture of more than 100 geese. More than 500 goose eggs were oiled to dissuade nesting in 2016 at a time where 30 adult geese were present. It was noted that only a handful of goslings were present following this effort. In 2017, the city hired a contractor to conduct three separate applications of a goose repellant (Goose Scram) at Half Moon Lake beach, which appeared to have minimal effect.

Using P load estimates from Moore et al. (1998), the feces from 30 and 100 adult geese would be expected to generate approximately 1.7 and 5.6 kg of respective TP loading during the summer months, which would contribute to water quality deterioration of Half Moon Lake, as well as elevated bacteria levels. As a result, it will continue to be important to control the goose populations at Half Moon Lake, especially near the beach where much of the phosphorus and bacteria in the runoff would be delivered to the lake.

It is expected that the city will need to conduct the following activities each year to ensure that goose populations are controlled and not contributing to water quality degradation and beach closings:

- Perform goose roundups every third year and egg oiling on an annual basis
- Manage/limit goose habitat along the Half Moon Lake shoreline
- Educate public to not feed ducks and geese at the lake
- Monitor changes to the goose populations and track bacteria levels at the beach
- Adjust management actions in response to changes to goose populations and/or bacteria levels

3.5 In-Lake Alum and Herbicide Treatments

The City of Eau Claire sponsored a Lake Management Planning Implementation project in 2017 that was intended to control internal sediment phosphorus loading in Half Moon Lake by applying alum. The lake

previously received an alum treatment in 2011 that was initially effective at meeting the TP goal, but recent monitoring indicated that the effects had diminished (as described in Section 2.1). The 2017 treatment was needed to bind available TP and limit the nutrient supply for algal uptake in the western arm of Half Moon Lake. The treatment involved application of a buffered alum (2:1 ratio of alum and sodium aluminate) dose in late May or early June 2017 to 28 acres of the western arm of Half Moon Lake that is encompassed by the 10 foot contour. The chemical dosage was based on sequestering the annual sediment P flux rate of 0.4 g/m^2 for 2 to 3 years and factored in an aluminum binding efficiency of 60% (James, 2016; James, 2017). The cost of the 2017 aluminum treatment was approximately $54,000 for 16,392 gallons of the combined chemicals specified for the application. The first whole-lake alum treatment, conducted in 2011, cost approximately $350,000 for the respective application of 150 g Al/m^2 and 75 g Al/m^2 to the western and eastern arms of Half Moon Lake. James (2016) recommended a three-year rotation for future in-lake alum treatments of the western arm of Half Moon Lake (with a 50 g Al/m^2 dosage) and a 5-6 year rotation for future treatments of the eastern arm of the lake (with a 25 g Al/m^2 dosage). The city's budget currently includes approximately $100,000 for alum treatments each year during 2019 and 2021. It is anticipated that future stormwater treatment retrofits, goose control, enhanced treatment of the Owen Park pumping and/or elimination of the Becca's Brook short-circuiting could significantly decrease the frequency of in-lake alum treatments that would be needed in the future.

Early spring herbicide treatment (using Endothall) of Half Moon Lake has occurred on an annual basis since 2009 for CLP, except during 2014 when the CLP spiked without the herbicide treatment. A 2,4-D herbicide application in 2009 successfully controlled Eurasian watermilfoil, which has not been detected in Half Moon Lake since the treatment. The native aquatic plant population is now dominated by Elodea in the main lake basin. It is anticipated that annual herbicide treatments will be necessary to control CLP for the foreseeable future. Grant funding is in place to continue herbicide treatment of the lake through 2019, which typically costs approximately $100,000 per year.

3.6 SS1 Subwatershed Study

As noted in Section 2.3, the TP loadings and estimated P loading rates in 2016, were significantly higher for the SS1 subwatershed than the other two monitored subwatersheds. Unlike the SS2 and SS4 subwatersheds, the SS1 subwatershed is larger with higher-density residential development, and has very few or no structural BMPs. As a result, it is recommended that a feasibility study be completed to evaluate options to retrofit the existing drainage systems for enhanced stormwater treatment before the flow from this outfall is discharged to Half Moon Lake. The primary focus of this study will entail an evaluation of the GIS-parcel coverage to identify city-owned and/or vacant properties, as well as public rights-of-way, which could be used for implementation of stormwater BMPs. In addition, soil types would be inventoried and mapped throughout the subwatershed to assist in determining the feasibility of infiltration practices and/or identify locations where filtration practices would likely represent the best option for stormwater retrofits.

It is recommended that this study occur in conjunction with the study to improve the water quality of the Owen Park pumping as both sources of flow originate from the same subwatershed. The results of this study can be applied to the other unmonitored subwatersheds that do not currently have stormwater

treatment and the efficacy of future implementation projects can be verified with additional monitoring at the SS1 outfall.

3.7 Community Engagement

Recommendations for supplementing the current levels of community engagement are provided in Section 4.2. In addition, an information and education component is included for each management measure contained in the Implementation Plan (Section 4).

4.0 Implementation Plan

This section develops the remaining elements of the Plan that pertain to implementation of the recommended management measures, along with some measures that may be considered if justified by lake ecology. Table 4-1 shows the considerations for each management measure for each Plan element.

4.1 Technical and Financial Assistance

The amounts and sources of technical and financial assistance and framework (e.g., ordinance changes) needed to implement the plan (including long-term maintenance, monitoring, outreach, and evaluation) depend on the resources of each project partner as well as the future outcomes of current and recommended management measures. As shown in Table 4-1, WI DNR has grant programs available that match up with each of the recommended management measures. In the case of past in-lake alum and herbicide treatments, the respective grant funds shown in Table 4-1 have already been utilized, along with the technical assistance of WI DNR staff and university researchers. Except for the ordinance changes (which will require input from an attorney), most of the remaining management measures shown in Table 4-1 will require engineering and WI DNR assistance, as well as monitoring plan considerations. It is expected that the implementation phase of one or more of the feasibility studies may require future financial assistance from WI DNR that would tap into the Targeted Runoff Management Grant Program for BMP construction.

4.2 Information and Education

The city and the Half Moon Lake Implementation Taskforce have already completed extensive information and education/outreach activities, including the dissemination of long-term goals and recommendations for further improvements. It is recommended that a meeting be scheduled with the taskforce and/or the public to present the preliminary management measures and the draft plan. Meeting objectives include:

- Provide background information on the watershed issues, trends in watershed management, and water quality; facilitate focused discussion to gather input on local ideas and feedback regarding the potential for stormwater management and in-lake improvements.
- Provide an update on results of the Plan analyses and initial BMP recommendations.
- Provide a presentation and factsheet on the Plan including BMP types and locations, cost estimates, potential sources of funding, evaluation criteria, etc.
- Develop and maintain a separate factsheet for developers and landowners to educate them on BMP design criteria and requirements for new developments and redevelopment projects in the Half Moon Lake watershed that are subject to City ordinance 19.30, as proposed to be amended.

Following the initial meeting, presentation and website materials will be prepared/disseminated to meeting attendees and made available for access after the meeting (see Table 4-1). Finally, it is recommended that the city continue to meet with the taskforce on a bi-annual basis to inform future implementation efforts and establish community capacity to ensure that water quality goals are met.

Table 4-1 Management measure considerations for each implementation plan element

No.	Management Measure	Technical and Financial Assistance	Information and Education	Implementation Schedule	Interim Milestones	Evaluation Criteria	Cost
1	Changes to BMP Design and Redevelopment Requirements	WI DNR Lake Ordinance Development Grants	Develop factsheet on ordinance changes for developers/landowners	2019	Update ordinance	Compare estimated water quality improvements to goals	$10,000
2	Improve Water Quality of Owen Park Pumping	WI DNR Lake Planning Grants for Large Scale Projects	Incorporate results of study into Plan factsheet/presentation	2019-2020	--	Compare estimated water quality improvements to goals	$15,000
3	Address Becca's Brook Short-Circuiting	WI DNR Lake Planning Grants for Large Scale Projects	Incorporate results of study into Plan factsheet/presentation	2019-2020	--	Compare estimated water quality improvements to goals	$40,000
4	Goose Control/Address Beach Closings	WI DNR Lake Protection Grants for Lake Management Plan Implementation; UWFWS Rhinelander for goose roundups	Install sign or kiosk at beach to educate public about not feeding geese/other controls	Ongoing	Maintain goose population below 20 adults during open water season	Maintain E. coli bacteria concentrations that meet the beach standard	
5	In-Lake Alum Treatment	WI DNR Lake Protection Grants for Lake Management Plan Implementation	Incorporate results of treatments into Plan factsheet/presentation	2019-2025	Maintain anoxic phosphorus release rate below 1 $mg/m^2/day$	Meet lake water quality goals for each basin	$50,000 per year
6	Lake Herbicide Treatment	WI DNR Aquatic Invasive Species (AIS) Prevention and Control Grants	Incorporate results of treatments into Plan factsheet/presentation	Ongoing	Maintain negligible CLP growth	Maintain negligible CLP growth; enhance native plant diversity	$100,000 per year
7	Improve Stormwater Treatment in SS1 Subwatershed	WI DNR Lake Planning Grants for Large Scale Projects	Incorporate results of study into Plan factsheet/presentation	2019-2020	--	Compare estimated water quality improvements to goals	$25,000
8	Community Engagement	WI DNR Lake Planning Grants for Large Scale Projects	--	Ongoing	--	Compare observed water quality to goals	
9	Mechanical Harvesting	Considered on as needed basis, as justified by lake ecology					
10	Storm Sewer Outfall Sediment Delta Management	Considered on as needed basis, as justified by lake ecology					

4.3 Implementation Schedule, Milestones and Evaluation Criteria

This section develops timelines for implementing the plan, including interim measurable milestones. This includes reviewing existing city CIP projects and schedules to look for synergies. This Plan summarizes past and ongoing water quality improvement measures that precede the development of the plan. Table 4-1 identifies additional interim measurable milestones for determining whether management practices or other control actions are being implemented as intended. Where possible, it describes the actions that will be taken if milestones are not being achieved, or are achieved ahead of schedule.

This Plan also provides criteria and a monitoring plan that can be used to determine if loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards and/or lake management goals. Based on the existing TMDL and modeling results (discussed in Section 3), it is possible to establish predictive goals for pollutant load reductions with BMP implementation and to estimate the potential benefit of implementing specific BMPs in some instances. Table 4-1, combined with the monitoring plan (see Section 4.4), establishes methods and data to assess whether criteria are met. This, in turn, can inform an adaptive management process to describe how the Plan can be modified if load reduction targets are not being met.

4.4 Monitoring Plan

This section recommends monitoring components, including a sampling and analysis plan to supplement ongoing monitoring, that can be used to evaluate the effectiveness of the implementation efforts over time, measured against the evaluation criteria described in Section 4.3.

4.4.1 Current and Past Monitoring

The City of Eau Claire is currently operating under a technical assistance agreement with University of Wisconsin, Stout for water quality monitoring, which will continue through 2020-21. As previously discussed in Section 1.2.2 and shown in Figure 1-2, this monitoring included the following:

- Lake limnological monitoring—six stations are sampled biweekly between May and early October and analyzed for several limnological parameters, including P mass, the potential for internal load and trends over time.
- Storm sewer monitoring—automated storm water samplers and flow monitoring equipment are installed at three sewers (SS1, SS2 and SS4) and used to determine summer hydrology, P concentrations and loadings; equipment at SS3 was previously vandalized and has not been monitored since 2014.
- Sediment chemistry—sediment cores are collected at stations 10 and 30 and analyzed for sediment P fractions and rates of P release under anaerobic conditions.
- Aquatic macrophytes—submersed macrophyte biomass is quantified using the point-intercept method during June and August for each plant species.

The Eau Claire County Health Department consistently tests water quality during the warm weather season at the Half Moon Lake beach area and maintains records for bacteria monitoring. It is expected

that this monitoring will continue in the future. Precipitation data from the Eau Claire airport were used in past assessments.

4.4.2 Recommendations for Supplemental Monitoring

Currently, there are data gaps that limit better understanding of the water and phosphorus budgets for Half Moon Lake. Stormwater flow measurements exist for 24% of the watershed area (not including lake surface), as well as the Owen Park pumping volumes, but no records exist for lake levels or discharges from the lake outlet or Becca's Brook. As a result, it is not clear how important the unmonitored stormwater runoff, Owen Park pumping and short-circuiting at Becca's Brook are at influencing the overall water balance of the lake, as well as the interaction between the individual lake basins or groundwater.

Regarding the phosphorus budgets for the lake, it is not clear how important the unmonitored stormwater runoff and short-circuiting at Becca's Brook are at influencing the overall phosphorus mass balance of the lake, as well as the flux between the individual lake basins or groundwater.

To assess project success, it is recommended that the current monitoring programs continue and that, at a minimum, the following additional monitoring components should be considered to supplement the data and address the monitoring data gaps:

- Lake levels—implementation should include installation and regular readings (preferably on a continuous basis) of staff gage measurements, with surveyed stage in mean sea level elevations.
- Outflow discharge measurements—a range of flows should be monitored (preferably on a continuous basis) at the Sherman Creek outlet and Becca's Brook, including development of a relationship between lake stage and outflow discharges at each site.
- Characterize unmonitored stormwater runoff—at a minimum, water quality grab samples should be collected over a range of flows from all of the unmonitored stormwater outfalls and analyzed for total and soluble P, as well as TSS, during the summer season. Where possible, flow measurements (preferably on a continuous basis) should supplement the water quality sampling.

(Note: the first two items (above) are recommended as a part of the Becca's Brook Feasibility Study recommendations, discussed in Section 3.3.)

5.0 References

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