Phosphorus Total Maximum Daily Load (TMDL) for Half Moon Lake, Eau Claire, Wisconsin

Wisconsin Department of Natural Resources

June 22, 2004 -- Final

Introduction

Half Moon Lake (Hydrologic Unit Code 070500006) is a small, shallow eutrophic lake that formed as an oxbow of the Chippewa River. The lake is geographically located within the City of Eau Claire and the Lower Chippewa River Basin. The lake is highly eutrophic and exhibits excessive algae and aquatic macrophyte growth (Borman, 1990; Brakke, 1995; Konkel and Borman, 1996; James et. al., 2001, 2002). Half Moon Lake was originally listed on Wisconsin's 303(d) impaired waters list in 1998 for eutrophic conditions and sedimentation and listed as a high priority for TMDL development on the October 2002 303(d) list.

Half Moon Lake is 53 hectares (132 acres) in size with a maximum depth of about 3 meters (slightly over 9 feet). The lake's watershed is 577 acres and approximately 85% of the shoreline is publicly owned by the City of Eau Claire. Land use in the watershed is 45% residential, 41% open land and 14% commercial (Barr Engineering, 1992). The City has a policy of purchasing properties abutting the lake when they become available and at the present time, only four privately owned properties remain along the shoreline.

Historical Background and Environmental Setting

During initial settlement of the City of Eau Claire, Half Moon Lake played an important role as a reservoir for logging operations during the late 1800's. Several sawmills were located on the lake and various channels connected the lake to the Chippewa River. These connections between the lake and river eventually filled in and water levels are now maintained by seepage, stormwater runoff and groundwater pumping from shallow wells. The pumping facilities consist of three shallow wells located near the edge of the Chippewa River with each pump rated at one million gallons per day. The pumps provide make-up water to the lake and operate year round on a rotating basis with two pumps running simultaneously at all times.

Some of the watershed drainage has been routed away from the lake, and the entire hydrologic system has been altered (Brakke, 1995). Use of the lake for log storage during the mid-1800s may explain the high organic content of its sediments (tree bark and sawdust), that also contribute to lake nutrient levels (Barr Engineering, 1992).

Since the early 1970s, many changes have occurred within the lake and its watershed, including:

- diversion of a significant portion of the storm sewer watershed to the Chippewa River,
- construction of an earthen dike to prevent inflow to the lake from Sherman Creek,
- construction of a new outlet structure on the southwest end of the lake,
- and, installation of wells and pumps in Owen Park along the Chippewa River to provide make-up water to the lake

The lake is used extensively for recreation, especially boating and fishing. Although boating is allowed on the lake, no outboard motors are allowed with the exception of the Ski Sprites, a local water-ski club that uses the lake for practice and exhibition shows during the summer. The Ski Sprites use ski boats with high horsepower outboard motors for these activities.

Because of its shallow depth, enriched sediments and excessive water column phosphorus levels, the lake experiences heavy macrophyte growth and severe algae blooms during the summer. These eutrophic conditions have significantly impaired body contact recreational activities.

Historically, the lake frequently experienced winterkill conditions, but since the City installed aerators in 1979, adequate dissolved oxygen conditions have been maintained throughout the winter.

Algae blooms in Half Moon Lake are often accompanied by excursions of the Wisconsin water quality criterion for pH. The elevated lake pH levels are due to removal of carbon dioxide from water during photosynthesis (by macrophytes and algae). The reduction in carbon dioxide levels during daylight causes an increase in pH. A reduction in phosphorus levels would result in a decrease in chlorophyll levels (a measure of productivity) and a reduction in maximum pH levels.

The lake was placed on the Wisconsin 303(d) list in 1998 and 2002 due to eutrophication and pH exceedances above the 9.0 water quality standard. Lake sampling conducted by the Wisconsin Department of Natural Resources (WDNR) during the summers of 1997 and 2001 found pH levels above 9.0 on 4 of 4 (100%) of the summer sample dates when all sites are considered. In addition, bi-weekly monitoring conducted by the U.S. Corps of Engineers (USCOE) during summer 1999 found pH violations on 8 of 11 dates (73%).

In 2001, a Half Moon Lake Advisory Task Force was appointed by the Eau Claire City Council to prepare a report and recommendations to improve water quality in Half Moon Lake. The task force (which was advised by WDNR staff) developed recommendations that form the basis of this TMDL.

Hydrologic Budget

The watershed contributing to Half Moon Lake is 577 acres and is served by eight main storm sewers from the developed portion of the watershed. There are several minor inlets to the lake from the Carson Park area, as well as direct drainage adjacent to the lake. An outlet structure is located in the southwest portion of the lake consisting of a standpipe that drains water from the lake when the pool elevation exceeds 234.5m mean sea level.

The average annual stormwater inflow to Half Moon Lake is 389 acre-feet and inflow from makeup water pumps is 1,680 acre-feet. Outflow from the lake is 1,607 acre-feet per year, resulting in a mean hydraulic residence time of about 162 days (Barr Engineering, 1992). An estimated 462 acre-feet is lost through groundwater seepage and evapotranspiration. The major source of water to the lake is groundwater that is pumped through a storm sewer from wells located at Owen Park, situated southeast of the lake along the Chippewa River. The lake also receives direct runoff from 3 sub-watersheds that are not drained by the storm sewer system.

Water Quality Study

During summer 1999, the USCOE conducted a study in Half Moon Lake to examine nutrient loadings from storm sewer inflows, profundal sediments, decaying macrophytes, and motor boat activity (James et. al., 2001). Water samples were collected from storm sewers and the outlet structure of Half Moon Lake to determine external loadings and discharges.

External sources of phosphorus include storm sewer discharges, precipitation, direct drainage and groundwater pumped into the lake from the Owen Park wells. These sources represent 21 percent of the seasonal phosphorus load to the lake (Table 1 and Fig. 1).

Internal sources of phosphorus, which account for 79 percent of the seasonal phosphorus load to Half Moon Lake, include nutrient release from sediments, decomposition of aquatic plants and mixing of bottom waters by motorboat activity. The enriched sediments represent the largest source of phosphorus to the lake (42%.) The lake intermittently stratifies during summer (the critical period) resulting in reduced dissolved oxygen conditions and increased phosphorus levels near the bottom. Wind occasionally destratifies the lake and distributes the sediment-released phosphorus throughout the water column resulting in additional algae growth.

The decomposition of plants also contributes a significant amount (20%) of phosphorus in the lake. The dominant macrophyte in the lake is curly leaf pondweed (*Potamogeton crispus)*, an aggressive exotic plant that begins growth in spring and dies off in mid-June. As the plants grow, they incorporate phosphorus from sediments, then release nutrients into the water column after they die and decompose. Approximately 60 kg of phosphorus becomes available for mixing into the water column by *P. crispus* decomposition during summer. The contribution from macrophytes is somewhat reduced by aquatic plant harvesting that removes approximately 30 kg of phosphorus on an annual basis.

Table 1. Lake wide seasonal (June - August) phosphorus load from various sources to Half Moon Lake (Source: James et. al., 2001).

Source	Seasonal Phosphorus Load (Kg)
External	
Storm sewers	15
Pumps (groundwater)	20
Precipitation	25
Internal	
Sediment release	125
P. crispus decomposition	60
Motor boat activity	50
Total:	295

Applicable Water Quality Standards

Half Moon Lake is included on the Wisconsin Department of Natural Resources (WDNR) 1998 and 2002 303(d) list of impaired waters. The lake is listed as a high priority waterbody and is impaired as a result of phosphorus from urban runoff and internal loading. The external load is nonpoint source dominated, with no industrial or municipal wastewater treatment plant discharges to the lake.

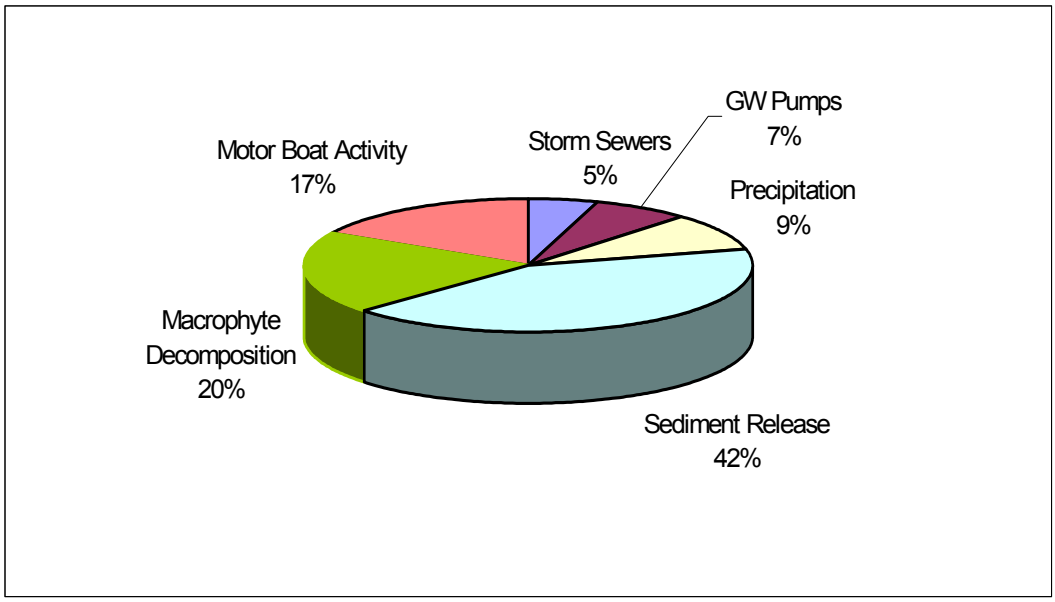

Figure 1. Relative proportion of sources of phosphorus loads to Half Moon Lake.

Half Moon Lake is currently not meeting applicable narrative *water quality criterion* as defined in NR 102.04 (1); Wis. Admin. Code:

> "To preserve and enhance the quality of waters, standards are established to govern water management decisions. Practices attributable to municipal, industrial, commercial, domestic, agricultural, land development or other activities shall be controlled so that all waters including the mixing zone and the effluent channel meet the following conditions at all times and under all flow conditions: (a) Substances that will cause objectionable deposits on the shore or in the bed of a body of water, shall not be present in such amounts as to interfere with public rights in waters of the state, (b) Floating or submerged debris, oil, scum or other material shall not be present in such amounts as to interfere with public rights in waters of the states, (c) Materials producing color, odor, taste or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the state."

This criterion describes the acceptable water quality conditions and guides the WDNR in setting a numerical target pollutant concentration. The application of a narrative criterion for Half Moon Lake necessitates the development of a site-specific in-lake phosphorus value for the purpose of this TMDL.

The designated use for Half Moon Lake is full body contact recreational use, with a warm water sport fishery as described in S. NR 102.04(3) intro., and (b), Wis. Adm. Code as:

"FISH AND OTHER AQUATIC LIFE USES. The department shall classify all surface waters into one of the fish and other aquatic life subcategories described in this subsection. Only those use subcategories identified in pars. (a) to (c) shall be considered suitable for the protection and

propagation of a balanced fish and other aquatic life community as provided in federal water pollution control act amendments of 1972, PL 92-500; 33 USC 1251 et.seq.

"(b) Warm water sport fish communities. This subcategory includes surface waters capable of supporting a community of warm water sport fish or serving as a spawning area for warm water sport fish."

The applicable water quality standard for this TMDL is listed in S. NR 102.04(4) intro, and (c), Wis. Adm. Code as follows:

"STANDARDS FOR FISH AND AQUATIC LIFE. Except for natural conditions, all waters, classified for fish and aquatic life shall meet the following criteria:

"(c) pH. The pH shall be within the range of 6.0 to 9.0, with no change greater than 0.5 units outside the estimated natural seasonal maximum and minimum."

Documented water quality standard pH violations were a primary reason for including Half Moon Lake on the 303d list. However, we found no clear relationship between pH and chlorophyll and/or phosphorus in Half Moon Lake. The pH exceedances may be more related to macrophyte photosynthesis and low buffering capacity than algal productivity. For this reason, goals established by this TMDL were not based on the pH criterion, but rather chlorophyll-a and phosphorus levels. Generally, reductions in phosphorus and chlorophyll-a levels should result in decreased pH levels.

Although Half Moon Lake is also on the 303d list for impairment caused by sedimentation, the sources of sediment to the lake have generally been controlled. Most of the inorganic sediment sources were short term and related to construction erosion in the watershed. Historical organic sedimentation from the logging era is a continuing source of phosphorus release.

Overview of Total Maximum Daily Loads

A Total Maximum Daily Load (TMDL) is the total amount of a pollutant (from all sources) that can enter a specific waterbody without violating water quality standards or impairing beneficial uses. Following are required elements of the TMDL that will be submitted to EPA:

1. A description of the geographic area to which the TMDL applies;
2. Identification of applicable water quality standards;
3. Assessment of the problem, including the extent of deviation of ambient conditions from water quality standards;
4. Evaluation of seasonal variation;
5. Identification of point and non-point sources;
6. Assessment of loading capacity of the specific waterbody;
7. Development of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources;
8. Identify a margin of safety.

Water Quality Goals

Chlorophyll *a* (algal biomass) levels in the lake are primarily a function of phosphorus concentrations. The USCOE model BATHTUB was used to relate phosphorus loads to chlorophyll *a* levels. The BATHTUB model is a lake and reservoir response model that can be calibrated to observed conditions and operated on a growing season or annual time step (WDNR 2001). The model was run to simulate the effect of various phosphorus load reductions on in-lake phosphorus and chlorophyll *a* concentrations. Various lake management alternatives were considered and a desirable and achievable water quality goal for mean summer chlorophyll *a* levels was determined. The model was then used to back-calculate the level of P load reduction needed to meet the water quality goal.

The overall water quality goal for Half Moon Lake is to reduce phosphorus concentrations in the lake sufficiently to decrease the severity and frequency of algal blooms. The goal proposed by the Task Force and WDNR staff is to achieve a mean summer in-lake chlorophyll-a concentration of 30 ug/l compared to the current level of 82 ug/l. This level of chlorophyll-a reduction would require a 52% decrease in the mean, summer in-lake total phosphorus concentration from 109 ug/l to 52 ug/l. Consequently, the water quality numeric goal is to achieve a summer lake mean epilimnetic phosphorus concentration of 52 ug/l in Half Moon Lake.

The in-lake phosphorus concentration goal represents a mean growing season (June – August) epilimnetic concentration. This goal is based on local public input and best professional judgment of WDNR staff using available monitoring data and modeling tools.

Loading Capacity

Loading capacity is the total permissible pollutant load that will achieve water quality standards. This capacity provides a reference for calculating the amount of pollutant reduction needed to bring a waterbody into compliance with water quality standards or designated uses. The total loading capacity of Half Moon Lake is primarily a function of in-lake phosphorus concentrations. Nutrient concentrations above this capacity cause the designated use impairments discussed earlier in this report.

The seasonal load that Half Moon Lake can receive and still meet the summer mean phosphorus concentration goal of 52 ug/l is 102 kg (225 pounds) which represents an overall 65% reduction in the phosphorus load (Table 2). Mean in-lake phosphorus concentrations above this level would likely result in continued severe algal blooms and use impairments.

Wasteload Allocation (Point Sources)

The only point sources in the watershed are eight storm sewers that discharge directly to the lake. These storm sewers contribute about 15 kg P (or 5% of the total phosphorus load) during the summer growing season. Since considerable stormwater management activities have already occurred in the watershed, including stormwater diversion and street sweeping, minimal additional reduction is likely to occur from this source. Increased frequency of street sweeping and implementation of other urban BMPs as needed in the watershed are expected to decrease the

stormwater phosphorus load. Increased street sweeping is expected to decrease the seasonal phosphorus load by about 10% (Cook 1999), resulting in a wasteload allocation of 13 kg of total phosphorus.

Background Load

Precipitation and groundwater (makeup water from pumping) are considered background conditions for purposes of this TMDL. These sources contribute about 45 kg, or 16% of the total summer phosphorus load.

Load Allocation

Internal phosphorus sources to Half Moon Lake consist of decomposition and release from aquatic plants, nutrient release from sediments and mixing of enriched bottom waters during motorboat activity. As mentioned earlier, these sources contribute about 79% of the total summer phosphorus load.

Macrophyte decomposition and resulting phosphorus release during mid-summer accounts for about 20% of the seasonal phosphorus load. Currently, City plant harvesting operations remove approximately 30 kg of phosphorus during the summer. Lake wide plant phosphorus mass available for flux to the water column after harvesting (assuming complete decomposition) is about 60 kg (James, et. al. 2001). Doubling the amount of plant mass harvested would result in an estimated 64% reduction in the amount of phosphorus available to the water column from

Table 1. Seasonal (June-August) phosphorus loads and TMDL load allocations for Half Moon Lake.

Source	Wasteload or Load Allocation (kg)	Inventoried Phosphorus Load (kg)	Percent of Total Load (%)	Planned Load Reduction (%)
Internal Load (load allocation)				
Sediment release	22	125	42	82
Macrophyte decomposition	22	60	20	64
Motor boat activity	0	50	17	100
External Load (background)				
Precipitation (direct)	25	25	9	0
Pumps (groundwater)	20	20	7	0
External Load (wasteload allocation)				
Storm sewers	13	15	5	10
Totals:	102	295	100	65

decaying plants. This estimate assumes some shift in the macrophyte community from *P. crispus* to more desirable species. The seasonal phosphorus load allocation for aquatic plant harvesting is 22 kg.

Eliminating resuspension of phosphorus generated by motorboats would be accomplished by relocating the water skiing club to another waterbody. Cessation of motorboat activity on the lake would reduce the phosphorus load from this source by 100 percent, resulting in seasonal phosphorus load allocation for this activity of zero. The Ski Sprites have indicated a willingness to relocate to another site with help from the City.

Approximately 42% of the seasonal phosphorus load originates as sediment release. The City and WDNR are currently exploring the use of alum (aluminum sulfate) as a means to seal the sediments and significantly reduce loading from this source. It is anticipated that if an alum treatment is feasible, phosphorus release from sediments can be reduced by 75 to 90 percent. The overall effectiveness of a lake alum treatment in reducing phosphorus release has been shown to be highly variable, thus an average value of 82 percent was used in estimating the potential load reduction. The seasonal phosphorus load allocation for sediment release is 22 kg.

A TMDL represents the maximum loading of a pollutant (phosphorus in this case) that can be discharged to a waterbody and still meet water quality standards. The TMDL consists of the sum of individual point source waste load allocations (WLAs) and load allocations (LAs) made up of the nonpoint and background sources. The equation representing the TMDL calculation for Half Moon Lake is as follows:

Loading Capacity =	*WLA +*	*LA +*	*Background*
(102 kg)	*(13 kg)*	*(44 kg)*	*(45 kg)*

Seasonal Variation

As the term implies, TMDLs are often expressed as maximum daily loads. However, TMDLs may be expressed in other terms when appropriate. In this case, the TMDL is expressed as an allowable seasonal load of phosphorus to or within the lake. Since the major use impairments (and water quality standards violations) occur during the summer months, a seasonal (June - August) load is most appropriate for Half Moon Lake. However, proposed management activities to address phosphorus loading would generally provide benefits to the lake year-round.

Margin of Safety

A margin of safety (MOS) is a required component of a TMDL to account for uncertainty of the relationship between pollutant loads and quality of the receiving waterbody. The statutory requirement that TMDLs incorporate a MOS is intended to account for uncertainty in the available data or in the actual effect controls will have on loading reductions and receiving water quality.

An implicit MOS is provided by conservative assumptions in predicting the performance of management practices. For example, literature suggests the range of effectiveness of a single alum treatment in reducing sediment phosphorus release ranges from 75 to 90 percent, and often

achieving levels above 80 percent (Welch and Cooke, 1999). We selected a mid-range value as a conservative estimate of the effectiveness of a treatment because a second alum treatment will be recommended if the first treatment does not achieve the intended results.

Actual success in achieving in-lake water quality goals will largely depend on effectiveness of the alum treatment (or treatments). In-lake monitoring will be used to determine whether additional alum treatments are needed. Applying adaptive management principals, the water quality goals will be achieved through a single or multiple alum treatments. A feasibility study will be undertaken prior to application of alum to determine the appropriate dosage and potential effectiveness of a lake wide treatment.

Another implicit MOS is provided by potential additional phosphorus control that may be achieved by the use of lime treatments (Calcium hydroxide) to control *P.crispus*. A feasibility study will be conducted in 2005 to examine the effectiveness of using lime treatments to reduce macrophyte growth. Several researchers have reported success in this lake management approach (Prepas, et. al. 2001, Reedyk, et. al. 2001). Potential phosphorus release reductions from lime treatments were not included in the load allocations but may help achieve the lake water quality goal.

Reasonable Assurance

The City of Eau Claire will be responsible for implementing management actions to meet the pollutant load reductions identified in this TMDL. The internal load reduction goals will be achieved through increased macrophyte harvesting, elimination of motorboat activity and potential alum treatments.

The City is committed to implementing management recommendations identified by the Half Moon Lake Advisory Task Force. While funding for these activities has not yet been secured a significant portion of the costs associated with the alum feasibility study and treatment may be cost shared with WDNR through the Lake Management grant program. If the feasibility study determines that an alum treatment would not be effective or appropriate, other sediment release control methods would be pursued.

The only aspect of this TMDL with a regulatory component is urban stormwater management. Stormwater management provisions were incorporated into the City of Eau Claire stormwater permit required under NR 216.07 (Wis. Adm. Code). The stormwater permit for the City of Eau Claire was issued in October 2003. Funding to implement urban stormwater BMPs is available through the WDNR Urban Nonpoint Source Stormwater grant program.

Public Participation

The Half Moon Lake Advisory Taskforce was appointed by the Eau Claire City Council in fall 2001 to develop recommendations to the City to improve the water quality of Half Moon Lake. The task force met monthly (or more often) for more than one year to develop its recommendations and a final report to the city council (Half Moon Lake Advisory Task Force, 2002). The task force represented a variety of local interests including neighborhood associations, environmental groups, recreation interests, private individuals and public agencies. Several WDNR staff were advisors to the task force. The task force recommendations and final report form the basis of this TMDL.

The task force report was approved by the City of Eau Claire Waterways and Parks Commission on January 22, 2003 and forwarded to the City Council for final approval on March 11, 2003. All commission and city council meetings were public noticed.

This TMDL was subject to public review for 30 days from May 4, 2004 through June 4, 2004. On May 4th, a news release was sent to over 900 entities, including newspapers, television stations, radio stations, interest groups and interested individuals. The news release indicated the public comment period and how to obtain copies of the public notice and draft TMDL. The news release, public notice and draft TMDL were also placed on Wisconsin DNR's website. In addition, hard copies of the public notice and the draft TMDL were sent to all member of the Half Moon Lake Task Force and city of Eau Claire staff. No comments were received.

Implementation

Half Moon Lake has had numerous lake management activities implemented over the past several decades. Although many of these management efforts have been successful at managing specific aspects of water quality impairments in Half Moon Lake, frequent summer algae blooms and nuisance aquatic plant growth still persist. Recent studies and lake planning activities determined pollutant sources causing water quality impairments, assessed the lake water quality response to nutrient loading decreases, surveyed community interest in the lake and developed management strategies to improve water quality in Half Moon Lake.

The Half Moon Lake Advisory Taskforce identified a variety of management actions to address lake water quality concerns, including:

- Reduction of sediment phosphorus release through an alum treatment. A feasibility study will be conducted prior to an alum treatment to determine the proper dosage and potential effectiveness. The feasibility study would be funded through a combination of state and federal programs that will be initiated in 2003. Upon completion of the feasibility study, a determination will be made as to cost and timing of the alum treatment. The cost of an alum treatment for Half Moon Lake could range from $1,250 to $4,000 per acre, depending on the necessary dosage rate. This cost may be offset by a lake restoration grant from WDNR that would cover 75% of the cost, with a maximum grant award of $200,000.

  In addition to the lake grant program, an alum treatment would be eligible for cost share funds from the WDNR Urban Nonpoint Source and Stormwater grant program. Up to 70% of the project costs may be funded through this program.

- Reduce the phosphorus load occurring from plant decomposition by increasing the current aquatic plant harvesting operation. The task force recommended that the City double the amount of macrophytes that are currently being harvested. The mechanical harvesting program in Half Moon Lake should be designed to maximize long-term improvements in the lake by;

  1) Concentrating harvesting efforts early in the year before *Potamogeton crispus* forms turions and begins to senesce,
  2) Continue monitoring the growth of *P. crispus* to determine when the harvesting program should begin each year,

3) And, begin the harvesting program each year as soon as the harvester can remove sufficient nodes per stem to prevent turion formation on *P. crispus*.

Costs associated with an increased plant harvesting program would include personnel costs and the need to purchase a second harvester. Additional personnel costs are estimated at $34,000 per year and a second harvester would cost about $105,000. State lake grant funds may be available to offset a portion of the cost of the harvester (Half Moon Lake Advisory Task Force, 2002).

- Eliminate motorboat activity by relocating the Ski Sprites from Half Moon Lake to another location. Motorboat activity on the lake currently contributes 17% of the overall P load. The Ski Sprites have indicated a willingness and desire to relocate to another site and feel such a move will not only benefit the lake, but will create a number of opportunities for the club to grow and expand. One of the prerequisites of an alum treatment would be the elimination of this phosphorus source.

- Implement additional watershed stormwater management controls. Although stormwater runoff represents a small portion (5%) of the phosphorus load to the lake, some benefit would be gained by reducing this source. The Taskforce recommended that street sweeping be increased within the Half Moon Lake watershed to a level that would result in an approximate 10% reduction in phosphorus from storm sewers. Phosphorus reduction from stormwater controls would help extend the longevity of a potential future alum treatment.

  Street sweeping within the watershed will be examined to determine the level of effort needed to reach the reduction goal, and to determine whether particular areas in the watershed should be targeted for maximum benefit. Currently, the City sweeps streets in the watershed approximately every 3 weeks during spring, summer and fall. The estimated cost to sweep streets in the watershed is about $1,200 per effort.

  The Taskforce also recommended that the City prepare a stormwater management plan to address sediment and phosphorus loading to the lake. The plan should:

  1. Recommend that the City adopt a grading and erosion control ordinance.

  2. Address runoff and erosion problems occurring from site-specific locations in the watershed.

  3. Recommend improvements to the Half Moon Beach parking lot

  4. Encourage the development and use of "rain gardens" to infiltrate stormwater runoff within the watershed.

  5. Encourage the use of stormwater management funds for installation of needed Best Management Practices (BMPs) to increase infiltration and filtration of storm water runoff.

  6. Study BMPs implemented to control storm water runoff from the Carson Park parking lots to determine whether they should/could be upgraded.

  7. Encourage stenciling of storm sewer drains within the watershed by volunteer or civic groups.

8. Distribute informational materials to property owners within the watershed regarding use of phosphorus free fertilizers and street cleaning.

As mentioned earlier, stormwater management provisions of the TMDL was incorporated into the City of Eau Claire stormwater permit in 2003. Funding to implement urban stormwater BMPs is available through the WDNR Urban Nonpoint Source Stormwater grant program.

Monitoring/ Evaluation

Baseline water quality conditions in Half Moon Lake were well established in 2001 by the USCOE study. Future monitoring will be conducted following changes in aquatic plant management activities and alum treatments. Aquatic plant surveys will be conducted every 3 years following initiation of increased macrophyte harvesting in 2004. Seasonal lake water quality monitoring will begin in 2004 and repeated annually for three years to determine effectiveness of the various management activities. Subsequently, monitoring will be conducted every three years to assess the longevity and effectiveness of the alum treatment and other implementation activities. Monitoring parameters will include nutrients, chlorophyll *a*, pH, temperature and dissolved oxygen at three sites in the lake.

Literature Cited

Barr Engineering. 1992. Management alternatives report on the diagnostic-feasibility study of Half Moon Lake water quality problems. Report prepared for the City of Eau Claire, WI. Procurement No. 9063. March. 1992. Barr Engineering Company, Minneapolis, MN.

Borman, S. 1990. Wisconsin aquatic plant control - Reconnaissance report. Wisconsin Department of Natural Resources, Western District. Eau Claire, WI.

Brakke, D. 1995. An evaluation of thermal structure, trophic status and the potential impact of boating on nutrient concentrations in Half Moon Lake, Wisconsin. Department of Biology, University of Wisconsin at Eau Claire, Eau Claire, WI.

Cook, C. 1999. A review of agricultural and urban best management practices for the reduction of phosphorus pollution. Wisconsin Department of Natural Resources. Publ. No. PUBL-SS-943-99.

Half Moon Lake Advisory Task Force. 2002. Report on Half Moon Lake water quality improvements. City of Eau Claire, WI.

James, W., J. Barko, and H. Eakin. 2001. Limnological analysis of Half Moon Lake, Wisconsin. U.S. Army Engineer Waterways Experiment Station. Eau Galle Aquatic Ecology Laboratory, Spring Valley, WI.

James, W., J. Barko, H. Eakin and P. Sorge. 2002. Phosphorus budget and management strategies for an urban Wisconsin lake. Lake and Res. Mgmt. 18(2): 149-163.

Prepas, E. B. Pinel-Alloul, P. Chambers, T. Murphy, S. Reedyk, G. Sandland and M Serediak. 2001. Lime treatment and its effects on the chemistry and biota of hardwater eutrophic lakes. Freshwater Biology (2001) 46, 1049-1060.

Reedyk, S. E. Prepas and P. Chambers. 2001. Effects of single $Ca(OH)_2$ doses on phosphorus of two boreal eutrophic lakes over 2 years. Freshwater Biology (2001) 46, 1075-1087.

Wis. Dept. of Nat. Res. 2001. Technical guidance for monitoring and model selection for TMDL development. Bureau of Watershed Management, Wis.Dept. of Nat. Res. Madison, WI.