Long Lake Management Plan

Phase III: Lake Management Plan

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Long Lake Preservation Association

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With assistance from:
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Long Lake Management Plan

Phase III: Lake Management Plan

Table of Contents

List of Tables

List of Figures

List of Appendices

Executive Summary

The study described by this report was initiated by the Long Lake Preservation Association to provide information to water resource managers and citizens regarding the management of Long Lake. The study determined that Long Lake is a mesotrophic to slightly eutrophic lake, which experiences slightly degraded water quality in the fall due to watershed runoff and internal loads of phosphorus. The lake is at a trophic level where it is very sensitive to even slight increases in nutrient loads.

During 1994, the Long Lake Preservation Association completed the first phase of a three-phase project to develop a Lake Management Plan. Phase I was designed to assemble the requisite data to provide an understanding of the interacting physical, chemical, and biological processes controlling the water quality of Long Lake. The project included taking periodic water samples from Long Lake and the five watershed lakes throughout the year and sending them to the Wisconsin Department of Hygiene Lab to be analyzed. Additional on lake activities included bimonthly monitoring of water clarity (Secchi disc) and temperature, dissolved oxygen, and conductivity of the water column at five sites in the lake. On shore activities included monitoring the lake level and precipitation on a daily basis throughout the spring, summer, and fall. A study of the data collected led to the following conclusions:

- Long Lake has very good water quality.
- Long Lake, on average, is a mesotrophic lake (ideal for fisheries and for recreational use).
- Most sampling locations noted at least one measurement in the "mildly eutrophic" category ("mildly problematic" category).
- Results show the lake is vulnerable to problematic conditions if uncontrolled development of the lake's watershed were to occur.
- A management plan for the lake is needed to protect it.

Phase II involved preparation of hydrologic and phosphorus budgets for existing watershed land use conditions. The budgets were used to provide an understanding of the sources of phosphorus to Long Lake and their effects on the lake's water quality. The following items summarize some results of this phase:

- Nearly 40 percent of the total phosphorus load to Long Lake comes from watershed surface runoff, with subwatershed A being the largest contributor.

- Subwatersheds B, C, D and the Mud Lake subwatershed yield the largest amount of phosphorus based upon their percentage of the overall watershed area.

- Subwatersheds A and B contribute their phosphorus loads directly to the lake and, therefore, increased loadings following new watershed development is very undesirable. Also, because subwatersheds A and B contribute their phosphorus loads to the most upstream portions of the lake, phosphorus loading from these watersheds affects the water quality of the entire lake.

The third phase of the project, described in this report, involves the preparation of the Long Lake Management Plan. The first step in the development of the management plan was the establishment of a long-term water quality goal for Long Lake. The lake's goal is to preserve the current water quality of the lake as defined by the 1994 water quality study. Specifically, the goal is to maintain an average summer total phosphorus concentration in the lake's mixed surface waters (i.e., upper six feet) of:

- 16 ug/L in Basin A
- 17 ug/L in Basin B
- 19 ug/L in Basin C
- 18 ug/L in Basin D
- 17 ug/L in Basin E.

The second step in the development of the lake's management plan was the evaluation of different watershed development scenarios to determine acceptable (i.e., the water quality of the lake is within the established goal) and unacceptable (i.e., the water quality of the lake fails to meet its goal) development options. A lake mass balance model calibrated to the 1994 lake water quality under existing watershed land use conditions was used to predict how the inputs from various watershed development scenarios would affect the water quality of Long Lake. The following items summarize the water quality modeling results of the Phase III portion of the Long Lake Management Plan:

- Long Lake's water quality is highly susceptible to increasing development within the lake's direct watershed. The water quality of Long Lake Basins A and E are the most susceptible, while Basin D is the least susceptible, to corresponding magnitudes of development.

- Development of a second tier of properties around the entire lakeshore would increase the phosphorus loadings to the lake such that none of the basins would meet their water quality goals. The water quality in Basins A and B would be the most affected by development of the second tier of properties.

- Failure of all of the septic systems around the lakeshore would also cause all of the lake basins to fall short of their water quality goals. Conversely, water quality modeling indicates that the average total phosphorus concentrations in Basins A, B, D and E would be reduced by 1 µg/L, respectively, if the septic system inputs were removed altogether.

- The water quality modeling indicates that Long Lake Basins A, C and E would fall short of their water quality goals, even if structural Best Management Practices (BMPs) were instituted for 50 percent medium-density residential development (i.e., one third to one acre lots) within the direct watershed. One hundred percent medium-density residential development (with completed structural BMPs) within the direct watershed would cause all of the Long Lake basins, except Basin D, to fall short of the water quality goals.

- As a result, complete medium-density residential development (i.e., one third to one acre lots) is not appropriate for ultimate land use development within the lake's direct watershed. A combination of less intensive landuses, along with implementation of structural BMPs, should be considered to ensure that Long Lake's water quality goals are met.

- Model results indicate development of the Long Lake watershed with 5 acre lots and implementation of structural BMPs would achieve the lake's water quality goal.

The final step in the development of the lake's management plan was the determination of specific management actions to preserve the quality of Long Lake. The recommended actions protect Long Lake by restricting the quantity of phosphorus loaded to the lake under future development conditions. Phosphorus loading is controlled by regulating development and by requiring Best Management Practices (BMPs) to reduce the quantity of phosphorus in watershed runoff waters reaching Long Lake. Details for these recommendations are found in the Long Lake Management

Plan section of this report. The following items summarize the recommended actions and refer the reader to the specific section of the plan for further information:

- Efforts should be made to ensure the Boy Scout Camp remains in place and that they continue their policy of minimum development in the camp (See Land Conservation).
- The following land use restrictions should be put in place for all shoreline new development and redevelopment (See Shoreland Ordinances):
  1. Minimum lot size of 40,000 square feet;
  2. Minimum lot width of 150 feet
  3. A maximum of 25% of a lot to be built upon (i.e., maximum of 25% impervious surface following lot development);
  4. A one hundred-foot set-back/buffer zone required for all new development and redevelopment around the lake.
- A minimum lot size of 5 acres required for all second tier and beyond development within the watershed (See Watershed Ordinances).
- All septic systems must be tested when properties change hands or building permits are issued for improvement (See Septic System Ordinance).
- Lake and inflow sampling should be completed on a three-year cycle to determine goal achievement. To make the program more cost effective, the self help water quality monitoring program should be continued on the lake. The sampling locations should be rotated so that each of the five lake basins is sampled on a three-year cycle (See Recommended Lake Water Quality Monitoring and Watershed Runoff Monitoring).
- The LLPA should work with Washburn County to establish the above regulations (See Long Lake Management Implementation).
- The LLPA should establish a Lake District that includes the entire Long Lake watershed (See Lake District Formation).
- LLPA should continue to work with the WDNR and other organizations to obtain grants for the purchase of land for conservation purposes (See Land/Wetland Conservation).
- All wetland around the lake should be identified by maps and a ground truth search. Additional regulations should be established to supplement the protection provided by the Wetland Conservation Act and protect the wetlands from further development (See Land/Wetland Conservation).

Whenever feasible, the LLPA should apply for additional lake management grant monies or lake protection grant monies to partially fund its projects.

Introduction

Long Lake is known as one of the premier, high quality fisheries in the northwestern region of the state and has been dubbed the "Walleye Capital of Wisconsin." Located on the headwaters of the Brill River in southeastern Washburn County, it is the largest lake in the county. The lake is approximately 19 miles in length, has a shoreline length of approximately 99 miles, and a surface area of 3,474 acres. The lake has a maximum depth of 74 feet and an average depth of 26 feet. Its 43,433-acre watershed is largely undeveloped. Approximately 24,976 acres of the watershed directly contributes watershed runoff to Long Lake, while the remaining watershed area is essentially landlocked. The Long Lake physical morphometry is tabulated in Table 1. Watershed development consists of approximately 600 residences and several resorts along the lake's shoreline and some agricultural land use near the lake. The Tomahawk Scout Reservation has preserved approximately 3,000 acres of land in its natural state, including approximately 8 miles of shoreline. Several streams and lakes contribute water flow to Long Lake including Slim Creek, Twin Lake, Big Devil Lake, Mud Lake, Little Mud, and a small tributary in Section 16. The lake has five developed public boat landings.

Table 1

Long Lake Physical Morphometry

Normal Elevation	1223.0 feet (MSL)
Surface Area @ Normal	3,474 acres
Maximum Depth	74 feet
Volume @ Normal	89,508 acre-feet
Mean Depth (Volume/Surface Area)	26 feet
Watershed Area to Lake Area Ratio	12.5 : 1

In presettlement times, the Long Lake basin consisted of at least three glacially formed lakes and their interconnecting streams. In the late 1800s, a dam was constructed to raise the water level approximately 8 feet, fusing these separate bodies of water into one. Loggers then used the lake to transport logs downstream. The raised water level, however, has resulted in a complex body of water. The lake contains several basins, and basin depths vary from 8 to 74 feet.

Since its "discovery" in the late 1800s as a logging site, development around the lake has been slow and controlled. However, the Long Lake Preservation Association (LLPA) is concerned that additional development in the Long Lake watershed may result in degradation of the lake's fishery. The LLPA collected a limited amount of water quality data during 1991 through 1993 to determine the existing water quality of the lake. The data suggest Long Lake would be assigned a trophic status of Mesotrophic, thus verifying its good water quality. However, the data suggest that algal blooms during the late summer months result in mildly eutrophic conditions in some portions of the lake. The data indicate the lake's water quality is vulnerable to degradation should uncontrolled watershed development occur. Therefore, the LLPA initiated a three-phase project to develop a management plan, designed to preserve the existing water quality of the lake. The three phases of the project include:

- **Phase I**—Collection of data (Barr, 1995).

- **Phase II**—Preparation of hydrologic and phosphorus budgets for existing watershed land use conditions (Barr, 1996).

- **Phase III**—Preparation of the lake management plan.

This report discusses the methodology, results, and conclusions from Phase III of the Lake Management Plan. The Phase III portion consisted of:

- Establishment of the long-term water quality goal for Long Lake;
- An evaluation of water quality modeling scenarios of Long Lake and its tributary watershed to predict the effect of new sources of phosphorus following various levels of development;
- A lake management plan to achieve the long-term water quality goal of Long Lake;
- A long-term monitoring plan to determine goal achievement.

Phase I Summary: Water Quality Study of Long Lake

The 1994 water quality survey of Long Lake was designed to provide an understanding of the interacting physical, chemical, and biological processes controlling the water quality of Long Lake. This information was used for model calibration during Phase II of the project. It was also designed to provide baseline water quality information for the lake to help the LLPA complete its Lake Management Plan in the Phase III portion of the project.

Long Lake has five distinct basins, and samples were collected from each of the five basins shown on Figure 1. Water samples were collected from Long Lake following ice-out and biweekly during the summer (late June through late August). Samples were collected from 0-2 meters (i.e., integrated composite samples) and analyzed for various water quality constituents including nutrients (i.e., phosphorus and nitrogen species), algal species, abundance, and biomass (i.e., phytoplankton and chlorophyll analyses), and water quality indicator parameters (specific conductance, pH, and alkalinity). In addition, total phosphorus samples were collected from above and below the thermocline whenever it existed and from one-half meter above the lake bottom. When no thermocline was noted, one mid-column sample was collected and analyzed for total phosphorus. In addition, biweekly measurements of Secchi disc transparency, temperature, and dissolved oxygen were completed.

1994 Long Lake Water Quality

Data collected from Long Lake during 1994 indicate its water quality is very good and is similar to the water quality noted in previous years. Results of each of the water quality monitoring parameters, below, are discussed in the following sections:

- Total Phosphorus
- Chlorophyll a
- Secchi Disc Transparency
- Temperature and Dissolved Oxygen

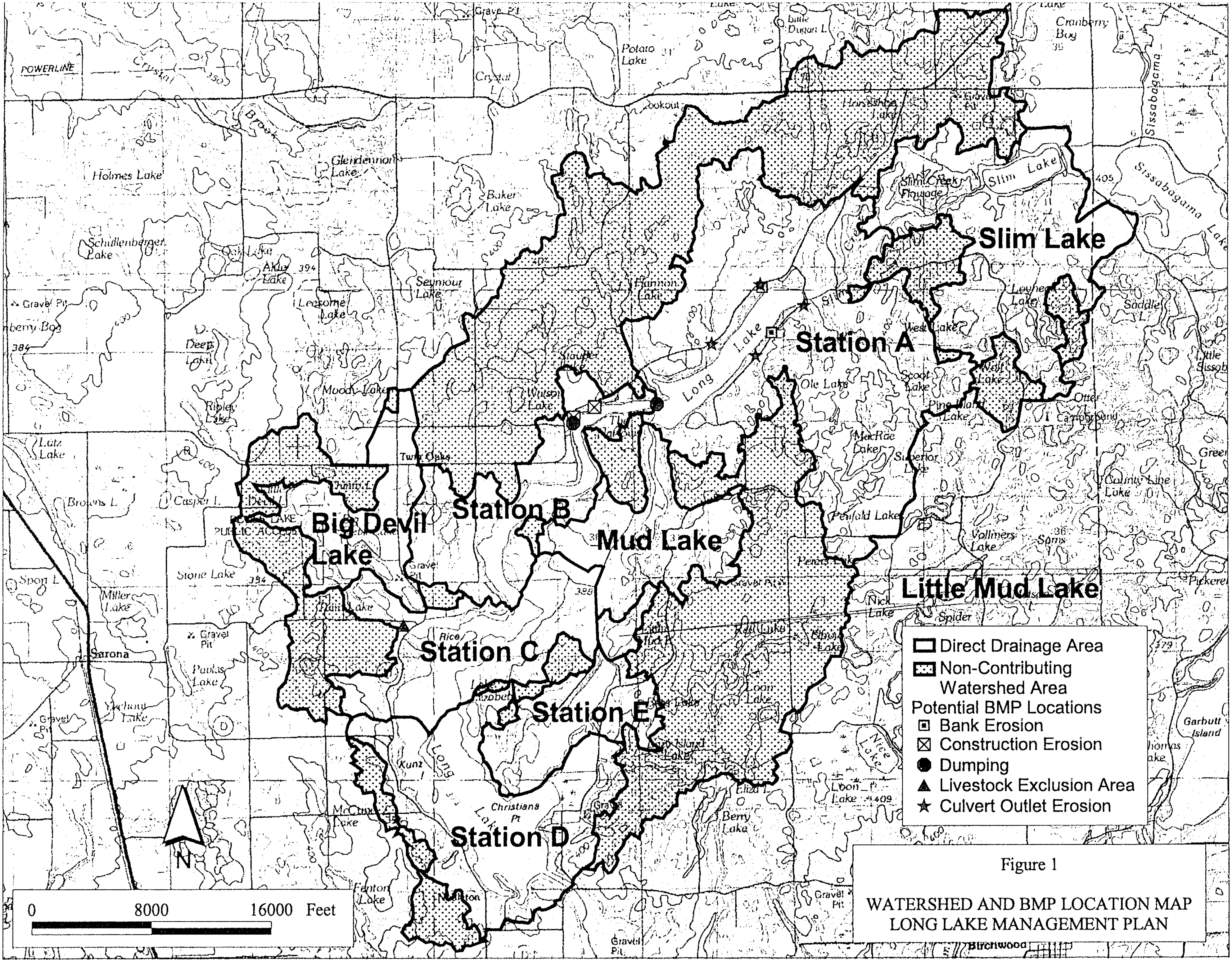

Figure 1

WATERSHED AND BMP LOCATION MAP
LONG LAKE MANAGEMENT PLAN

Total Phosphorus

Total phosphorus is the nutrient limiting algal growth within Long Lake. As such, it indicates the lake's potential for algal growth, and indicates the lake's level of eutrophication. Total phosphorus data collected from Long Lake during 1994 indicate the lake would have a designated trophic status of mesotrophic. This means the lake is receiving a moderate level of phosphorus loading and its water quality is very good. Average summer epilimnetic total phosphorus concentrations from all five sample locations within Long Lake were within the mesotrophic category. In addition, nearly all individual sample points from these locations were within the mesotrophic category. Exceptions occurred during the late summer when concentrations at Stations C, D, and E were within the eutrophic category. Long Lake total phosphorus data collected at depths indicate phosphorus recycling from bottom sediments occurs during the summer months. These data indicate that judicious management of the lake's watershed is essential to preserving the lake's current mesotrophic trophic status.

Chlorophyll a

Chlorophyll a is a pigment found within algae. Its measurement indicates the quantity of algae found within a lake, and provides a measure of a lake's level of eutrophication. Chlorophyll a data collected from Long Lake indicate the lake's trophic status ranges from mesotrophic to mildly eutrophic. Average summer chlorophyll a values from Stations B, C, and D were within the eutrophic category, while the average summer value from Station A was borderline mesotrophic/eutrophic. Station E noted an average summer value within the mesotrophic category. These data indicate algal yield from the lake's phosphorus concentration is slightly higher than expected. As indicated previously, average phosphorus concentrations were entirely within the mesotrophic category.

Algal populations increased throughout the summer at all Long Lake sample locations. Chlorophyll a values at all locations were within the mesotrophic category during the early summer and were within the eutrophic category during the late summer. Differences in the rate of increase of chlorophyll a values were noted at the individual sample locations. In general, stations at the northern end of the lake increased more rapidly than stations at the southern end of the lake.

Chlorophyll a data corroborate the phosphorus data and support the need for a management plan to prevent additional increases in the lake's algal population. The lake's current chlorophyll a concentrations are not considered problematic. However, the mildly eutrophic trophic status indicates that additional increases would likely result in problematic conditions during the summer period.

Secchi Disc Transparency

Secchi disc transparency provides a measure of a lake's water clarity. Because increasing eutrophication is associated with decreasing water clarity, Secchi disc measurements can provide an indication of a lake's level of eutrophication. The 1994 Long Lake average summer Secchi disc transparency values were all within the mesotrophic category. The mesotrophic conditions occurred despite algal growth which was higher than expected from the lake's phosphorus concentrations. Algal species differ in their impact on a lake's transparency because of their different morphologies and light scattering properties. Consequently, a lake's transparency is sometimes better or worse than expected, based upon its chlorophyll concentrations. In 1994, Long Lake exhibited better transparency than expected from its chlorophyll concentrations. Its summer average transparency was entirely within the mesotrophic category, while summer average chlorophyll values ranged from mesotrophic to eutrophic.

The 1994 water transparency measurements indicate that Long Lake was suitable for all types of recreational activities throughout the summer. Individual transparency values, with few exceptions, were within the mesotrophic category. Most locations, however, noted at least one value within the mildly eutrophic category during the late summer period. The data indicate the lake currently has very good water transparency, but also indicate the importance of lake management to prevent additional increases in the lake's algal population, particularly during the late summer period.

Temperature and Dissolved Oxygen

Depth/time relationships or isopleths were used to determine the stratification (mixing) pattern at each Long Lake sample site (i.e., temperature isopleths) and to assess the loss of oxygen near the lake bottom (i.e., oxygen isopleths). Temperature isopleths indicate Long Lake became thermally stratified following spring overturn and remained stratified until the fall overturn. The density difference between the warm surface waters and the cold bottom waters caused the hypolimnion (bottom waters) to be "sealed-off" from the atmosphere by the epilimnion (surface waters). The oxygen in the hypolimnion (bottom waters) was not replenished by wind and wave action as occurred in the epilimnetic (surface) waters. Instead it was depleted by decomposition of organic matter. The dissolved oxygen isopleths indicated that extremely low dissolved oxygen concentrations were noted in the hypolimnion (bottom waters) at all sampling locations during the summer period. Oxygen depletions in the bottom waters of Long Lake affect its fishery, and result in the release of phosphorus from its lake sediments. This release of phosphorus from the sediments is known as the lake's "internal load." The lake's thermal stratification can "seal off" most of the phosphorus rich bottom waters from the epilimnion (surface waters) until the fall overturn period. However, some of the phosphorus recycled from bottom sediments can diffuse into the epilimnion and contribute to increased algal growth during the late-summer months. Hence, the internal phosphorus load from the lake's bottom waters appears to be at least partially responsible for the increasing epilimnetic phosphorus concentrations during the late-summer period and likely becomes available to be released into the surface waters during the fall overturn period.

1994 Watershed Lakes Water Quality Study

Data collected from lakes within the Long Lake watershed provide an indication of total phosphorus concentrations entering Long Lake from its subwatersheds. Mud Lake phosphorus concentrations were approximately four times higher than concentrations noted in Long Lake. Little Mud Lake and Slim Creek Flowage exhibited concentrations approximately three times and two times higher, respectively, than Long Lake concentrations. Big Devil Lake noted concentrations similar to concentrations measured in Long Lake.

Phase II Summary: Lake Water Mass Balance Budgets

Preparation of the 1994 hydrologic and phosphorus budgets for existing watershed land use conditions was designed to provide an understanding of the sources of phosphorus and how the inputs affect the water quality of Long Lake. The following items summarize the results of the Phase II portion of the Long Lake Management Plan:

- Nearly 40 percent of the total phosphorus load to Long Lake comes from watershed surface runoff, with subwatershed A being the largest contributor. Other major contributors include atmospheric (16 percent), groundwater (15 percent), and internal loads (24 percent).

- Subwatersheds B, C, D and the Mud Lake subwatershed yield the largest amount of phosphorus based upon their percentage of the overall watershed area. Cropland contributes approximately 10 percent of the total load to Long Lake Basins B, C and D, and is a negligible input for the remaining basins. Internal loading from the lake's bottom waters provides larger inputs to Long Lake Basins B (16 percent), C (17 percent), and D (24 percent), while providing approximately 12 percent to the remaining basins. The water quality of Long Lake Basin D is mostly influenced by the phosphorus loads coming from the internal load and upstream basins. Septic system loading represents larger inputs to Long Lake Basins E (6.7 percent), B (3.3 percent), and D (3.3 percent), while providing less than 3 percent to the remaining basins.

- Subwatersheds A and B contribute their phosphorus loads directly to the lake and, therefore, increased loadings following new watershed development is very undesirable. Also, because subwatersheds A and B contribute their phosphorus loads to the most upstream portions of the lake, phosphorus loading from these watersheds affects the water quality of the entire lake.

Phase III: Methods

The methods used for Phase III of the Lake Management Plan project are discussed in the following sections of this report. Included in the discussion are:

- Revised Hydrologic and Phosphorus Budget Determinations
- Watershed Land Use Evaluation
- Rainfall, Evaporation, and Lake Outlet Data
- Hydrologic Budget
- Phosphorus Budget
- Lake Water Quality Mass Balance Modeling

Revised Hydrologic and Phosphorus Budget Determinations

A visit to the Long Lake watershed during the spring of 1997 revealed that various portions of the lake's watershed area are made up of depressions which do not directly contribute overland flow to Long Lake under normal climatic conditions. Approximately 24,976 acres of the 43,433-acre total watershed area directly contributes overland flow to Long Lake, while the remaining watershed area is essentially landlocked. Therefore, the hydrologic and phosphorus budgets for Long Lake were revised.

The Long Lake direct watershed (i.e., 24,976 acres) was divided into nine subwatersheds which included five of the tributary watershed lakes and the remaining areas draining directly to each of the lake basins. Table 2 shows the direct watershed areas for each of the nine subwatersheds. Subwatersheds A and B and the Slim Lake subwatershed, alone, comprise more than 50 percent of the total watershed area.

Table 2

Long Lake Direct Watershed and Water Surface Areas

	Watershed Area (acres)	Water Surface Area (acres)
Watershed A	7,696	529
Watershed B	2,398	475
Watershed C	2,488	667
Watershed D	3,491	1,413
Watershed E	1,352	423
Slim Lake Watershed	3,904	315
Mud Lake Watershed	1,836	125
Big Devil Lake Watershed	1,599	194
Little Mud Lake Watershed	212	61
Total Watershed Area	24,976	4,303

Watershed Land Use Evaluation

The 43,433-acre total Long Lake watershed primarily consists of undeveloped forest land. The woodland in the Long Lake watershed is primarily Aspen and Northern Hardwood. The Northern Hardwood cover typically consists of Red Oak, White Oak, and Paper Birch interspersed with Quaking Aspen, Basswood, White and Red Pine. In some areas Red and Sugar Maple make up the under story suggesting a change in timber cover in the future. Quaking Aspen is the dominant species of Aspen in the Aspen cover type.

Cropland comprises less than 6 percent of the watershed, approximately 2,176 acres (excluding pasture). Approximately 401.8 acres are known to be considered highly erodible land (HEL). The area contains three known dairy farms and a few livestock (beef cattle and sheep, animal numbers unknown) farms. The cropland has an average rotation of one year corn, one year oats, and then the land is seeded to four or more years of hay. Therefore, average soil loss is well below the tolerable level. Spring moldboard plowing is the most common type of tillage done. A few people are trying to reduce tillage, with some even experimenting with no-till.

The soils in the Long Lake watershed vary greatly from silt loam texture to areas primarily sandy in surface texture. The majority of soil in the watershed has a sandy loam texture surface. The watershed soils are underlain primarily by acid sand and gravel, thereby promoting very good drainage. A small amount of the soil in the watershed (approximately 5 percent) is considered an organic soil comprised of peat and muck.

A fringe of development is found immediately next to Long Lake consisting of approximately 600 residences and several resorts. The Tomahawk Scout reservation has preserved approximately 3,000 acres of land in its natural state, including approximately eight miles of shoreline.

Rainfall, Evaporation, and Lake Outlet Data

Rain gages accurate to within 1/100th of an inch were installed at two locations within Long Lake's watershed and read daily by volunteers during the 1994 ice free period, to determine daily precipitation amounts. Measurements were made between April and November, 1994. Data from the Wisconsin State Climatologist for the Chetek Agricultural Experiment Station was used during the winter months to determine total precipitation amounts for the unmonitored periods.

Evaporation from the lake water surface area, during the study period, was estimated using methods developed by Adolph Meyer (1947). This method uses average monthly temperature, wind speed, and relative humidity to predict monthly evaporation from water surfaces. Monthly temperature, wind speeds, and humidity used for input in the Meyer Watershed Model were also taken from 1994 data from the Chetek Agricultural Experiment Station. The Meyer Watershed Model was also used to estimate watershed runoff during 1994. Daily precipitation, temperature, and watershed imperviousness are used as inputs in the model to estimate the daily watershed runoff. Calculations of watershed yield within the model are based upon methods derived by Adolph Meyer in his book *Elements of Hydrology* (Meyer, 1947).

A staff gage was installed and surveyed in on April 21, 1994. The gage was read on a daily basis during the period April 21 through November 19. The staff gage readings, together with an outlet rating curve and information supplied by the Washburn County Highway Department on operation of the dam, were used to determine daily lake volume changes and average lake outflow volumes.

Hydrologic Budget

A hydrologic (water) budget for Long Lake was determined by measuring or estimating the important components of the budget. The important components of the budget include:

- Precipitation
- Surface Runoff
- Lake Outflow
- Evaporation
- Groundwater Flow
- Change in Lake Storage

Due to the limited scope of the project, there was insufficient information to differentiate between groundwater and the surface runoff from the watershed. As a result, surface runoff from the watershed was estimated using the Meyer Watershed Model and the net groundwater flow (inflow minus outflow) was determined by solving the Long Lake water balance equation as presented below.

$$GW = OF + EVAP - P - RO + S$$

Where:

GW	=	Net Groundwater Flow (Inflow minus Outflow)
RO	=	Watershed Runoff
OF	=	Lake Outflow
EVAP	=	Evaporation from the Lakes Surface
P	=	Direct Precipitation on the lake's surface
S	=	Change in Lake Storage

The WATBUD model, developed by the Minnesota Department of Natural Resources, performs lake water balance modeling similar to the Meyer Watershed Model; however it allows for the automatic adjustment of lake groundwater seepage coefficients to provide the best solution to the above equation. Daily precipitation and the daily surface water runoff and evaporation results from the Meyer Watershed Model were used as input for the WATBUD model. The WATBUD model was then calibrated to the observed Long Lake water levels. An average annual net groundwater inflow of 4.65 feet (over the lake surface area) provided the best fit between the simulated and observed lake levels during the summer of 1994.

Phosphorus Budget

The overall Long Lake phosphorus budget was determined using the tributary lake water quality data and corresponding watershed runoff volumes. These data were combined with the export rates for each of the phosphorus input sources within the direct watersheds to estimate the total loads to each of the lake's basins. The phosphorus budget for Long Lake was determined by measuring or estimating the important components of the budget. The important components of the budget include:

- Watershed Surface Runoff from Forested, Row Cropland, Non-Row Cropland and Pasture/CRP Landuses
- Internal Loading
- Groundwater Loading
- Atmospheric Wet and Dry Deposition on the Lake Surface
- Septic System Loading
- Monitored Tributaries

The watershed surface runoff component was estimated using annual phosphorus export coefficients for each land use type within the direct subwatersheds. An annual phosphorus export coefficient of 0.07 lbs/ac/yr was used for the forested portions of the subwatersheds. This corresponds with the most likely default coefficient in the WILMS model (Panuska and Wilson, 1994), as well as that observed by Singer and Rust (1974). The total phosphorus export coefficient of 1.16 lbs/ac/yr observed by Hensler et al. (1970) was used for the row cropland land use. The non-row cropland and pasture/CRP phosphorus export coefficient of 0.58 lbs/ac/yr, used in this analysis, agrees very well with that observed by others (Burwell et al., 1975; Converse et al., 1976). An atmospheric wet and dry deposition rate of 0.27 lbs/ac/yr, used as the most likely export coefficient in the WILMS model (Panuska and Wilson, 1994), was applied to the surface area of Long Lake. The net groundwater loading component to the lake basins was estimated using an assumed total phosphorus concentration of 20 µg/L and the estimated groundwater inflow from the water balance modeling. The watershed runoff component from the tributary lakes was estimated using the measured lake concentrations and estimated Meyer Watershed Model runoff from each of the tributary watersheds.

Phosphorus export rate computations, used in the WILMS model and published by the U.S. EPA (NALMS, 1988) for septic systems, were used to estimate an annual load from drain fields. The equation used for Long Lake estimated the septic system load as follows:

$$\text{Total Septic System Load (kg/yr)} = Ec_{st} * \text{\# of capita-years} * (1-SR)$$

Where:

Ec_{st}	=	export coefficient to septic tank systems (0.5 kg/capita/yr)
cap.-yrs.	=	# of people occupying a dwelling each year
	=	(# of permanent residents/dwelling)*(permanent dwellings) + (# of seasonal residents/dwelling)*(days/yr)*(seasonal dwellings)
SR	=	weighted soil retention coefficient (85 for most likely value used in model)

The LLPA determined the number of septic systems within each of the three townships surrounding the lake and determined the total number of septic systems for both permanent and seasonal residences. The most likely soil retention coefficients of 90 and 40 were chosen for properly and improperly functioning systems, respectively. Ten percent of the septic systems were assumed to be improperly functioning, yielding a weighted soil retention coefficient of 85. Each permanent and seasonal dwelling unit was assumed to have four residents, on an average. The seasonal dwelling units were assumed to have been occupied 100 days per year, while each of the Long Lake resorts were assumed to have an average of ten residents throughout the year. Finally, the USGS Quad Maps were used in conjunction with the number of septic systems within each township to assign the number of resorts and dwellings adjacent to each of the five basins of Long Lake. The ratio of permanent to seasonal residences was kept the same as the total for each of the five basins. The assumptions made regarding the septic system inputs agree well with the estimates made for both Balsam and Antler Lakes in Polk County, Wisconsin (Bursik, 1996).

Lake Water Quality Mass Balance Modeling

Numerous researchers have demonstrated the relationship between phosphorus loads, water loads and lake basin characteristics to the observed in-lake total phosphorus concentration. The relationship was used to verify the annual phosphorus load into Long Lake based on average surface phosphorus concentrations, the lake's hydrologic budget, and lake basin characteristics. The relationship has many forms. The equation used for Long Lake was adapted from one developed by Dillon and Rigler (1974), modified by Nurnberg (1984) and has the form of:

$$P = \frac{L_A (1 - R_P)}{Q_S} + \frac{L_I}{Q_S}$$

Where:

- P = is the mean phosphorus concentration
- L_A = amount of phosphorus added per unit surface area of lake from all sources except from the internal load of the lake
- R_P = the coefficient which describes the total amount of phosphorus retained by the sediments each year
  = $15/(18+Q_s)$
- Q_S = the outflow of the lake divided by its surface area
- L_I = mass of phosphorus added to the lake from internal loading

In the case of Long Lake, all variables of the equation were measured or could be estimated based on data collected during the study. This equation was added to the Wisconsin Lake Model Spreadsheet (WILMS) (Panuska and Wilson, 1994) and compared with the other predictive lake water quality equations already present in WILMS.

Internal loading (L_I in the above equation) was estimated for each of the lake basins using the total phosphorus data from the lake's water column. The summer internal load, for each basin, is the product of the fraction of hypolimnetic phosphorus released to the surface waters, the sediment phosphorus release rate, the fraction of the lake basin surface area experiencing anoxia, and the duration of hypolimnetic anoxia. The 1994 dissolved oxygen profiles of each basin were used to estimate the duration of anoxia (D.O. < 0.5 mg/L). The fraction of each lake basin's total surface area experiencing anoxia was based on the depths of the observed summer anoxia and the morphometry of each basin. The sediment total phosphorus release rate of 6 mg/m^2/day was estimated using the lake's trophic status and a relationship developed by Nurnberg et al. (1986). This sediment release rate agrees well with the observed increase of total phosphorus over the anoxic portion of the hypolimnetic waters of each basin during the summer of 1994. Finally, the fraction of hypolimnetic total phosphorus released to the surface waters was estimated to facilitate the calibration of the lake mass balance model. For the calibrated model, this fraction ranged from 0.15 to 0.38 for all basins except Basin C. This range agrees well with that observed by other researchers (Nurnberg, 1985). A larger fraction (0.80) was used for Basin C because it had a considerably larger epilimnetic (surface) layer and flushing rate than the other basins. This release fraction agrees with that observed by Nurnberg and Peters (1984).

Phase III: Results and Discussion

The Phase III Results and Discussion section presents the results of the revised hydrologic and phosphorus budgets and the resultant revised lake water quality mass balance model. Also presented are the results of lake water quality modeling of:

- a scenario in which all existing septic systems are assumed to malfunction;
- several development scenarios;
- the use of Best Management Practices (BMPs) in conjunction with development scenarios;
- a development scenario that achieves the long-term Long Lake water quality goal.

Hydrologic Budget

Table 2 shows the watershed and water surface areas for each of the lakes and sub-basins that are directly connected to Long Lake. The 1994 hydrologic budget indicates that watershed runoff, groundwater and direct precipitation play an important role in providing water to Long Lake. Watershed runoff represents 27 percent and groundwater represents 48 percent of the inflows to Long Lake, while direct precipitation provides the remainder. Evaporation (18.89 inches) was significantly less than precipitation (29.40 inches) during 1994. Ordinarily, evaporation would be expected to be approximately the same as the observed annual precipitation amount. Average evaporation for this portion of Wisconsin is 28 inches (Linsley, Jr., et al., 1982). However, the low evaporation amount is attributed to below average temperatures observed in 1994.

The amount of watershed runoff that reached the lake during 1994 indicates that watershed runoff has an impact on the water quality of Long Lake. The majority of the storm event runoff which reached the lake came from the direct subwatersheds and the Slim Lake subwatershed. Subwatershed A and the Slim Lake subwatershed are the largest subwatersheds and experienced enough runoff during 1994 to account for approximately 40 percent of the total watershed inflows. Watersheds B and D combined to provide another 22 percent of the total watershed inflows to Long Lake.

The hydrologic budget is an important factor in determining the breakdown of nutrient loads into Long Lake. Because phosphorus is the parameter of most concern, the discussion of nutrient budgets will be limited to phosphorus only.

Phosphorus Budget and Lake Water Quality Mass Balance Model

As previously mentioned, the tributary lake water quality data and corresponding watershed runoff volumes combined with the export rates for each of the phosphorus input sources within the direct watersheds were used to estimate the total loads to each of the lake's basins. The computations revealed that the total annual phosphorus load into Long Lake is approximately 5,779 pounds per year, based on 1994 data. Phosphorus export rates, used in the WILMS model and published by the U.S. EPA for septic systems, and the septic system survey information were used to estimate an annual load of 233 pounds per year from drain fields. Depending on the soil retention capacity and export rates assumed for this computation, this value may actually range from 19 to 498 pounds or 0.3 percent to 8.6 percent of the total load. An atmospheric wet and dry deposition rate used by the WILMS model of 0.27 lbs/ac/yr was applied to the surface area of Long Lake. The computation indicates that the atmospheric component of the load is approximately 928 pounds per year. The watershed runoff component was estimated using the measured lake concentrations and estimated runoff from each of the tributary watersheds along with phosphorus export coefficients for each of the direct subwatersheds. The result is an estimate of 2,332 pounds per year from the watershed surface runoff. The groundwater loading component yielded an estimate of 877 pounds per year using an assumed total phosphorus concentration of 20 µg/L and the estimated groundwater inflow from the water balance modeling. Internal loading represents the remaining 1,409 pounds of phosphorus into the lake.

The relative phosphorus loading components of the nutrient budget were further broken down and analyzed. Nearly 40 percent of the total phosphorus load to Long Lake comes from watershed surface runoff, with subwatershed A being the largest contributor. Other major contributors include atmospheric (16 percent), groundwater (15 percent), and internal loads (24 percent). Subwatersheds B, C, D and the Mud Lake subwatershed yield the largest amount of phosphorus based upon their percentage of the overall watershed area. Cropland contributes approximately 10 percent of the total load to Long Lake Basins B, C and D, and is a negligible input for the remaining basins. Internal loading from the lake's bottom waters provides larger inputs to Long Lake Basins B (16 percent), C (17 percent), and D (24 percent), while providing approximately 12 percent to the remaining basins. The water quality of Long Lake Basin D is mostly influenced by the phosphorus loads coming from the internal load and upstream basins. Septic system loading represents larger inputs to Long Lake Basins E (6.7 percent), B (3.3 percent), and D (3.3 percent), while providing less than 3 percent to the remaining basins.

Subwatersheds A and B contribute their phosphorus loads directly to the lake and, therefore, increased loadings following new watershed development is very undesirable. Also, because subwatersheds A and B contribute their phosphorus loads to the most upstream portions of the lake, phosphorus loading from these watersheds affects the water quality of the entire lake.

Each of the phosphorus input loadings was used to calibrate the lake mass balance model to the water quality observed in each of the lake's basins during 1994. During 1994, both the evaporation (as previously mentioned) and the average annual runoff from the Long Lake watershed were less than normal (4.3 inches as opposed to 12.2 inches). The fraction of total phosphorus in the bottom waters that would be released to the lake basin epilimnion (or surface water) following fall turnover, used to estimate internal load, was the only refinement that had to be made to the original phosphorus loading estimates to calibrate the mass balance model. With the exception of Basin C, the predicted average total phosphorus concentration from the calibrated model is slightly higher than, or the same as, the observed concentration in each of the basins. This is probably because the average observed concentration only includes data from May through the end of August, in 1994. The average observed concentration would likely be larger (and therefore, very close to the predicted concentrations) if total phosphorus data had been collected in September and October, following fall turnover. The data suggest that with increased watershed development the greatest potential for increased nutrient loads into Long Lake will be from the lake's tributary watershed and drain fields.

Lake Water Quality Modeling of Development Scenarios

Development of a lake management plan affords the opportunity to establish long-term water quality goals for the lake. Different watershed development scenarios can be evaluated to determine acceptable (i.e., the water quality of the lake is within the established goal) and unacceptable (i.e., the water quality of the lake fails to meet its goal) development options. Several watershed development scenarios of the Long Lake watershed were evaluated to determine their impact on the water quality of Long Lake. The modeling results:

- show the degree of water quality degradation expected to occur in Long Lake if uncontrolled development were allowed to occur
- provide the compelling reason for the adoption of ordinances to control watershed development
- determined the watershed development/redevelopment ordinances required to preserve the current water quality of Long Lake.

Because medium density residential development (i.e., 1/3 to 1 acre lots) is believed to be the most likely type of development to occur in the Long Lake watershed, medium density development was used for all modeling scenarios. All of the development scenarios modeled assumed that forested areas were being converted to medium-density residential land use.

The following development scenarios were evaluated to determine their impact upon the water quality of Long Lake:

- Total development of the lakeshore
- Development of a second tier around the entire lakeshore
- 20, 50, 80, and 100 percent development of the entire watershed. The resultant water quality changes in Long Lake are shown on an individual basin basis to provide information regarding the development impacts of each individual subwatershed (i.e., the 20, 50, 80 and 100 percent development scenario). The 20, 50, and 80 percent development scenarios assume the Boy Scout Camp would remain in place. The 100 percent development scenario assumes the Boy Scout Camp land area would be developed in the same manner as the remaining portion of the watershed.
- Specific development scenarios identified by LLPA

In addition to development, the role of septic systems on the water quality of Long Lake was evaluated. A modeling scenario was completed in which all of the existing septic systems were assumed to malfunction. A second scenario was completed in which all septic system inputs were removed. This scenario shows the water quality improvement that would occur if a sanitary sewer district replaced all existing septic systems.

The modeling results (See Figure 2) show the predicted increase in total phosphorus concentration for each Long Lake basin for each of the above scenarios. The 1994 average total phosphorus concentration for each basin is presented in the upper right-hand corner of Figure 2. Therefore,

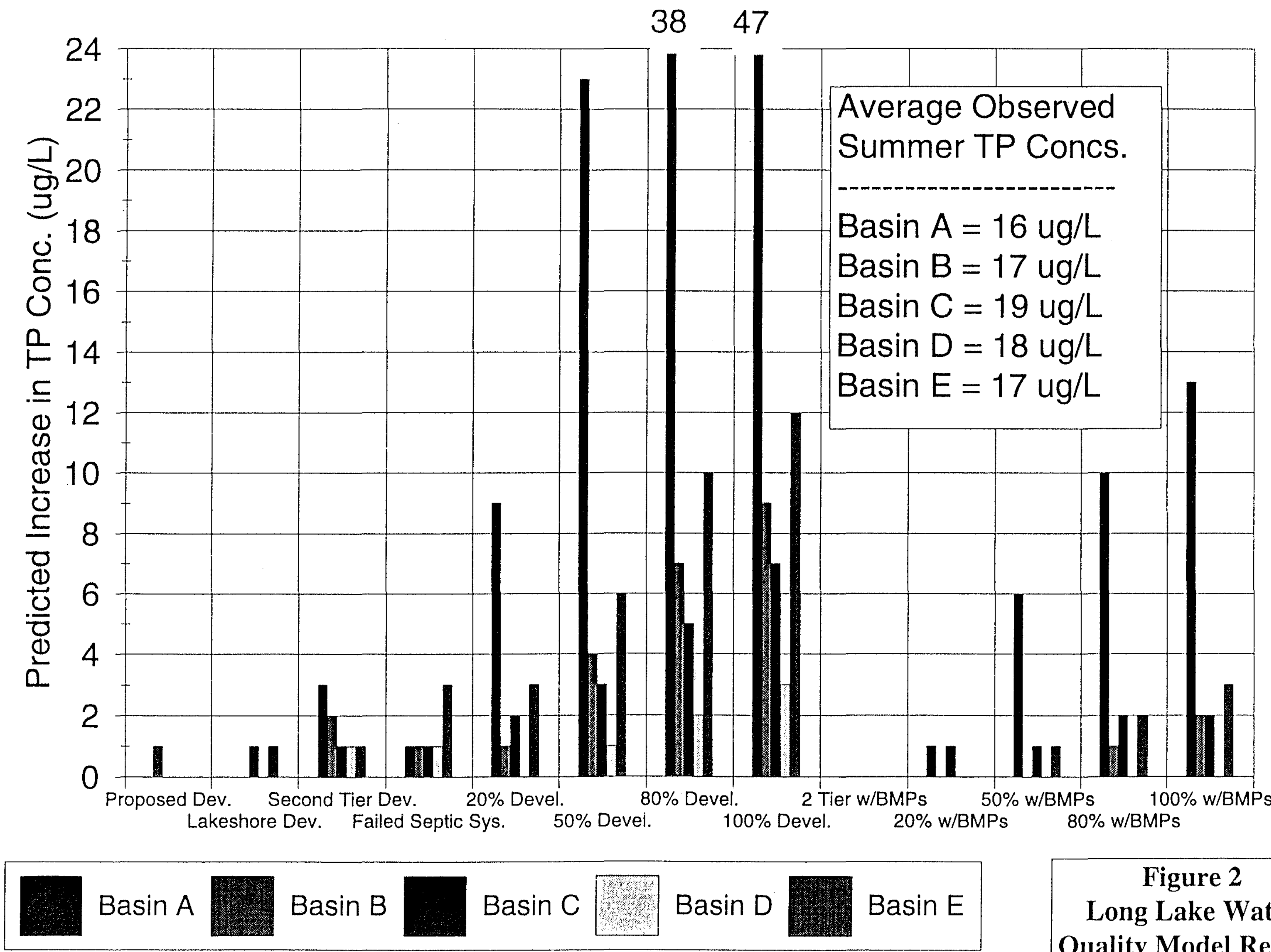

Figure 2
Long Lake Water Quality Model Results

the total expected phosphorus concentration for each basin is the sum of the 1994 average total phosphorus concentration and the predicted increase from the model results.

As suggested by the LLPA, development of three different sites within the Long Lake watershed was analyzed for its effect on the Long Lake water quality. The most likely sites for development in the near future are found in subwatersheds A, B, and Mud Lake. The first site is a 400-acre development proposed for the Mud Lake subwatershed which would greatly increase both its yield and annual contribution to Long Lake. The second site is a 50-acre area east of Todd Road and south of the golf course in Subwatershed B. The third site is a 125-acre area between County Road B and the Belvidere Park area in Subwatershed A. All three development scenarios were modeled together and are shown in Figure 2 as "Proposed Dev.".

The second modeling scenario shown in Figure 2, "Lakeshore Dev." assumes that all of the remaining undeveloped lakeshore lots are converted to medium-density residential land use. The third modeling scenario, called "Second Tier Dev.", assumes that a tier of properties adjacent to the lakeshore lots are converted to medium-density residential land use. The fourth modeling scenario shown in Figure 2, "Failed Septic Sys.", assumes that all of the lakeshore septic systems are improperly functioning. This would yield a weighted soil retention coefficient of 40 for the total septic system loading equation referred to in the Methods section.

Development scenarios involving new development on a whole watershed basis were also modeled to determine development impacts on Long Lake water quality. Development scenarios included 20%, 50%, 80%, and 100% watershed development. Modeling was also completed with structural BMPs in place to determine resultant Long Lake water quality improvements. Structural BMPs were assumed to be wet detention ponds capable of removing 60% of the total phosphorus load from the developments. Development scenarios with structural BMPs included second tier development and watershed development scenarios of 20%, 50%, 80%, and 100%. The predicted water quality benefits to Long Lake following implementation of BMPs are shown on the right side of Figure 2.

The following items summarize the water quality modeling results (shown in Figure 2) of the Phase III portion of the Long Lake Management Plan:

- Long Lake's water quality is highly susceptible to increasing development within the lake's direct watershed. The water quality of Long Lake Basins A and E are the most susceptible, while Basin D is the least susceptible, to corresponding magnitudes of development.

- Development of a second tier of properties around the entire lakeshore would increase the phosphorus loadings to the lake such that none of the basins would meet their water quality goals. The water quality in Basins A and B would be the most affected by development of the second tier of properties.

- Failure of all of the septic systems around the lakeshore would also cause all of the lake basins to fall short of their water quality goals. Conversely, water quality modeling indicates that the average total phosphorus concentrations in Basins A, B, D and E would be reduced by 1 µg/L, respectively, if the septic system inputs were removed altogether.

- The water quality modeling indicates that Long Lake Basins A, C and E would fall short of their water quality goals, even if structural Best Management Practices (BMPs) were instituted for 50 percent medium-density residential development within the direct watershed. One hundred percent medium-density residential development (with completed structural BMPs) within the direct watershed would cause all of the Long Lake basins, except for Basin D, to fall short of the water quality goals.

- As a result, complete medium-density residential development is not appropriate for ultimate land use development within the lake's direct watershed. A combination of less intensive land uses, along with implementation of structural BMPs, should be considered to ensure that Long Lake's water quality goals are met.

The results of the above modeling scenarios were used to determine a development scenario that would accomplish the LLPA goal of long-term preservation of the current water quality of Long Lake. The minimum lot size selected for lakeshore development/redevelopment was 40,000 square feet and the minimum lot size selected for all non lakeshore development within the Long Lake watershed was 5 acres. The implementation of structural BMPs was assumed for all non lakeshore watershed development. It was assumed that each developed/redeveloped lakeshore lot would not exceed a 25% imperviousness. The modeling results predict the Long Lake goal of nondegradation would be achieved. Therefore, the long-term preservation of the current water quality of Long Lake appears feasible. The key to preservation is the control of development throughout the lake's watershed.

Prior to the development of a lake management plan, the following questions are answered:

1. What is the water quality of the lake under existing watershed development conditions?
2. What is the long-term water quality goal of the lake?
3. Does the current water quality of the lake achieve its water quality goal?
4. What will be the water quality of the lake if unchecked development is allowed to occur?
5. Will the lake's water quality goal be met if unchecked development is allowed to occur?

If the answer to question five is no, the following question is asked.

6. Can the lake's water quality goal be achieved with the implementation of lake and/or watershed management practices?

If the answer to question six is yes, a lake management plan is completed to outline the management practices which must be implemented to achieve the lake's long-term water quality goal.

The above six questions were answered prior to the development of the Long Lake Management Plan. The answers are as follows:

1. The current water quality of Long Lake is within the mesotrophic category. This means the lake is moderately rich in phosphorus and its water quality is good. The lake's water quality is suitable for all recreational activities, including swimming.

2. The long-term water quality goal of Long Lake is to preserve the current water quality as defined by the 1994 water quality study of Long Lake. The specific epilimnetic (i.e., upper six feet of mixed lake water) summer average total phosphorus goals for each of the lake's five basins are:

- 16 ug/L for Basin A
- 17 ug/L for Basin B
- 19 ug/L for Basin C

- 18 ug/L for Basin D
- 17 ug/L for Basin E.

3. The long-term goal is equal to the current water quality of the lake. Therefore, preservation of the existing water quality of the lake will achieve its long-term goal.

4. Unchecked development of the lake's watershed will cause degradation of the lake's water quality. The degree of water quality degradation increases with increasing development. Implementation of structural BMPs during watershed development reduces the severity of water quality degradation. However, degradation is expected to occur under all development scenarios evaluated except the development of a second tier with BMPs.

5. The lake's long-term goal will not be met if unchecked development is allowed to occur.

6. The lake's water quality can be achieved with development restrictions and the implementation of watershed management practices.

The following management plan outlines the management practices which must be implemented to achieve Long Lake's long-term water quality preservation goal. The plan protects Long Lake by restricting the quantity of phosphorus loaded to the lake under future development conditions. Phosphorus loading is controlled by regulating development and by requiring BMPs to reduce the quantity of phosphorus in watershed runoff waters reaching Long Lake. Restrictions are defined by zoning and ordinance regulations that include shore land and watershed (i.e., non shore land) development/redevelopment.

The Long Lake Management Plan addresses the following:

- Formation of a Land Use Zoning District;
- Establish ordinances to control watershed development/redevelopment:
  - Shore land ordinances
  - Watershed ordinances
  - Stormwater ordinances
  - Septic System ordinance

- Watershed best management practices (BMPs)
- Runoff quality management practices
- Land/wetland conservation
- Lake district formation
- Establish boating regulations
- Control exotic species introduction
- Plan implementation
- Lake and watershed runoff monitoring

Land Use Zoning District

Control of land development within the Long Lake watershed is critical to the preservation of the lake's water quality. The proposed vehicle to maintain control of development is a proposed Land Use Zoning District. It is proposed that Washburn County establish Land Use Zoning Districts on a county wide basis. Each District would consist of the watershed tributary to a county lake and all land within each Land Use Zoning District would be subject to special regulations. A permit from the county would be required to develop land or to change land usage within the Land Use Zoning District. The county should adopt minimum development requirements and land use restrictions applicable to all Districts and a provision that establishes more stringent requirements whenever warranted by a lake management plan (i.e., the Long Lake Management Plan). Therefore, the Long Lake Management Plan would determine ordinances and permit requirements for development occurring within the Long Lake watershed. The basis of the establishment of the Districts and the purpose of District regulations is stated in Section 114.26 of Chapter NR115 of the Wisconsin Shoreland Management Program, "to prevent and control water pollution." The proposed regulations for the Long Lake Land Use Zoning District are outlined in the following paragraphs.

Ordinances for Long Lake Land Use Zoning District

Ordinances to control development throughout the Long Lake watershed are necessary to achieve the lake's water quality goal of preservation of current water quality conditions. The following ordinances should be implemented by Washburn County to restrict phosphorus loading to Long Lake, thereby achieving its goal.

Shoreland Ordinances

Shoreland ordinances should be implemented by Washburn County to restrict phosphorus loading from riparian areas. The ordinances will become particularly important as redevelopment of shoreland property occurs with the passage of time. Washburn County has adopted shoreland ordinances and is currently in the process of revising existing ordinances to further reduce phosphorus loading to county lakes. An evaluation of the proposed revisions to the ordinances indicates additional changes are needed to adequately protect the water quality of Long Lake. The discussion of shoreland ordinances is divided into two sections. The first section discusses **recommended revisions** to the proposed revised version of the Washburn County shoreland ordinances. The second section discusses **more restrictive additions** to the ordinance.

Shoreland ordinances proposed for the Long Lake Land Use Zoning District are based upon the existing Washburn County shoreland zoning regulation adopted from the Wisconsin state regulation and the changes currently being considered by the County Board (shown in Appendix A). However, because additional restrictions are needed to protect the water quality of Long Lake, further recommendations are made to the proposed changes. The following items summarize the recommended changes to the proposed Article XXVII Shorelands Regulations revisions:

- Erosion Control -- Section 271, (1), states that retaining walls may not be permitted within the 75 foot setback. **This should be changed or further clarified, because in some cases involving shoreland bank erosion, retaining walls may represent one of a few feasible alternatives to prevent further erosion.**

- Buffer Strips -- A buffer strip is a permanently vegetated area (i.e., not mowed grass, however) whose function is to remove pollutants from runoff waters and to slow the flow of runoff waters, thereby encouraging infiltration. Buffer strips remove phosphorus from runoff waters and, therefore, restrict phosphorus loading to lakes from shoreland property. Buffer strips provide a means of mitigating impacts from redevelopment by removing additional pollutants from runoff waters. Section 271, (4), states that nonconforming principal structures between 50 and 75 feet from the ordinary high-water mark which include at least 600 square feet of enclosed living area may be expanded to a total maximum of 1500 square feet provided that (in Item c.) the property owner implements and maintains a shoreland buffer strip restoration plan as required in Section 272 (6). Section 272 (6) states "At the time of application for a zoning permit....the Zoning

Administration shall evaluate the status of the shoreland buffer strip and shall require restoration of the buffer strip to the requirements of the Ordinance as a condition of approval of the permit." Neither the requirements for restoration of the buffer strip, nor the required contents of the shoreland buffer strip restoration plan, are defined in this Ordinance. The buffer strip (and restoration plan) must have clearly defined minimum requirements because the ability of a buffer strip to remove phosphorus from runoff waters varies with its width, vegetation types, and vegetation densities. **The ordinance should be changed to specify minimum buffer strip requirements. Recommended minimum buffer strip requirements that must be included in the buffer strip restoration plan are included as Appendix B.**

- Buffer Strips -- A national survey of 36 local buffer programs revealed the median width selected for a buffer was 100 feet (Heraty, 1993). Schueler (1995) recommends a minimum base width of at least 100 feet to provide adequate stream protection relative to phosphorus removal. The results of studies of buffer programs indicate a 100-foot wide buffer strip would provide adequate phosphorus removal to achieve the Long Lake water quality goal. Shoreline buffers are permanently vegetated areas designed to manage critical nonpoint sources or to filter pollutants from nonpoint sources immediately adjacent to both lakes and streams. Therefore, modification of the Washburn County Ordinance is recommended to ensure adequate phosphorus removal of runoff waters from Long Lake shoreland property. **In general, the proposed dimensions that control the effective width of the buffer strip in Sections 271 and 272 should be increased to minimally provide for a 100-foot wide buffer strip from the ordinary high-water mark. The buffer width may also be increased to fully incorporate adjacent wetlands, steep slopes or critical habitat areas.**

- Shoreland Cover Removal -- Shoreland cover encourages infiltration of runoff waters and filters pollutants, thereby restricting phosphorus loading to the lake. Preserving existing shoreland cover will limit phosphorus loading from shoreland property to Long Lake. Section 272, (1), states that "Within the first 35 feet of the ordinary high-water mark no shore cover shall be removed, except from one 30 foot wide access corridor. Within the defined access corridor, up to fifty percent of shore cover may be removed, but the corridor shall not be clear cut." Since there are a few 50 foot wide lots surrounding Long Lake, these lots would be allowed to remove shore cover from up to 60 percent of their lakeshore area. **To comply with the state standard, this proposed item must be changed to**

limit shore cover removal to 30 feet or 30 percent of the shoreline area, whichever is less. The 30 feet wide access corridor should be reevaluated to determine whether this width could be reduced. If the true intention of the access corridor is to just provide access to the lake, then the corridor width should not need to be wider than the width of a vehicle, or the widest object requiring access to the lake. Also, it should be specified that the corridor is generally perpendicular to the shoreline to minimize the cleared area within the buffer strip. Establishment of additional restrictions for shoreland cover removal is needed to limit phosphorus loading to Long Lake and achieve the lake's long-term water quality goal.

- Shoreland Cover Removal -- Section 272, (2), states that "Within the area extending from 35 feet from the ordinary high-water mark to 75 feet from the ordinary high-water mark no more than 30 percent of the shore cover shall be cut or removed." **The ordinance should be changed to limit the shore cover that is cut or removed to the agreed upon access corridor width.** This restriction will maximize the water quality treatment efficiency of the buffer strip. The additional restriction is needed to limit phosphorus loading to Long Lake and achieve the lake's long-term water quality goal.

- Sediment and Erosion Control -- Sediment and erosion control play an important role in restricting phosphorus loading to lakes during storm runoff events. **The ordinance should be changed to include recommended changes to Sections 273, 274 and 275 that are discussed in the stormwater ordinance section. The changes involve implementation of erosion control design standards and a required stormwater management plan that can be reviewed by the County Board as a part of a building permit.**

The following item describes additional ordinance provisions that should be implemented in addition to the above recommended changes:

- Shoreland Development -- The Washburn County Ordinance and proposed revisions fail to address several key development variables including lot size, percent impervious area, and location of septic systems. These variables play an important role in determining the phosphorus load to the lake. Washburn County should add the following ordinances to restrict the phosphorus load to Long Lake because the restrictions are needed to achieve the lake's long-term water quality goal. The recommended ordinances are based upon existing ordinances from another state. The ordinance provisions were selected because they not only address the Long Lake goal achievement needs, but are legally defensible. The Washburn County Shorelands Regulations do not set standards for minimum lot sizes and fail to address percent impervious area and location of septic systems. The Wisconsin Chapter NR115 Shoreland Management Program requires a minimum lot size of 20,000 square feet and a minimum average width of 100 feet. A larger lot size is required to achieve the lake's long-term water quality goal. Also, percent imperviousness area and location of septic systems are not addressed by the Wisconsin Shoreland Management Program. Therefore, Minnesota Department of Natural Resources Shoreland and Floodplain Management regulations (Minnesota Rules, Ch. 6120) were selected as a basis for the shoreland development ordinance. They have a considerably larger scope and are more restrictive than the Wisconsin Chapter NR 115 Shoreland Management Program. The additional restrictions are needed to achieve the Long Lake long-term water quality goal. **The Minnesota DNR Shoreland Management regulations (shown in Appendix C) for recreational development lakes without public sewers provide the following standards, which should be added to the Washburn County Shoreland Ordinances:**

- **Riparian lots must have a minimum average width of 150 feet and a minimum area of 40,000 square feet.**

- **The structure setback is 100 feet from the ordinary high-water level.**

- **Construction is limited within bluff impact zones and steep slopes, and there are restrictions on vegetative alterations, stairways, lifts, and landings, structure height, and the encroachment of decks.**

- **Impervious surface coverage of lots must not exceed 25 percent of the lot area.**

- **On-site sewage treatment systems must be set back 75 feet from the ordinary high water level.**

Watershed Ordinances

As previously mentioned, complete medium-density residential development (i.e., 1/3 to 1 acre lot size) is not appropriate for ultimate land use development within the lake's direct watershed. Watershed development must include less intensive land uses, along with implementation of structural BMPs, to ensure that Long Lake's water quality goals are met. Model results indicate that a minimum lot size of 5 acres for all second tier and beyond development/redevelopment within the watershed and the implementation of BMPs to treat runoff waters would result in achievement of the long-term Long Lake water quality goal. **Therefore, the LLPA should work with Washburn County to implement an ordinance to require a minimum lot size of five acres for all non shoreland development/redevelopment within the Long Lake Watershed.**

The LLPA should work with Washburn County to establish additional watershed ordinances that promote innovative approaches to minimizing water quality degradation and disturbance of critical areas. Cluster development is an example of one such innovative approach. Cluster development allows a greater density of homes or structures on one portion of the site in exchange for open space elsewhere on the site. The higher density gives the designer more flexibility in reducing the size and geometry of individual lots than is normally allowed under subdivision codes. Depending on the original lot size and road network, cluster development can reduce site imperviousness by 10 to 50 percent (Schueler, 1994). As a result, cluster development reduces stormwater runoff and pollutant loads, concentrates runoff where it can be most effectively treated, and preserves open space for better wildlife habitat and larger wetland, lake and stream buffer zones. Cluster development within the Long Lake watershed must use an average minimum lot size of 5 acres.

Regardless of whether uniform lot sizes or cluster development are used to develop the land outside of the lakeshore properties, site planning considerations play an important role in determining how much impact additional stormwater inputs will have on the water quality of the lake. **Washburn County should establish a site development ordinance that requires site development to be planned in such a manner that it will (1) reproduce pre-development hydrological conditions, (2) confine development and construction activities to the least critical areas, (3) fit development to the existing terrain, (4) preserve and use the natural drainage system, and (5) maximize conservation of woodland and vegetative cover (Sykes, 1989; Coffman et al., 1997).** Reproducing pre-development hydrological conditions involves preventing a change in the peak discharge, runoff volume, infiltration capacity, base flow levels, and groundwater recharge from a site. Areas to avoid for development whenever possible include the shoreline of lake or streams, steep slopes, dense vegetation, porous soils, and natural drainageways (Sykes, 1989). Development will fit the terrain if local streets branch out in short loops and cul-de-sacs along ridgelines and avoid natural drainage areas. Keeping pavement and other impervious surfaces out of low areas, swales and valleys prevents localized flooding and allows for natural water quality treatment processes such as infiltration, absorption and biological uptake to take place within vegetated low-lying areas. When properly designed, cluster development can meet all of the aforementioned objectives (Schueler, 1994).

The LLPA should work with Washburn County and perform required water quality modeling to determine any additional land use zoning combinations that achieve the Long Lake water quality goal. **Zoning ordinances and a comprehensive plan should be developed to implement other development options and to address issues of concern such as "dockominiums."**

Stormwater Ordinance

Currently, nearly 40 percent of the annual total phosphorus load to Long Lake comes from watershed surface runoff (i.e., stormwater runoff). Increased phosphorus loads to Long Lake from stormwater runoff will further degrade the lake's water quality and prevent achievement of the lake's long-term water quality goal. Stormwater management, sediment, and erosion control ordinances offer the opportunity to control phosphorus loading to Long Lake from watershed runoff. The following stormwater, sediment, and erosion control ordinances are required to achieve the Long Lake long-term water quality goal.

The Washburn County Shorelands Regulations must be revised to achieve the Long Lake water quality goal. Sections 273, 274 and 275 of the Washburn County Shorelands Regulations addresses filling, grading, and ditching within the shorelands area. However, these sections do not require a Grading Permit for projects that do not exceed one of the three thresholds under Section 274 (1). In addition, these sections do not set erosion control design standards or require submission of a stormwater management plan that can be reviewed and approved by the County Board, or as part of a building permit. Finally, these sections do not apply watershed areas outside of the shorelands of the lakes and navigable streams. Failure to address these issues would prevent the achievement of the Long Lake water quality goal. **Therefore, the LLPA should work with Washburn County to implement a sediment and erosion control** (i.e., aquatic weed) species. **The LLPA should control exotic species introduction to Long Lake by education of lake users and constant vigilance by lake residents.** The two most likely control points are the public boat launch and the water inlets to the lake (i.e., Slim Creek, Twin Lake inlet, Big Devil inlet, Mud Lake inlet, and Little Mud inlet).

The education component could involve posting signs at the boat launch reminding lake users to remove aquatic plants from boat trailers before entering and before leaving the lake to prevent the introduction of unwanted species. Volunteers from the LLPA could be present at the boat launch during busy weekends in June through August to inspect boats and trailers, distribute educational flyers, and advise boat owners to always remove vegetation from boats and trailers before entering or leaving Long Lake. Alternatively, informational materials could be left at the public boat launch and users encouraged to pick up the materials via a sign.

The lake inlets should be inspected regularly throughout the summer for possible pioneer Eurasian Watermilfoil or curlyleaf pondweed establishing in that area. An inspection schedule could be established for volunteers to insure that regular inspection occurs.

Lastly, constant vigilance by lake residents will be needed to identify changes in curlyleaf pondweed growth within the lake and/or the establishment of Eurasian Watermilfoil in the lake. The LLPA could form inspection teams to conduct surveys during June of each year. The team could make the inspection an annual weekend event followed by a cookout/social gathering. The team would establish a schedule to survey the shoreline of the lake to identify Eurasian Watermilfoil introductions or changes in curlyleaf pondweed growth. Individual plants identified by the survey should be removed by covering with a fine mesh bag[1] and attempting to remove the root crown of the plant. This is likely to require snorkeling equipment. The plants that are dug up should be removed from the lake and disposed of where they have no chance of being washed into the lake. The areas with Eurasian Watermilfoil beds or curlyleaf pondweed beds should be marked clearly on a map and could also be supplemented with markers along the shoreline. A treatment approach for the beds should be identified and a WDNR permit for treatment obtained. Curlyleaf pondweed beds should be treated with the chemical Reward or harvested during the spring following the identification of problematic growth. Eurasian Watermilfoil should be treated with a herbicide treatment of 2,4-D at a concentration found to be effective. Treatment of

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[1]Nitex - a nylon mesh used for plankton nets can be purchased from aquatic suppliers, such as WILDCO and mesh bags could be sewn from the material. A 300 micron mesh would be adequate for capturing plants, including plant fragments.

Eurasian Watermilfoil should occur shortly after florescence because it is a vulnerable period for the plants and occurs prior to peak autofragmentation.

Long Lake Management Plan Implementation

The Long Lake Management Plan for Long Lake is expected to achieve the LLPA goal of protecting the current water quality of Long Lake. Implementation of the plan will involve a six step process:

- **The LLPA should work with an attorney to draft the ordinances outlined in the Long Lake Management Plan.** Example ordinances are provided as attachments to assist the LLPA with this process.
- **The LLPA should present the proposed ordinances to Washburn County and work with the County until the ordinances are passed.**
- **The LLPA should obtain petition signatures of 51% of the owners of land within the proposed Long Lake District and petition the County to establish the Lake District.**
- **The LLPA should draft boating regulations to address concerns regarding boating in the narrows portion of the lake.** The LLPA should either work with the County and have the County submit the proposed regulations to the WDNR or wait until lake District formation and submit the proposed regulations to the WDNR as a lake District.
- **The LLPA should initiate educational programs to prevent the introduction of exotic species to the lake and organize citizen teams to regularly inspect the lake for possible introduction of exotic macrophyte species.**
- **The LLPA should complete the following water quality monitoring programs.**

Recommended Lake Water Quality Monitoring and Watershed Runoff Monitoring

The success or failure of a lake management plan is determined from the plan's ability to achieve the water quality goal of the lake being managed. Therefore, a long-term water quality monitoring program is needed to determine goal achievement of the Long Lake Management Plan. **The five Long Lake basins should be monitored once every three years to determine water quality changes and to establish a data base suitable for trend analysis.** The monitoring

Research results indicate the LLPA water quality concerns are valid. Yousef et al. (1980) showed that continuous motor boat operation can rapidly increase turbidity and phosphorus concentrations in the water column, and that the turbidity persists for several hours after cessation of the boat activity. Other studies using controlled boat passes at known speeds with different sizes of boats have demonstrated that the extent of the sediment disturbance is a function of boat speed and hull dimensions (Gucinski 1982), engine horsepower (Yousef et al. 1978) water depth, and sediment type (Garrad and Hey 1988). The effects of motor boats on sediment resuspension and concurrent effects on nutrient regeneration and algal stimulation were investigated by the WDNR in the summer of 1994. Study results indicated motor boats influence water clarity through increased turbidity from sediment resuspension. The WDNR used the study as a basis to recommend that boat management efforts be focused on lakes or areas of lakes that are shallow, protected from major wind resuspension, have flocculent sediments with low Calcium levels, sustain high levels of boating, and have good water quality (Asplund 1995). Based upon the results of these studies, management of the boat traffic within the narrows portion of the lake is recommended.

The LLPA should prepare an ordinance that establishes the narrows as a slow/no wake zone. The ordinance should be submitted to the WDNR for approval. The ordinance can be submitted by Washburn County at this time or by the LLPA following formation of a lake District. Lake districts and counties can adopt lake use ordinances pertaining to the regulation of equipment, use, operation or inspection of boats, personal watercraft, skin diving, waterskiing, including landing and taking off of aircraft and travel across icebound lakes by snowmobiles and other motor vehicles. A proposed lake use ordinance must be submitted to the WDNR for advisory review and then a public hearing on the proposed ordinance must be conducted. Bart Halverson, the WDNR Warden in Spooner, would have to approve any proposed lake use ordinance. He can be reached at (715) 635-4112.

Control Introduction of Exotic Species to the Lake

Long Lake riparian owners have raised concerns regarding the introduction of exotic species (i.e., not native to the Long Lake area) to Long Lake. Therefore, the Long Lake Management Plan addresses the issue. The species of greatest concern is the aquatic plant, Eurasian Watermilfoil. Another exotic species of concern is curlyleaf pondweed. Although a very limited growth of curlyleaf pondweed is currently found in Long Lake, additional introduction of this species or changes in its growth patterns within Long Lake could be hurtful to the lake's native macrophyte

control ordinance to address the problems associated with these construction sites (i.e., details of the ordinance were discussed in the Stormwater Ordinance section).

Two more sites within the first tier area of the Station B subwatershed had piles of exposed soil and debris that appeared to have been dumped and were without temporary or permanent sediment and erosion controls. **Adoption of a sediment and erosion control ordinance would address this problem.** Finally, there is an area of pasture along both sides of the stream between Twin Lake and Long Lake. This pasture contains several dairy cattle that are likely increasing nutrient loadings to the lake. **The LLPA should pursue a cost-sharing agreement with the State and the farmer to exclude the livestock from the pasture.**

Other Potential Runoff Quality Management Practices

There are other potential BMPs that the LLPA may wish to investigate for protecting the water quality of Long Lake. **Table 3 lists ordinances, non-structural (i.e., source control) and structural (i.e., runoff treatment) BMPs that should be considered for the first tier of lakeshore properties.** In general, these BMPs are listed in order of increasing cost and management (maintenance) effort required by the County. The effectiveness of these BMPs varies and is difficult to predict. **Many of the ordinances and non-structural BMPs listed in Table 3 should be considered for implementation within the second tier of lakeshore properties, as well.**

Table 3. Additional Recommended BMPs for Tier I and Rural Subwatersheds

Tier I	Rural Subwatersheds
Fertilizer and Pesticide Management Ordinance	Agricultural Waste and Runoff Management Systems
Litter and Dumping Controls Ordinance	Conservation Tillage, Crop Rotation, and Terracing
Landscape Requirements to Reduce "Connected Impervious Area"	Contour Farming
Proper Storage of Chemicals and Household Wastes	Streambank Protection
Effective Use of Deicing Chemicals	Livestock Exclusion
Management of Residential/Commercial Yard Wastes	Wetland Development
Onsite Sewage Disposal System Inspections	Pasture Management and Nutrient Management
Infiltration Basins/Trenches	Grassed Waterways
	Filter Strips and Field Windbreaks

The LLPA should work with the Natural Resources Conservation Service (Spooner area office) to promote agricultural and rural BMPs such as those listed in Table 3. These BMPs for rural subwatersheds are generally listed in decreasing order of their effectiveness at removing sediment and adsorbed nutrients. The cost and effectiveness of these BMPs varies and is difficult to predict. However, if properly implemented, 30 to 90 percent reductions in phosphorus and soil export from the watershed are possible (Brach).

Land/Wetland Conservation

Several thousand acres of minimally developed public use lands surround Long Lake, thereby preserving its current water quality. A significant tract of minimally developed land is owned by the Boy Scouts of America. The Tomahawk Scout Reservation comprises more than 2,500 acres and includes more than eight miles of shoreline. The small amount of development within the camp has been planned and executed with the greatest concern for maintaining the unspoiled nature of the whole lake. In any summer week nearly 500 Scouts, from as near as Wisconsin and Minnesota to as far as Puerto Rico and Hawaii, come for a week-long outdoor living experience. Over 5,000 Scouts and their leaders visit the camp annually. With current valuation of shoreline property at $300-$400 per foot, the potential value of the camp represented by shore alone is more than $12 million. Adding to this the value of the inshore land pushes the property to more than $50 million in potential value. **Efforts should be made to ensure that the Boy Scout Camp remains in place and that they continue their policy of minimum development within the camp.** Should the property be offered for sale, acquisition of the property by Washburn County or the LLPA for land conservation purposes would be cost prohibitive. Continuation of the Boy Scout Camp protects the lake's water quality and provides significant public use and public enjoyment of Long Lake.

Washburn County owns a large tract of land within the Long Lake watershed. A portion of the land includes part of the lake's shoreline. **The LLPA should work with the WDNR and other organizations to obtain grants for the purchase of county owned land for conservation purposes. It is also recommended that Washburn County use a portion of its land to establish a park, which includes the lake's shoreline.** The park may contain hiking trails, picnic facilities, and public restroom facilities. The park would prevent residential development of the land and would provide an opportunity for public use of the land.

Numerous wetlands are located throughout the Long Lake watershed. The wetlands serve as natural water quality treatment areas. They remove pollutants from stormwater runoff and protect the lake's water quality. The wetlands must be protected from development to ensure continued preservation of the lake's water quality. The first step in wetland protection is the identification of all wetlands within the watershed from maps and aerial photographs and a ground truth search. **Following identification of wetlands, the LLPA should work with Washburn County to establish additional regulations to supplement the protection currently provided by the Wetland Conservation Act. The regulations should prevent the filling of any wetland within the watershed (i.e., not allow the wetland mitigation option offered by the Wetland Conservation Act which allows wetland areas to be filled provided mitigation occurs elsewhere).**

Lake District Formation

The LLPA should petition the Washburn County Board to establish a lake improvement District for Long Lake. Formation of a Lake District will enable the LLPA to work in partnership with Washburn County to implement the Long Lake Management Plan. Lake districts possess a mix of powers and governance provisions, including taxing authority, tailored to fit the needs of lake communities. The taxing authority of the Lake District will provide the financial stability necessary for the long-term management of Long Lake. The LLPA should request that the boundaries of the lake District be identical to the Long Lake watershed boundaries. Although the initial decision on the proposed boundaries for a lake district should be made by the LLPA, the final decision rests with the county board that will vote to create the district. A larger district can spread costs over a larger tax base and include more of the land areas that affect the lake. However, a large district may also mean more difficulty in organizing and reaching consensus on issues. The lake district can only be initiated with a petition from property owners within the boundaries of the proposed district. In order for the county board to create the lake district, the petition must be signed by either: (1) 51% of the owners of land within the proposed district, or (2) the owners of 51% of the land area within the proposed district. More detailed information about the requirements of the petition process is contained in "A Guide to Wisconsin's Lake Management Law," published by the Wisconsin Lakes Partnership. The University of Wisconsin Extension (UWEX) helps organizations interested in forming a lake district. Bob Korth of the UWEX may be reached at (715) 346-2192.

Establish Boating Regulations

Boating regulations should be implemented to address LLPA concern over water quality impacts resulting from recreational boat usage along the narrows portion of the lake (i.e., located between Basin A and Basin B). Boating in the narrows portion of the lake has caused sediment resuspension, resulting in poor water quality. This area of the lake exhibits excellent water clarity when no or little boat traffic occurs and very poor clarity during periods of high boat traffic (Genrich, Personal Communication, 1997). The primary concern is the increase in turbidity and release of nutrients caused by propeller scour and boat wake impinging on bottom sediments. A further concern is the effect of turbidity on water quality, aquatic plant growth, and fish habitat.

program followed during the 1994 study should be repeated during each sampling year. The following recommendation will maximize the cost effectiveness of the lake monitoring program. The LLPA currently participates in the WDNR Water Clarity/Water Chemistry Self Help Monitoring Program. It is recommended that the LLPA continue its participation in the program, but sample the lake's five basins on a rotating basis. The five lake basins will then be monitored at least once every three years. The following parameters should be added to the Self Help Monitoring Program to duplicate the monitoring program completed in 1994: dissolved oxygen, temperature, and specific conductance. In addition, the 1994 lake macrophyte survey should be repeated once every three years to evaluate changes in coverage, density, and species composition.

To facilitate data evaluation, the data summary format used in the 1994 program should be followed for each sampling year. Graphs depicting summer average conditions (i.e., June through August concentrations of total phosphorus and chlorophyll *a* concentrations and Secchi disc transparency) should be updated following each sampling year. The total phosphorus, chlorophyll *a*, and Secchi disc graphs will enable the LLPA to determine water quality changes and to detect problematic conditions. Any change in summer average conditions would indicate a water quality change. Increased average summer total phosphorus and chlorophyll *a* concentrations and/or decreased summer average Secchi disc transparency values would indicate Long Lake water quality degradation. Conversely, decreased average summer total phosphorus and chlorophyll *a* concentrations and/or increased average summer Secchi disc transparency values would indicate water quality improvement. Data points falling within the eutrophic category indicate undesirable conditions for Long Lake. Summer averages within the eutrophic category would indicate severe water quality degradation of Long Lake and a need for remedial action. The specific values that would alert the LLPA of a change from mesotrophic (i.e., current condition) to eutrophic (i.e., problematic condition) conditions are:

- Total phosphorus concentration of 0.024 mg/L
- Chlorophyll *a* concentration of 7.5 ug/L
- Secchi disc transparency value of 2 meters.

The LLPA should monitor major tributaries to the lake to detect illicit discharges and changes in phosphorus loading to the lake. Continuous flow loggers and automatic sampling equipment should be used in the study. Lake and inflow monitoring programs should be completed in concert with additional water quality modeling to evaluate changes in annual phosphorus loading to Long Lake. The lake and inflow monitoring data would provide verification of the water quality modeling. Evaluation of the lake, inflow, and modeling results would identify needs for changes in ordinances or BMPs.

It is recommended that the Slim Creek, Twin Lake, and Big Devil lake inlets be monitored on a three-year rotating basis. It is further recommended that the respective lake basins receiving inflow from these inlets be monitored concurrently. Continuous flow data should be collected from snowmelt runoff to late fall when ice-in conditions occur. An automatic sampler should collect samples during snowmelt, two spring, three summer, and two fall rainstorms (i.e., rainstorms are defined as having more than 1/2 inch precipitation). Samples will be flow-composited and analyzed for total phosphorus and total suspended solids. In addition, grab samples or samples collected by the automatic sampler should characterize baseflow conditions. Three samples per month (i.e., approximately one sample each ten day period) should be collected during April through October. Following completion of data collection, the annual phosphorus budget from the subwatershed corresponding to the sampled inlet should be recalculated based upon the flow and water quality data collected from the inlet. The revised budget should be evaluated to determine the success of ordinances and BMPs. Concurrently, the lake data from the basin receiving flow from the inlet should be evaluated to determine goal achievement. Regular evaluation of the actual phosphorus loading to the lake and the resultant water quality of the lake will determine whether changes in ordinances or BMPs are necessary to achieve the lake's long-term water quality goals.

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