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Mirror Lake Management Plan

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The following document was prepared during Spring Semester 2008 as part of the requirements for completion of "Lake Management: A Multidisciplinary Approach", a course offered in the Departments of Plant Biology and Zoology, University of New Hampshire. The authors were undergraduate students in the College of Life Sciences and Agriculture. It includes and reflects the statements of the four authors assigned to investigate background information on Mirror Lake in the watersheds of Wolfeboro and Tuftonboro, New Hampshire (USA).

It is likely that future *in situ* studies of Mirror Lake will provide more evidence of cyanobacterial growth dynamics and distribution, as well as additional evidence of phosphorus loading (as phosphate) that almost inevitably promotes the growth of these photosynthetic bacteria.

Photographs and other related documents may be appended at a later time.

A.L. Baker and J.F. Haney, Instructors

I. Introduction

A. Background

Mirror Lake is located mostly in Tuftonboro, NH, with one bay and part of the lake's watershed in Wolfeboro, NH. The lake area is 377 acres, making in a medium sized water body, but it's extremely close proximity to Lake Winnipesauke means that it receives less visitor traffic than it might otherwise. There are roughly 90 residences on Mirror Lake, with the majority within 50 feet of the water's edge. All of these houses are using private septic tanks for sewage. Other nearby potentially lake health-affecting structures are adjacent roads (Rt. 109, Lang Pond Rd, and Mirror Lake Dr.) and the Wolfeboro Wastewater Treatment Facility (WWTF), which is upstream of the lake.

In the summer of 2007 a cyanobacterial bloom took place at Mirror Lake, causing local authorities (though not the New Hampshire Department of Environmental Services, or NHDES) to close the lake to swimming for a short period of time. This was the first recorded bloom on Mirror Lake. Prompted partially by the algal bloom of 2007, the fall semester 2007 Field Limnology class at UNH surveyed Mirror Lake. Measurements were taken using a multi-parameter probe along several horizontal transects of the lake, as well as a vertical profile taken at the deepest point on the lake. Key measurements included an average phosphorus concentration of 10.8 μg/l, which exceeds the 10 μg/l value necessary for cyanobacterial blooms (Table 1.1), and a high concentration of phycocyanins (a cyanobacterial indicator) that corresponded significantly with the peak turbidity value (unpublished data).

Table 1.1: Total Phosphorus Data (μ/L)

NHDES Trophic Report Data

July 1992	Jan 1993
13.0	11.0
11.0	8.0

UNH Limnology Class Data

Fall 2007	10.4
	10.0
	12.0

VLAP Data

Location	Fall 2007	Winter 2008
ML-AL	29.0	26.0
ML-WA	49.0	15.0
ML-WB	23.0	13.0
ML-WRD	18.0	156.0
ML-EI	2.0	249.0

Concern over the source of the bloom and the risks posed by further blooms prompted the spring 2008 UNH Lakes Management class to investigate the lake, culminating in the creation of this preliminary Lake Management Plan (LMP). The LMP addresses the most pertinent initial concerns for the lake, including primary sources of excess phosphorus input, how to address changing these inputs, the importance of resident education concerning the health and basic ecology of the lake, and recommendations for the future care of the lake.

B. The Comprehensive Lakes Inventory

As a source of baseline information for evaluating the health and use of the lake, a Comprehensive Lakes Inventory (CLI) was created for Mirror Lake. While the CLI should be referenced directly for a full description, some key factors affecting health are given here. Mirror Lake has a relatively small watershed area to lake area ratio, making it easier to identify the possible sources of problems observed. The lake has four discrete defined inlets from a single brook and one undefined inlet from a marsh to the northeast. There is a single outlet at the northwestern corner. With an average depth of 13 feet and 64% of the lake within the littoral zone, primary production is high. With the epilimnion having been seen to form at around 9 feet deep, much of this production takes place in the hypolimnion. Also, Mirror Lake is dimictic, and has a hydraulic resonance time of two years at last measurement (1993).

II. Possible Causes of Problem

The recent algal bloom of Mirror Lake has caused great concern throughout the state, and created the need for a lakes management plan. The algal bloom contained cyanotoxins that not only create a green scum on the surface of the lake, but also cause toxicity of the waterbody. These cyanotoxins are lethal to small animals, and pose as serious health risks for humans. Some of the health effects include skin irritation, vomiting, liver failure, and negative effects to the nervous system. Children are more susceptible to lower concentrations than adults due to their lower weight (WDPH, 2004). Harmful algal blooms typically result from the excess nutrient loading of phosphorus, which is normally a limiting nutrient to the growth of algae. When it is present in excess in a waterbody, the algae is able to grow without limitation.

Within any watershed, there are many potential sources of phosphorous. These sources can be classified as point sources which are large businesses, factories, or any establishment which increases the amount of impervious surface in the watershed. Another less obvious source of phosphorus for any water body is household input, a non-point source (Figure 2.1). Both classifications of phosphorus sources have a significant impact on the overall health of the waterbody, and each should be given equal attention and consideration.

Household input of phosphorus can add up quickly. There are many simple ways to reduce the amount of phosphorus contributed per household. Much like point sources, it is essential to minimize the amount of impervious surfaces. Impervious surfaces do not allow nutrients to enter the soil and be taken up naturally by surrounding vegetation. This causes increased runoff of nutrients. For example, improper disposal of chemicals when washing your car on your paved driveway is a common example of a non-point source of pollution. Rooftops and walkways are other examples of impervious surfaces of a household.

Another non-point source of pollution is the use of phosphorus containing fertilizer. The excess use of fertilizer can greatly increase the nutrient loading into a waterbody. Animal waste is also another source of phosphorous on a lawn. If left on the lawn without proper disposal, this waste can add to the amount of phosphorus which makes its way into the lake. Lastly, fertilizer is not the only chemical containing phosphorus that has potential to enter the lake. Household detergents and cleaners should also be examined. By using phosphorous free chemicals, excess nutrient loading can be avoided. When dealing with any chemical it is important to ensure proper disposal and removal from the household.

Another risk of phosphorous input is improper maintenance of personal sewage systems. Household sewage systems should be inspected annually. Also, the lawn above the sewage system should remain level, without the presence of any vegetation. It is important to make sure the ground is level, to disallow the accumulation of water on the ground above the sewage system. This allows for maximum absorption of wastewater, and allows for the settling of the solid waste in the system. By cutting down on household water use, as well as avoiding the flushing of unnecessary solids, sewage systems can regulate themselves regularly.

Natural vegetation is a great way to control input of phosphorus. By maintaining the natural shoreline, vegetation can not only provide habitat for animals, but these plants also use the nutrients in the soil for growth. Vegetation on the land adjacent to the lake is important for shoreline stabilization as well. If the natural vegetation is removed, increased sedimentation can occur as well as direct input of nutrients.

Natural input of phosphorous does occur, but these sources cannot be regulated as the input from point and non-point sources can (Figure 2.1). Leaching of phosphorus from the sediments does take place, as well as sedimentation and atmospheric input of nutrients. These inputs do not occur at high enough levels to cause an algal bloom on their own. By eliminating, or significantly reducing, the excess phosphorus input the occurrence of toxic algal blooms can be avoided.

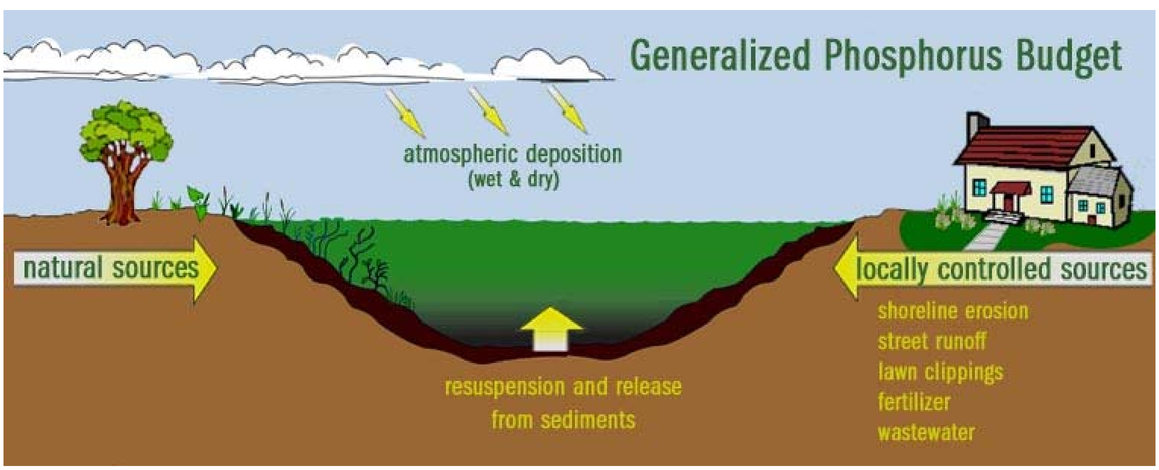


Figure 2.1: Phosphorus Sources

III. Solutions

A. Addressing the Sources of Phosphorus

Mirror Lake and its respective watershed are shared by two towns. This fact cements the need for the towns of Tuftonboro and Wolfeboro to work together in addressing the water quality issues in Mirror Lake. There have been indications and observations that some people accuse the WWTF of being the sole source of the problem. While the WWTF does contribute unknown amounts of phosphorus to Mirror Lake, residents should not blame the any single individual for the phosphorus loading problems. It is important to remind citizens that wastewater treatment facilities are not producing the phosphorus that they discharge. The water that the WWTF is treating comes from domestic homes and facilities in Wolfeboro that use the public wastewater system. The WWTF is receiving an increasing amount of wastewater which contains high amounts of nutrients that require disposal. While the WWTF is changing its methods of disposal to deal with the increase, citizens can assist these efforts from their households. By changing a few household practices, domestic houses as well as other facilities that use the public wastewater system can greatly reduce the amount of phosphorus they contribute to the system. If everyone made an effort it would vastly reduce the amount of phosphorus entering the WWTF. This would reduce the amount of phosphorus that the WWTF would be responsible for removing and as a result decrease the amount of phosphorus released from the facility. One household practice that would benefit the amount of water that the WWTF has to treat is water conservation. Simply being conscious of the amount of water you use every day would help decrease the amount of wastewater you produce. A further incentive for water conservation is it would also save the homeowner money.

B. Household Practices

Outside of the House

- Fertilizer Usage: Phosphorus containing fertilizers can contribute greatly to phosphorus loadings. There are a few methods to avoid this:
  - Less is more! Try to avoid over fertilizing.
  - Use non phosphorus containing fertilizer.
  - Don’t fertilize. It is often the case that fertilizing is not necessary to have a healthy lawn.
- Animal Waste: This is also a source of phosphors and a simple solution is picking up after your pet(s).
- Natural Buffer: For lakeside property owners, maintaining a natural buffer of vegetation on the lake shore would help reduce phosphorus loadings. The vegetation of a natural buffer is not a manicured lawn; it is made up of native shrubs and trees in the area.

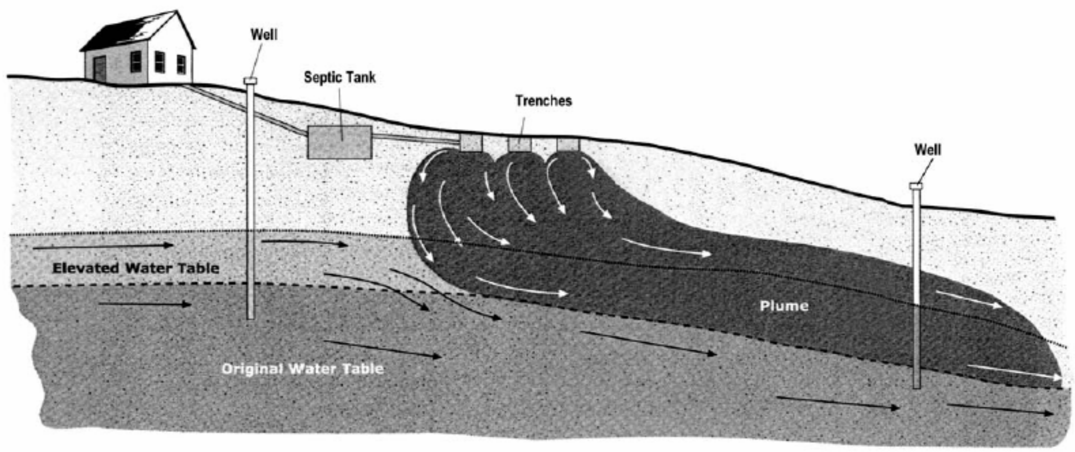
Inside the House

- Detergents & Cleaning Solutions: These generally account for the most phosphorus entering wastewater (septic and public) from households. Using non-phosphorus based detergents and cleaning solutions would help immensely.

- Garbage Disposals: Foods also contain phosphorus (eg. dairy, meat & fish). A solution would be throwing leftovers in the trash instead of using a garbage disposal for high phosphorus containing foods.

Septic Tanks

- Septic tank effluent enters the groundwater and may enter a waterbody if the septic system is adjacent to it (See Figure 3.1). Septic tank failures can also contribute to phosphorus loading. The primary reason for septic failures is incorrect operation and maintenance. The list in Table 3.1 from the Stormwater Manager's Resource Center is important for septic system owners to know.



Source: Adapted from NSFC, 2000.

Figure 3.1: Septic System Effluent Diagram

Table 3.1: Steps That Can Reduce Pollutant Loadings from Septic Systems
1. Do not wait until septic system shows sign of failure. Inspect the system annually and have it pumped-out at least once every three years. 2. Keep records of pumping and maintenance and a map of the location of your system and drainfield. 3. Practice water conservation indoors and divert roof drains and surface water away from the system. 4. Use caution in disposing materials down the drain. Household chemicals can kill the bacteria that make the system work and non-degradable materials (cigarette butts, etc.) can clog the system. 5. Keep heavy equipment and vehicles off your system and drainfield. 6. Don't cover your drainfield with impermeable surfaces that can block evaporation and the air needed for effluent treatment.

- Chemical Additives: Many organic solvents are advertised but there is little scientific proof that they work. They have the potential of being more harmful for the septic system than helpful (SMRC).
- Garbage Disposals: It is not advised to have a garbage disposal if you are using a septic system. They "contribute to the loading of suspended solids, nutrients, and BOD to septic systems, as well as increasing the buildup of solids in septic tanks" (SMRC).

- Location: Another reason for septic failure is if the septic tank and leach field were not put in an adequate location (SMRC). Make sure if you are receiving a new septic system, that it is installed in an appropriate area on your property.

C. Wolfeboro Wastewater Treatment Facility Plans

What is Being Done

The WWTF has been receiving a steadily increasing amount of wastewater for several years. The facility has recently analyzed the existing, as well as new, methods for treating the town's wastewater. The most efficient and cost effective method they found in their analysis has been chosen and currently being implemented. The new system that the WWTF is converting to is called a Rapid Infiltration Basin System (RIBS). RIBSs "are permeable earthen basins, designed and operated to treat and disperse municipal wastewater" (MPCA, 2005). This system is being built on a site that has adequate soils for the system to operate correctly. The system will eliminate the overland flow of wastewater that was a result of excess wastewater being sprayed. The WWTF is also looking into further methods of nutrient removal from municipal wastewater.

Options & Reccomendations

A recommendation which was referred to previously, is water conservation practices and the reduction of phosphorus use and in households and facilities in Wolfeboro that use the public wastewater system.

The second recommendation concerns a further method of nutrient removal from municipal wastewater. There are several options for the removal of excess nutrients in wastewater that are available. One method that was recommended by the NHDES Wastewater Engineering Bureau is using polyaluminum chloride as a coagulant. This chemical precipitant may be used for phosphorus removal, total suspended solids removal, chemical oxygen demand reduction, biological oxygen demand removal, and total organic carbon removal. This is considered one of the better coagulant removal techniques because it does not produce as much sludge as other coagulants.

IV. Recommendations for the Future

With the past, present and future efforts and actions of the local citizens, the WWTF, and the NHDES, Mirror Lake is on its way to solving its water quality issues. Headway has already been made by the changes at the WWTF as well as the involvement of the local citizens. The following is a list of recommendations devised to help in the remediation of the lake:

Complete the CLI

As stated previously the CLI is an important source of baseline documentation that assists in evaluation the health of the lake. A CLI for Mirror Lake has been started but it is missing valuable information. Having a completed CLI would potentially help an analyst understand the probable causes of specific issues in or around the lake.

Resident Education

As with any local issue resident education is highly important. Local citizens should be informed about the lake's issues and the ways that they can help. For example, they should be informed of ways to reduce household input of phosphorus into the water system and why these practices are significant. This education and communication with the local citizens can be accomplished in a number of ways; town meetings, local workshops, newsletters, pamphlets, presentations, and newspaper articles. It is also important not to exclude younger generations from this education.

Resident Survey

It is often helpful to perform an anonymous survey of the individuals that live around the lake. General questions include but are not limited to: fertilizer usage, septic systems, ground cover, impervious surfaces, buffers, recreation, and personal values of the lake. This information is important for the development of a lake management plan because it is used to determine how to best inform residents of the effects of their household practices.

Water Budget

In order to better assess current lake health and to be able to better predict the future of the lake, we also recommend the creation of a water budget. A goal of a water budget is as simple as it sounds, determining how much water is entering the lake and from where, and how much water is leaving the lake and from where. In reality, determining these values can be more difficult than it seems. While the primary inlet brook and outlet stream will probably account for the majority of the flow, other flow options include precipitation, evaporation, overland flow, groundwater seepage (in or out), and springs. There is also the question of what volume of flow is derived from Nineteen Mile Brook through the marsh on the eastern side of the lake. Preliminary flowage data from the primary inlet and outlet, annual precipitation, and calculated evaporation will give you a baseline water budget that can be refined further based on investigation of other likely water flow options. For details on correctly assessing flow, consult an expert in the field.

Phosphorus Budget

Creating a phosphorus budget is another highly recommended means of assessing current lake health and also projecting future trends. Similar to the water budget, the phosphorus budget identifies inputs and outputs determining the total lake phosphorus content. Creation of a phosphorus budget requires a functional water budget and regular appropriate sampling of the lake water, sediments waters, and sediments themselves. Because phosphorus is a key limiting element for organism growth in Mirror Lake, especially cyanobacteria, monitoring its concentration and location (due to various modes of cycling in the lake) is very important to lake management. While interpretation of phosphorus data and recommendations on management actions require special training, collection of the raw data can be carried out by volunteers with minimal training.

V. Timeline for Implementation

Summer 2008

1. Establish a comprehensive panel of "stakeholders" for Mirror Lake, all of whom will be involved in following work on the lake. Involving everyone concerned from the initial steps is the best way to avoid later complications, even if it can be difficult at first. We recommend bringing a suitable lake ecology expert onto this panel.

2. Develop a plan for the future biological monitoring of Mirror Lake that will provide the necessary record of lake health necessary in all further lake assessment. This should specifically include phosphorus, phycocyanins, chlorophyll, turbidity, and transparency, as well as any other parameters that the panel and lake experts deem necessary. This sampling regime should include samples from multiple parts of the lake, as well as immediately upstream of the lake in the inflowing brook. It should also record a vertical profile of the lake (at the deepest point) with every sampling period, and should sample multiple times per year, dates being determined by the proper lake expert.

3. Create a resident survey to collect information that can inform resident education to be able to target the issues of chief concern. These include septic tank age and condition, fertilizer use (amount and formulation), amount of impervious surface on the property, and types of lake use. Other subjects may be added as the lake panel sees fit.

Fall 2008 and Into the Future

4. Implement the monitoring plan developed in Step 2.

5. Conduct resident survey. Create educational mailing for lake residents addressing phosphorus impact on Mirror Lake, household phosphorus sources (highlighted by survey results), how to limit phosphorus inputs, and any additional areas of concern highlighted by the survey.

6. Develop phosphorus and water budgets for Mirror Lake. The use of these is in determining your relative progress in phosphorus remediation, and in forecasting future conditions. Creating the budgets will require the increased phosphorus monitoring provided for in Step 2, as well as water flow data that can be taken utilizing a combination of flowmeters at the inlet and outlet of the lake, and knowledge of the size of the inlet and outlet. These budgets will be able to be refined over time and with continued sampling. Consult a lake expert for carrying out these budgets.

7. Complete the Comprehensive Lake Inventory begun by the UNH Lakes Management class. This will fill out your baseline information database for Mirror Lake.

Additional Educational Information

8. As an additional recommendation, anyone interested in comprehensive but understandable overview of lake ecology and lake management is encouraged to read "Managing Lakes and Reservoirs", available at www.nalms.org for around $30. It may be helpful for a copy of this text to be available for loan from the local library.

VI. Reference List

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"Algae Blooms: Blue-Green Algae/Cyanobacteria." *Wisconsin Division of Public Health* (WDPH). 2004. <http://dhfs.wisconsin.gov/eh/Water/fs/Cyanobacteria.pdf>

"Figure 2.1." *Lake Access* (LA). <http://lakeaccess.org/lakedata/lawnfertilizer/p-budget.jpg>