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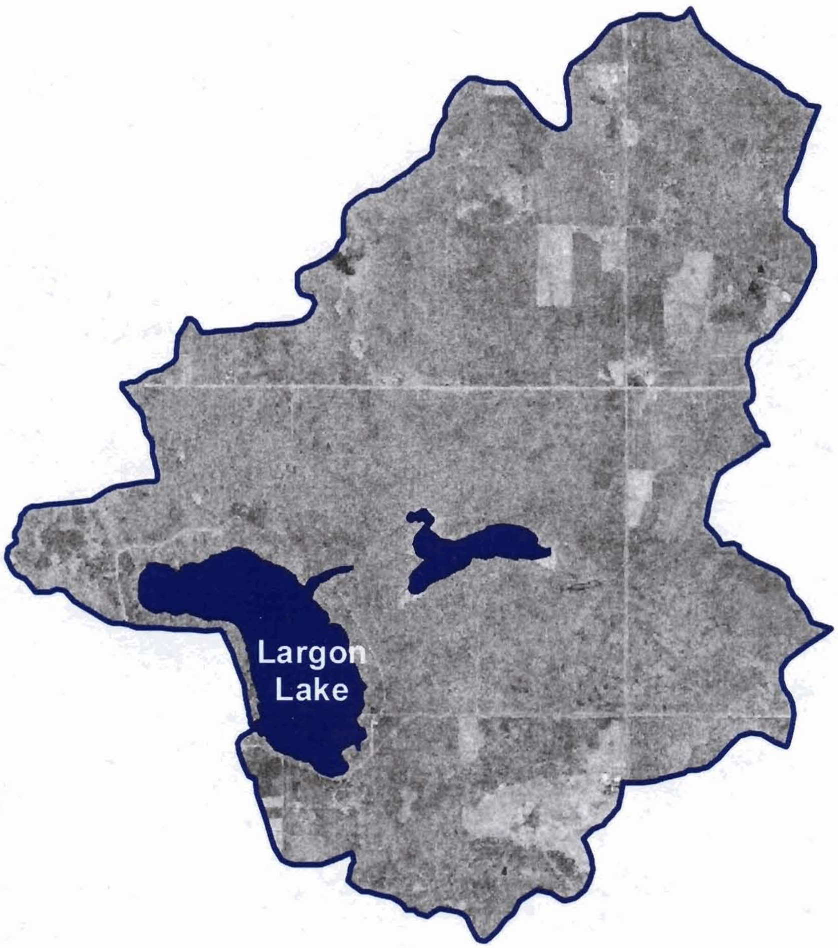
LARGON LAKE



Prepared by:

Polk County Land & Water Resources Department

Report Completed June 2002

Largon Lake Management Plan, 2002

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This report was funded through the DNR Lake Management Planning Grant Program.

The authors would like to extend a special thank you to the volunteers who slogged through wet weeds, battled waves, and endured sun and bugs to collect the data that made this report possible. Local residents are the primary stewards of Largon Lake and its associated land resources. The decisions they make today and the degree to which they involve themselves in efforts such as this will do more to shape the future of Largon Lake than any other factor.

TO: LARGON LAKE ASSOCIATION MEMBERS

FROM: BROOK WAALEN, POLK COUNTY LWRD

DATE: AUGUST 31, 2002

RE: LARGON LAKE MANAGEMENT PLAN, 2002

To understand Largon Lake one must understand its recent history. Largon Lake took its present form about 1900 when beavers built a dam at the outlet (Shea, Richard J. 1980). The dam flooded what may be described in today's terms as a deep marsh. The higher water level attracted people who used the area for recreation and ultimately built cabins along the shoreline. The beaver were trapped in the early 1970s and the dam deteriorated to the point of collapse. Without the beaver dam the water level dropped to its shallow, pre-dam level. During the winter of 1974 the lake experienced a freeze out[1].

The collapse of the dam and the subsequent winter kill served to galvanize the shoreline property owners who then organized the Largon Lake Association. They focused their energy and resources into building a concrete dam at the lake's outlet to maintain water at a height that would support both water recreation and a diverse fishery. In those terms their effort has been a monumental success. The fishery has been supplemented over the years through fish stocking by the Wisconsin Department of Natural Resources (WDNR). Maintenance of an aeration system protects the fishery by preventing winter freeze out.

One intended consequence of maintaining relatively high water levels was to provide for human recreational desires. Conversely, one unintended consequence of manipulating both the water level and fish community was to create a lake that has relatively poor water clarity and nuisance algal blooms. The reason this lake study was initiated was due to landowners' water quality concerns that focused primarily on the frequency and severity of these algal blooms.

Note: The algal blooms that occur with an unpleasant odor are actually not an algae but rather a type of bacteria called *cyanobacteria*. Cyanobacteria is a natural part of Wisconsin lakes and there is no simple method to rid the lake of it. However, it may be possible to reduce the frequency and severity of the blooms that occur.

The work that went into both the lake study and this report was focused on addressing nuisance cyanobacteria blooms. In doing so this report covers several topics:

- An inventory of the lake and its surrounding land resources;
- 2000 Sociological Land Owner Survey;
- Water quality data and water chemistry testing results;
- Fish stocking history and WDNR fish management recommendations; and,
- Lake modeling;

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[1] "Freeze out" also referred to as "winter kill" is an event that occasionally occurs in lakes when wintertime dissolved oxygen levels fall and are unable to support fish. A number of factors may be involved in a freeze out such as water depth, amount of decaying matter on the lake bottom, and duration and thickness of ice cover.

This report also elaborates on the feasibility, cost, and involvement of the following management options:

- **Reduce nutrient inputs** from adjoining inlets, gullies, and property;
- Lobby for **stronger enforcement of zoning laws** (theses laws are designed to protect lakes);
- Treat the lake with **alum** (in an effort to limit nutrient availability to cyanobacteria);
- Add **microorganisms** to the lake (in an effort to out-compete cyanobacteria);
- Run a **circulation system** or **aeration system** year round (to keep oxygen levels high and reduce in-lake phosphorus cycling);
- Treat the lake with **barley straw** (to limit algae growth lake-wide or at specific locations such as inflows);
- Treat the lake with **herbicides** (to kill cyanobacteria just before it blooms); and,
- Alter the limits on predator fish as a method of **biomanipulation** (to ultimately increase the number of zooplankton that eat algae and cyanobacteria).

There are other management options. Furthermore, combinations of management options were not explored due to funding and time limitations.

On the whole Largon Lake currently provides a productive fishery and opportunity for the widest possible variety of recreation. Furthermore the diversity of plant life both in and adjacent to the lake provide food and habitat for an array of wildlife. Largon Lake property owners enjoy a serene setting complete with wildlife, boating opportunities, and good fishing.

The future of Largon Lake obviously cannot be predicted. However, it is not unreasonable to assume that the opportunities that this area offers will attract people and development. Residential development within the watershed would increase the nutrient load to the lake and negatively affect the surrounding ecosystem. Roads, driveways, rooftops, and yards are sources of pollution and they make crummy wildlife habitat.

Largon Lake is considered a *eutrophic* lake which is characterized by cyanobacteria dominance and prolific aquatic plant growth. Continued nutrient inputs will eventually push the lake to *hypereutrophication* which is a state characterized by heavy algal blooms throughout the summer and dense beds of aquatic plants. Hypereutrophic lakes don't offer nearly as many recreational opportunities as eutrophic lakes. **It is the opinion of the Polk County Land and Water Resources Department that the primary goal of managing Largon Lake should be to prevent further eutrophication of the lake in order to preserve the current recreational opportunities in balance with a healthy ecosystem.**

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Characteristics of Largon Lake

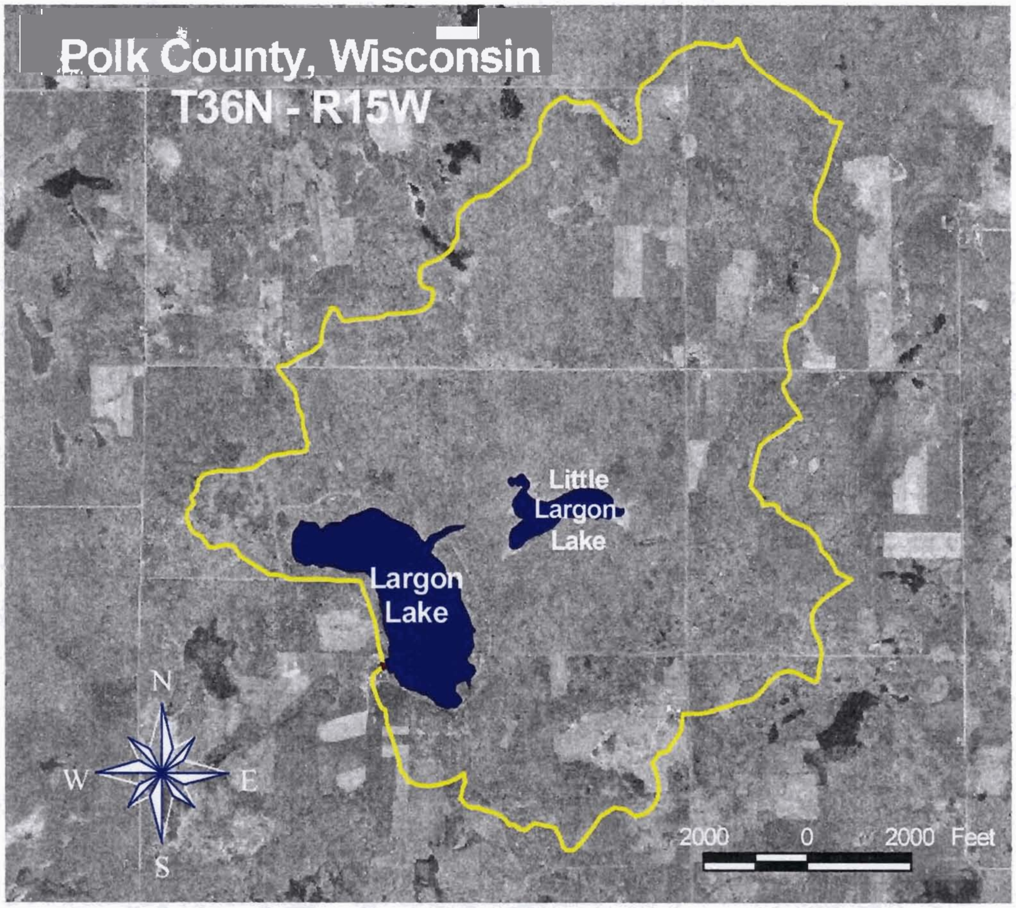


Figure 1: *Largon Lake Watershed Map*

1.	**Lake Area:**	129 acres
2.	**Watershed Area:**	2480 acres
3.	**Lake Volume:**	826.5 acre-feet or 269 million gallons
4.	**Mean Depth:**	6 feet
5.	**Maximum Depth:**	10 feet
6.	**Miles of Shoreline:**	2.34 miles
7.	**Residence Time:**	0.7 years

8. Areal Water Load:

The annual areal water load is estimated to be 2.54 m/yr. The areal water load is the hydraulic load divided by the lake surface area. Hydraulic load is the amount of water that enters the lake, and is a function of yearly rainfall, land uses and amount of impervious surfaces.

9. Annual Precipitation:

The annual precipitation in 2001 at the station in Amery is 36.42 inches.

10. Annual Evaporation:

The average annual evaporation rate for Polk County is approximately 44.15 inches per year. This figure was used from the closest station that measures mean "pan evaporation" located in Minneapolis.

History of Largon Lake

Largon Lake is located in northeastern Polk County, twelve miles northwest of Cumberland. A dam on the west side of the lake enables the lake to retain water that drains from the watershed. This would classify the lake as an impoundment.

The watershed area contains one other lake, Little Largon Lake. This lake is a 19-acre lake with a maximum depth of 29 feet. A stream drains Little Largon Lake and flows into the northeastern side of Largon Lake. Surface water drainage into Largon Lake occurs directly from the riparian area through five streams which drain sub-watersheds.

Largon Lake is in the St. Croix River Basin. This basin has a temperate, continental climate. The average annual precipitation is 36.42 inches. In this portion of the St. Croix River Basin, an average of 9 inches of precipitation enters streams and lakes through surface and groundwater (Young and Hindall, 1973).

The lake took its present form when beavers built a dam at the only outlet for the watershed around the year 1900 (Shea, Richard J. 1980). As water levels rose, people built cabins on the lakeshore, and increasingly used the area for recreation.

HISTORY OF THE DAM

According to a report from the Largon Lakes District by Richard John Shea in 1980, Largon Lake had one of its periodic severe winterkills in 1973. The beaver, which had maintained a dam on the only outlet since approximately 1900, were trapped out during the winter. In the spring of 1974, the dam deteriorated because of lack of repairs and was swept away. This caused the lake water level to drop drastically.

Resident cabin owners built a sandbag dam in an attempt to raise the lake water level to prevent a total freeze during the coming winter. Within a week after construction of the dam, the town board was notified by the DNR that the dam must be removed. It was illegal because the dam had not been approved by state authorities. The dam was then removed and the lake level fell again. In 1974, the lake suffered a total winter freeze out.

After several months of studying their options, the 24 cabin owners formed a lake district in order to gain some leverage for acquiring a dam on the lake. The Largon Lake Protection and Rehabilitation District was formally chartered on November 7, 1975, with the township as one of the property-owning members.

A dam permit was applied for on March 2, 1976. In May of 1976, at the cost of $2,800.00, the dam was completed.

The dam, named New Dam, was located at the westerly outlet of Largon Lake. The dam's purpose was to maintain a lake level and water depth consistent with a sport fishery and human recreational requirements.

AERATORS

Due to the shallow depth of Largon Lake, winterkills occurred frequently. Winterkills occur because there are low levels of dissolved oxygen in the water, which is often a consequence of early and heavy snow cover that decreases photosynthesis by aquatic plants. The plants die and decompose under the ice, consuming dissolved oxygen in the water. If dissolved oxygen levels become too low, fish will die.

Through the Largon Lake Protection and Rehabilitation District, the lakeshore residents installed an aerator in late July of 1977. The location of the current aerators and the dam can be found in Figure 2.

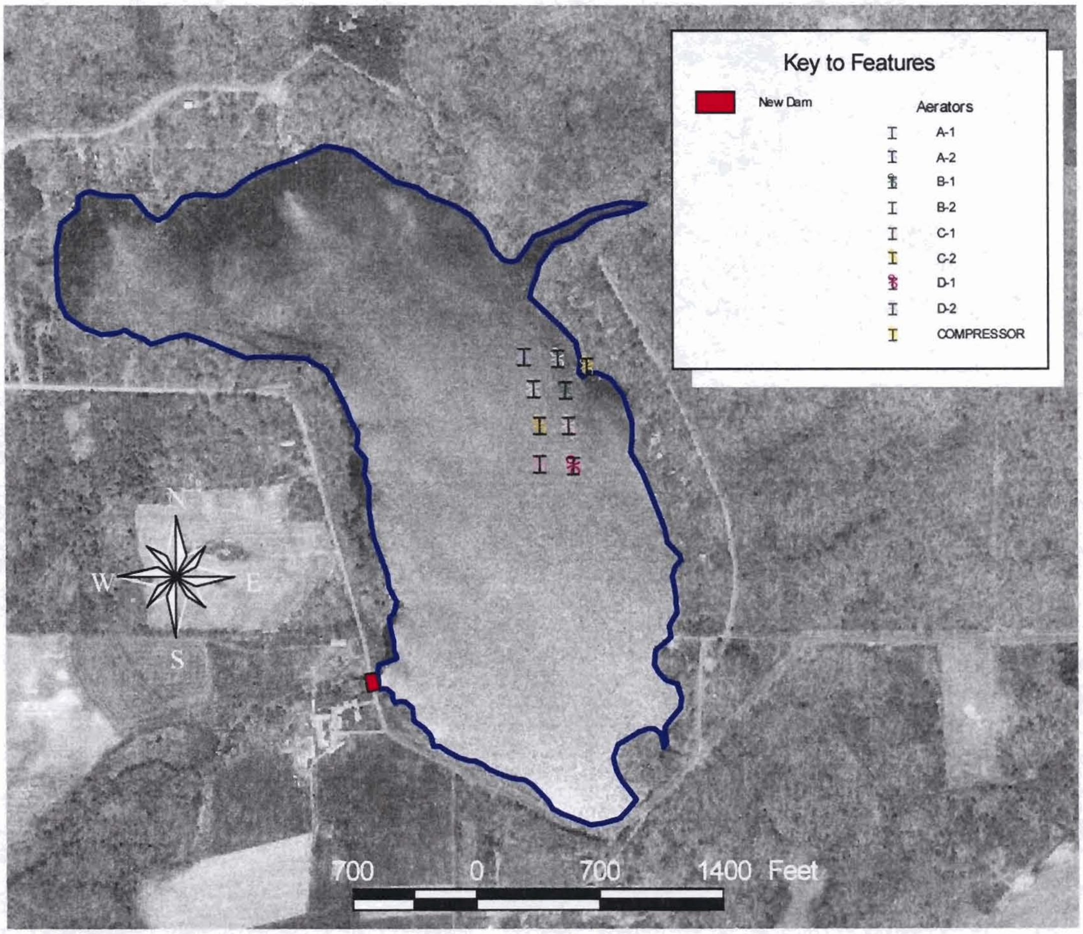


Figure 2: *Location of Aerators and New Dam*

Land Use in the Watershed

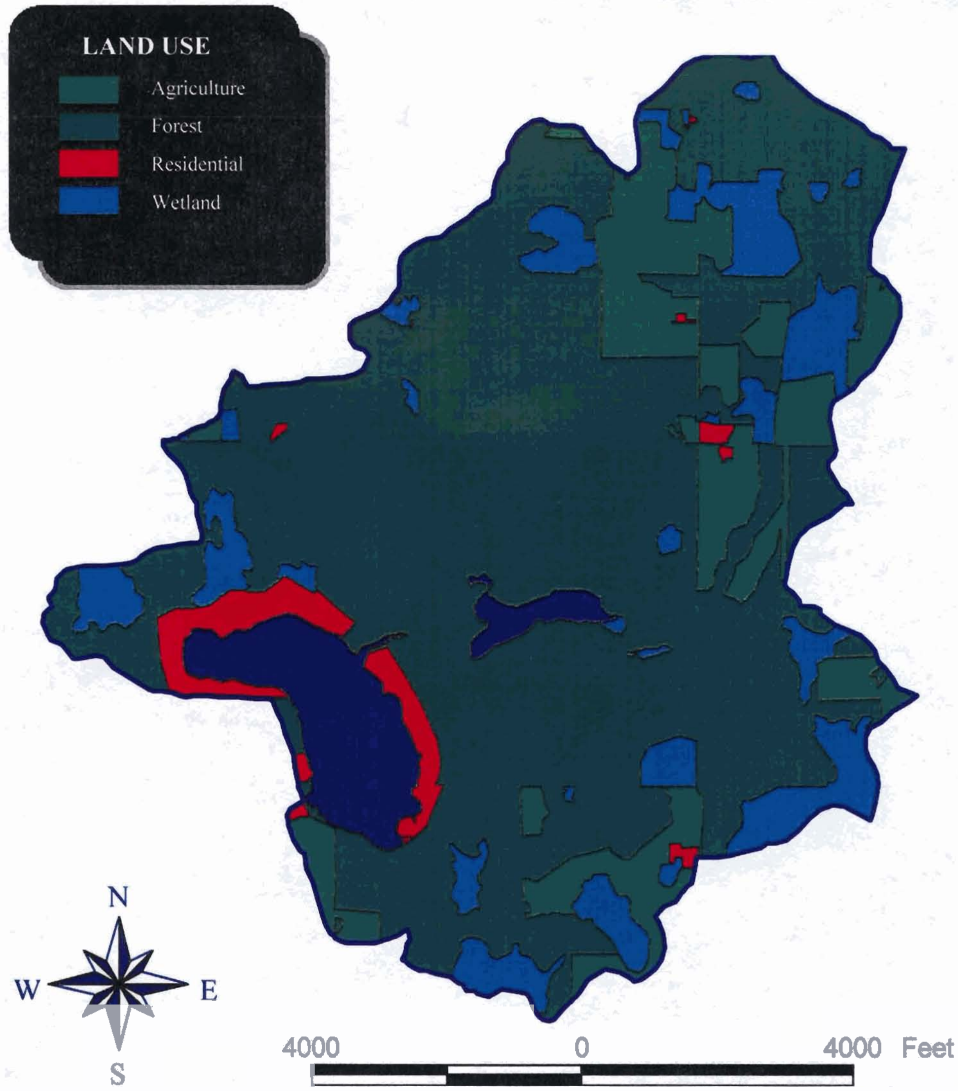


Figure 3: *Land Use within the watershed*

Land use within the watershed is an important factor that impacts lake water quality. Factors such as soil characteristics, topography, and human activities affect the quality of the surface water. The surface water can make its way to Largon Lake and can affect the quality of the water entering the lake. Land use in the watershed breaks down as follows:

Agriculture	**319.6 acres**	**13.8%**
Forest	**1589.8 acres**	**68.5%**
Residential	**124.0 acres**	**5.3%**
Wetlands	**288.3 acres**	**12.4%**

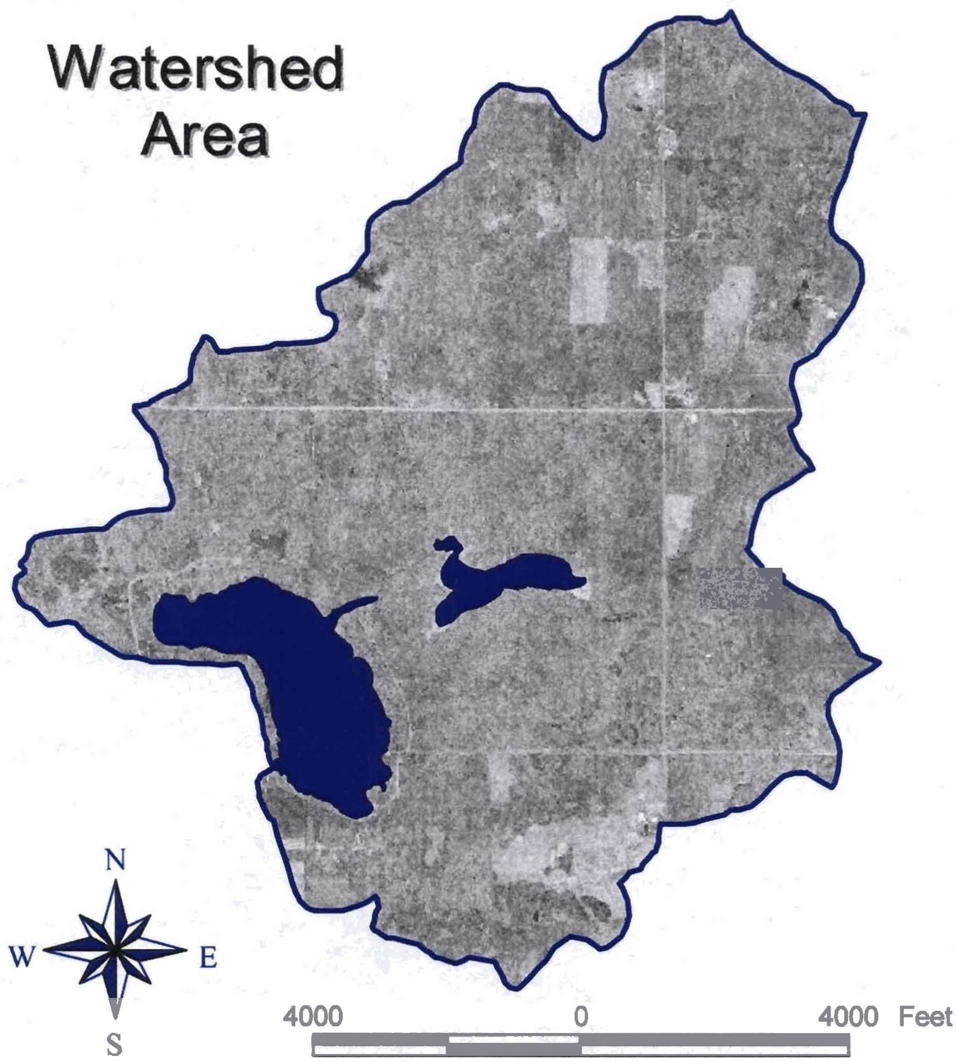


Figure 4: *Aerial photograph of watershed area*

The two lakes, Largon Lake and Little Largon Lake, have a combined acreage of 159.5 acres. In comparison, this is only 6.9% of the size of the entire watershed.

Lake Largon drains about 2320 acres of land. The watershed area to lake area ratio is a substantial 14:1. The larger the ratio, the more the watershed will impact the lake through runoff of pollutants such as nutrients, pesticides, and soil erosion.

Profile of the Lake Community

The Largon Lake Watershed Property Owner Survey, 2000 was distributed to each household in the watershed. This survey was created to assess the needs and to identify issues that are important to property owners on and near Largon Lake. Of the 76 households in the watershed that the survey was distributed to, there were 40 responses. Over half (26/40) of these were from landowners who had lakefront property.

LARGON LAKE ATTRIBUTES

It is clear that members of the watershed community are attracted to Largon Lake by its beauty and the lake lifestyle. The main reasons for purchasing the property on or near the lake are for passive enjoyment and fishing (Figure 5).

Non-motorized and motorized water sports are also principle reasons for purchasing property in the watershed. Although passive enjoyment of lake is enjoyed by a larger portion of the community, water sports will greatly impact the future management of the lake. For instance, recreation trends have been moving steadily

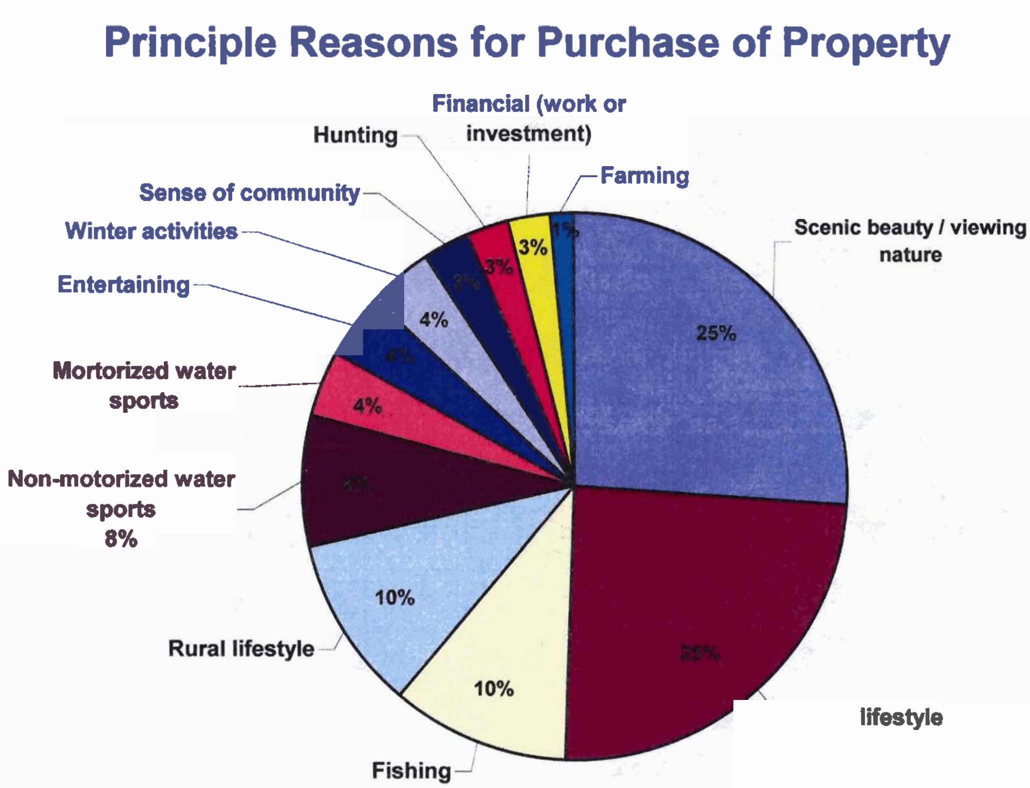


Figure 5: *Reasons lakeshore owners purchased property*

away from small boats and motors towards personal watercraft, large boats and motors, and water toys. This type of recreation conflicts with the more passive enjoyment identified as important by current property owners.

RESIDENCY

Most respondents are not full-time residents. Due to the strong appeal of the summer activities available at Largon Lake, many of the property owners use their property as a seasonal residence.

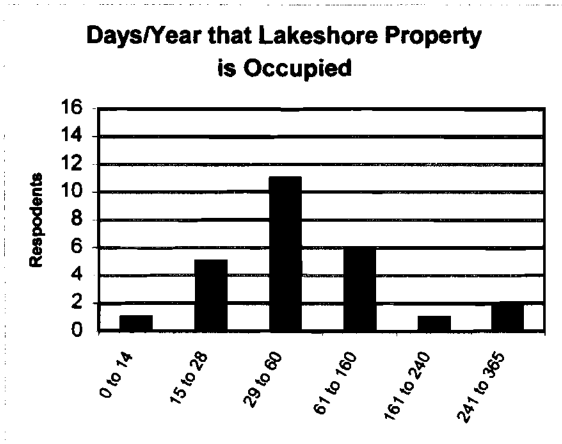


Figure 6: *Occupancy by Lakeshore Residents*

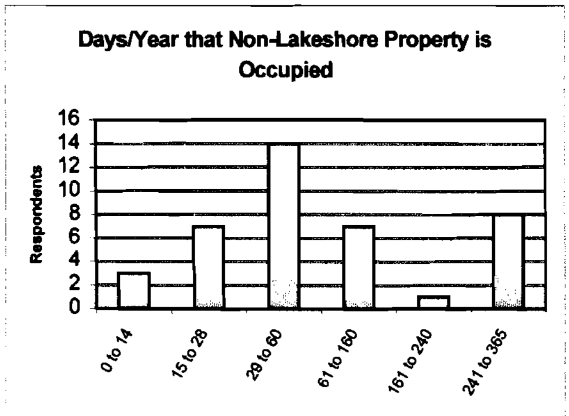


Figure 7: *Occupancy by Off-Lake Residents*

This seasonal residence is evident in the properties that are located off the lake, as well as the properties located directly on the shoreline. Figures 6 & 7 show the trend in both situations.

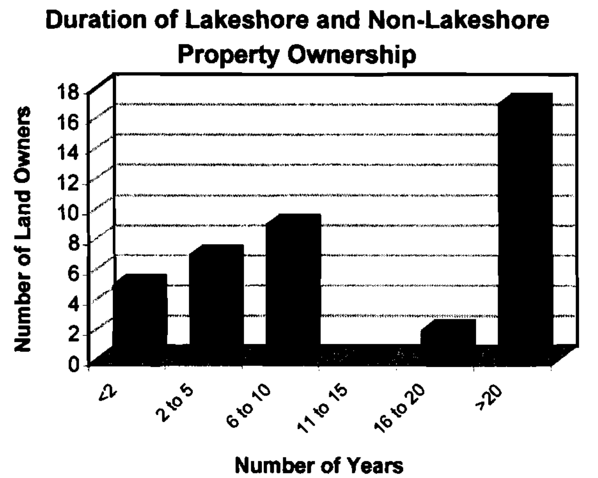


Figure 8: *Duration of Ownership of On and Off-Lake Property*

The number of people who are willing to commute longer distances to work has fostered a surge in property sales in the area for development over the past ten years. This trend is expected to continue (Figure 8).

WATERCRAFT

Lakeshore community members also use the lake for motorized activities. This is often in conflict with the expectations of a more peaceful lakeshore community, but is enjoyed by many. The average number of watercraft owned per respondent is 1.65. Over half of the total number of watercraft are motorized. The majority of watercraft are motorboats and pontoons, as well as canoes and kayaks (Figure 9).

There are a number of reasons why boat activity is an important issue. The number of registered

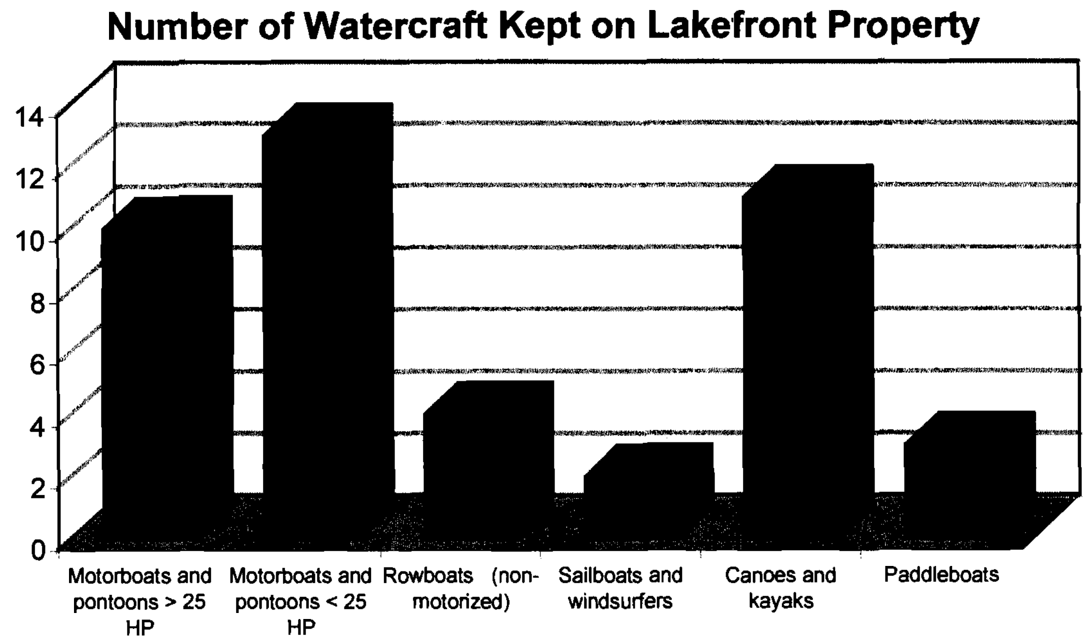


Figure 9: *Number and types of watercraft kept on Largon Lake*

boats in Wisconsin has increased by 87% since the late 1960's. Size of boats has also increased: over 40% of the registered boats were between 16 and 39 feet long in 1997-98 compared to just 18% in 1968-69. Along with the bigger boats have come bigger engines.

There are many positive and negative effects of having motorized watercraft on the lake. Over half of the people who enjoy fishing use motorboats to easily maneuver to their fishing spots. There are also many other benefits to watercraft such as the enjoyment of taking a leisurely pontoon ride over the lake or using a motorboat to navigate to areas where you are easily able to view wildlife. Unfortunately, there are also negative effects of motorized watercraft which include:

- **Algae and decreased water clarity**
- **Lower water quality**
- **Shoreline erosion**
- **Negative wildlife effects**

Algae and Decreased Water Clarity

Propellers disturb the lake or river bottom directly, or indirectly through the wash or turbulence they produce, especially in shallow water. This may affect water clarity by increasing the amount of sediment particles in the water or may cause nutrients that are stored in the sediments, such as phosphorus, to become available for algal growth.

Waves created by watercraft contribute to shoreline erosion, which can cloud the water. Shallow lakes (less than 10 feet in depth), shallow parts of lakes and rivers, and channels connecting lakes are the most susceptible to impacts.

Lower Water Quality

Water quality refers to the chemical nature of a water body, particularly as affected by human sources. Metals (lead, cadmium, mercury), nutrients (phosphorus, nitrates), and hydrocarbons (methane, gasoline, oil-based products) can all be added directly to the water column through a number of sources, including boat motors.

Boat engines are designed to deliver a large amount of power in a relatively small package. As a result, a certain amount of the fuel that enters into a motor is discharged unburned and ends up in the water. Estimates vary as to how much fuel may pass into the water column (25-30% is a reasonable average) and depends upon factors such as engine speed, tuning, oil mix, and horsepower. Other concerns include lowered oxygen levels due to carbon monoxide inputs, and spills or leaks associated with the transfer and storage of gasoline near waterbodies.

Shoreline Erosion

Waves or wakes produced by boats is the primary factor by which boats can influence shoreline erosion. Wave heights depend upon speed, size and draft of boat, but can reach heights of 40-50 cm (15-20 in.) which are equivalent to storm-induced waves. Small lakes, such as Largon Lake, are likely to be most influenced by boat-induced waves, as boats may operate relatively close to shore and wind-induced waves are reduced.

Propeller turbulence from boats operating in near shore areas may also erode shorelines by destabilizing the bottom. Shoreline erosion has been documented in lakes and rivers and has been attributed to frequency and proximity of boat traffic. Poorly vegetated banks are more susceptible to shoreline erosion.

Negative Wildlife Effects

Boats may have direct impacts on wildlife through contact with propellers or disturbance of nests along the shoreline by excessive wave action. Disturbance by watercraft or even the presence of humans near feeding ground or breeding areas may prevent certain species, especially birds, from being successful. Noise or harassment may cause some wildlife to vacate nests, leaving eggs or young vulnerable to predators. Indirect effects may include destruction of habitat, food sources, or impaired water quality.

WATER QUALITY

The observations regarding water quality by lakeshore property owner respondents are mixed. Only 8% of survey respondent owners describe the current water quality in Largon Lake as above average. Fifty percent of respondents would describe the water quality as below average (Figure 10).

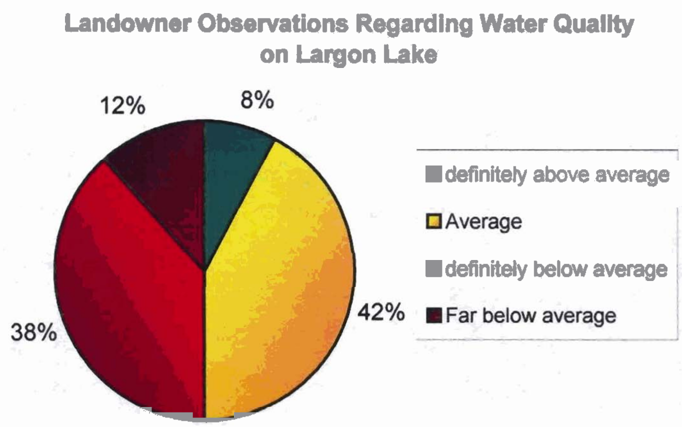


Figure 10: *Water quality observations by property owners*

Land owners were also asked to describe the change in water quality since they have lived on or owned property near the lake. Over fifty percent thought the water quality degraded. Only 15% thought there was slight improvement (Figure 11).

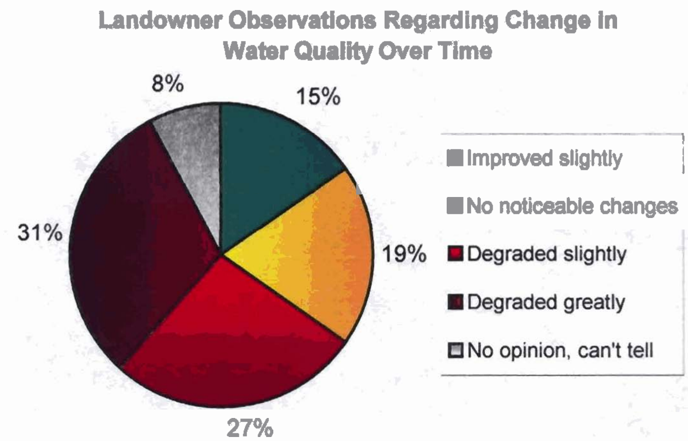


Figure 11: *Observation of the change in water quality over time*

Figure 12: *Example of a quality shoreline*

When asked about the quality of the shoreline, most respondents believed that the quality was average (Figure 13). Having a healthy shoreline helps to trap sediments and to slow runoff from flowing directly into the lake.

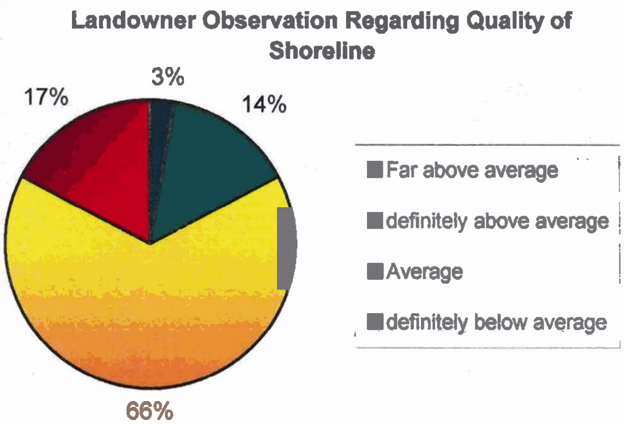


Figure 13: *Observations of the quality of the shoreline*

In addition to the multiple choice questions, respondents were also asked three open ended questions. These questions provide further insight into the concerns of land owners.

1. What do you like most about Largon Lake?

Most respondents enjoyed the quiet atmosphere of the lake, as well as its small size. There were many comments about the beauty of the area and the ability to watch various forms of wildlife. People also enjoyed fishing and the convenient location to the Twin Cities. Other comments are listed below:

- **"It's a small, peaceful lake… (with a) nesting pair of eagles"**
- **"A beautiful, small lake with a sense of community with most cabin owners."**
- **"The smallness of the lake – no really large boats, no large lot sizes or trailers."**
- **"Good fishing. Relatively quiet most of the time… so far, (there are) few, if any, jet skis."**
- **"Largely wooded shoreline and good association of property owners."**
- **"Good size lake for what we like doing: fishing, sailing, ice-skating and cross-country skiing."**
- **"Nice area and people (seasonal and permanent)."**
- **"Proximity to the twin cities."**

2. What do you like least about Largon Lake?

The characteristic of Largon Lake that landowners liked the least was the blue-green algae. A few respondents noted that the algae becomes predominant by late July. Some were concerned about the number of boats on the lake and the development of property on the shoreline. Most, however, were concerned primarily with the water quality. Listed below are comments made by landowners regarding their concerns:

- **"Continued destruction of wildlife habitat along the lakeshore… too much removal of brush, trees, and mowing to make lawns."**
- **"The awful, stinky algae bloom starting in July… makes one not want to eat the fish, swim, or entertain guests, as it really smells on warm, humid days."**
- **"When lots of boats are here on the weekend, it gets noisy."**

- "It used to be a quiet lake where one could enjoy the peace and tranquility. Now, with lake lots being sold, this asset is rapidly vanishing."
- "I can hear motor boats 1 mile away."
- "Water quality by July is increasingly worsening. The water looks like pea soup."

Comments regarding Largon Lake

Listed below are more concerns that landowners made about Largon Lake and its surrounding land resources. By using an open-ended question vs. multiple choice, the results expressed concerns that may not have been addressed previously, and allowed further input form landowners.

- **"I am concerned with water quality… this is taken for granted by so many with misuse and pollution. I love to catch crappies in Largon and release all fish that are too small. I feel the large fish population may be decreasing. I've wondered if it is over-fished or if people are not allowing mature growth. I am happy to see there is concern with the water quality of Largon Lake."**
- **"High powered boats should be banned from the lake because they disturb the bottom of this shallow lake."**
- **"Perhaps speed limits should be set on the lake and surrounding roads and dust control on gravel roads financially supported by cabin owners."**
- **"I wonder if there should be portable bathroom facilities at the much used public landing. I've observed people (using the lake for such purposes)… close to shore."**
- **"As agriculture use in the watershed has declined and cabin/recreation use has great increased, water quality seems to be declining."**

POTENTIAL CONTRIBUTION

Eighty percent of those surveyed were willing to provide financial support to maintain or improve the quality of Largon Lake and its associated land resources (Figure 14 & 15). Over half of these respondents were willing to contribute $50 or more (Figure 16). This shows great enthusiasm in the community for the lake and for the recreational resources it provides.

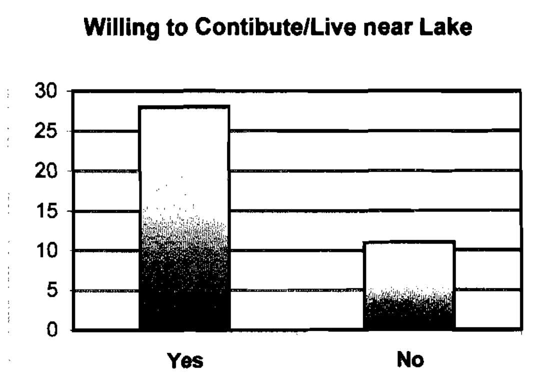


Figure 14: *Number of landowners who live near the lake that are willing to contribute to improve lake quality*

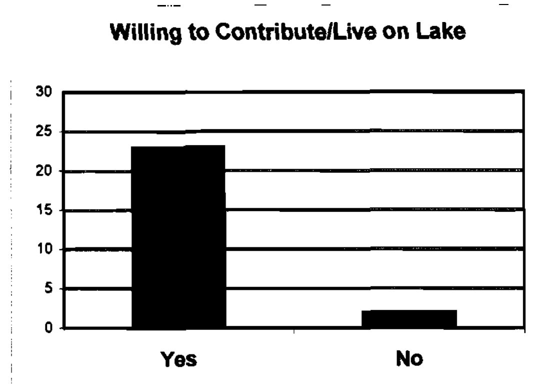


Figure 15: *Number of landowners who live on the lake that are willing to contribute to improve lake quality*

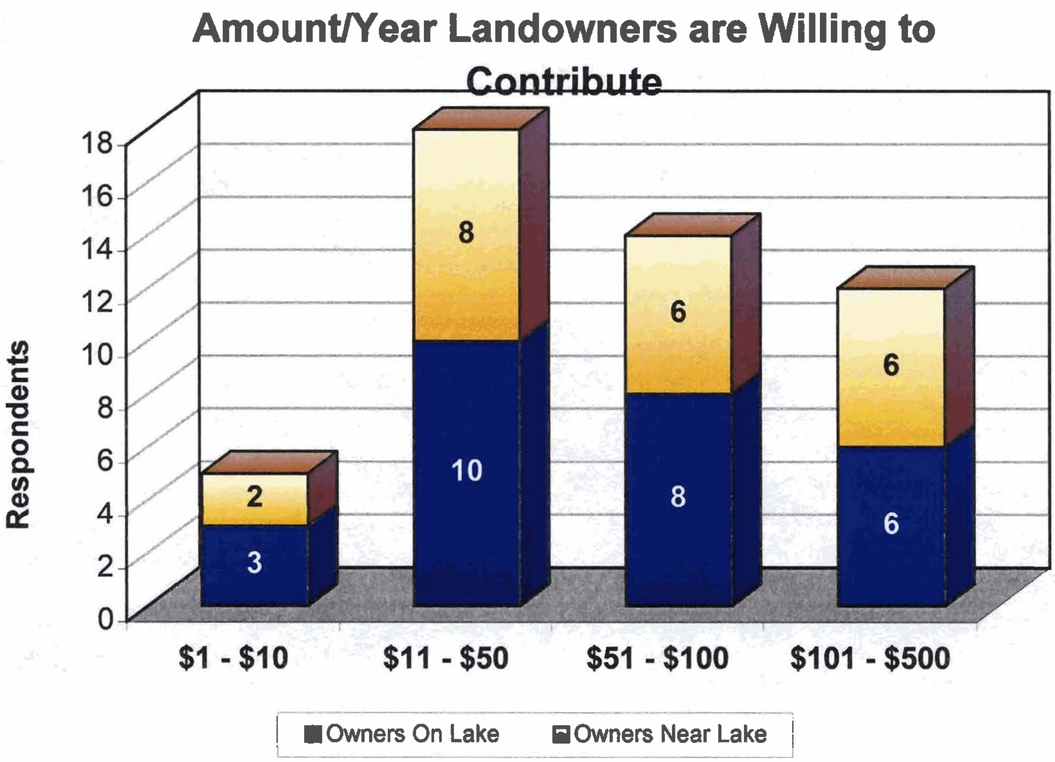


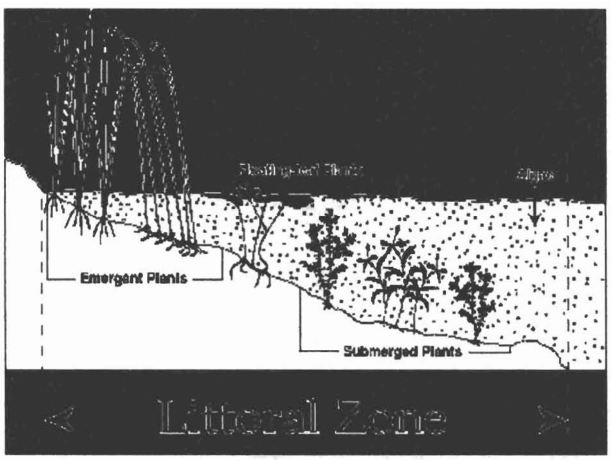
Figure 16: *Amount of money per year that those who are willing to contribute to lake quality would donate*

Water Quality at Largon Lake

The quality of water at Largon Lake affects the clarity, the growth of algae, the plant growth, the quality and amount of fish, and the birds and other wildlife who utilize this resource. By looking at water quality data, we can pinpoint the source of problems that occur, such as the algae growth. This information will help to determine the best management options for Largon Lake.

ALGAE

Algae are microscopic plants that are found in all lakes. The more algae present in a lake, the greener and less clear the water will appear.



Although sometimes a nuisance, algae are important to the ecosystem. Algae are eaten by microscopic animals called zooplankton. The zooplankton are eaten by fish. These fish are then eaten by larger fish. Humans and other animals may consume these larger fish.

Blue-green algae (Cyanobacteria) which have been observed at Largon Lake are inedible to most zooplankton and waterfowl such as ducks and geese. This type of algae can quickly become a problem because it has few natural predators. One of the most unpleasant effects of the overabundance of algae is the algae blooms that occur.

Although algae is a natural part of Wisconsin's lake environment, it is important to remember that these microscopic plants serve as indicators to the overall health of the aqua-system(s). As the addition of nutrients into lakes increases, algal populations are likely to increase. One possible way to decrease the occurrence or severity of algae blooms is to reduce the amount of nutrients entering the lake.

SECCHI DISK

A Secchi disk is an 8 inch black and white plastic disc which is lowered into a lake to measure the transparency of the water (Figure 17). The disk is lowered into the water, usually from a boat at the deepest part of the lake, until it disappears from view. It is then

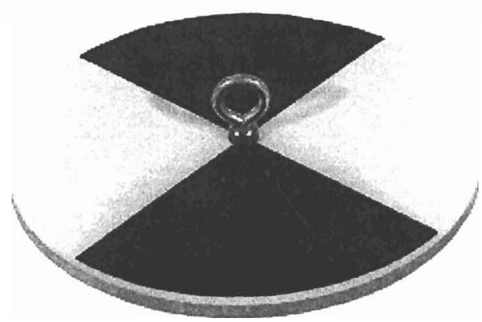
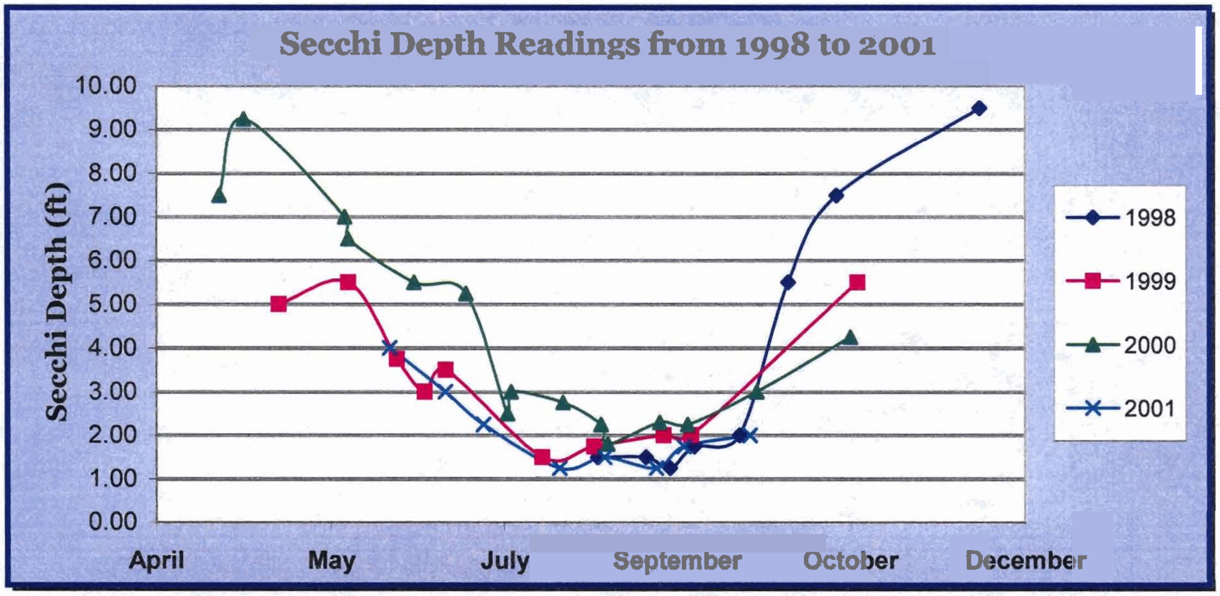


Figure 17: *Secchi disk*

raised until just visible. An average of the two depths is recorded as the Secchi disk reading.

Usually a reduction in transparency over time



indicates that the amount of algae present in water is increasing. The algae can greatly affect the Secchi depth readings by clouding the water. However, turbidity from soil erosion or tan color from decaying vegetation will also reduce Secchi disc readings.

Landowners have observed that the algae becomes most predominant in July and August. The decrease in Secchi depth readings during this time is most likely due to the algae blooms that have been reported to occur during these months (Figure 18).

CHLOROPHYLL a

Chlorophyll a is a measure of the green pigment in phytoplankton, and is an indicator of algae. Chlorophyll a can indicate when algal abundance occurs and assist in determining effectiveness of control strategies. Five Chlorophyll a samples were collected in 2001. Concentrations ranged from 2.7 to 50 ug/L.

Data shows a strong correlation between chlorophyll *a* concentrations and Secchi depth. It appears the amount of chlorophyll *a* inversely affects water clarity, as shown in Figure 19.

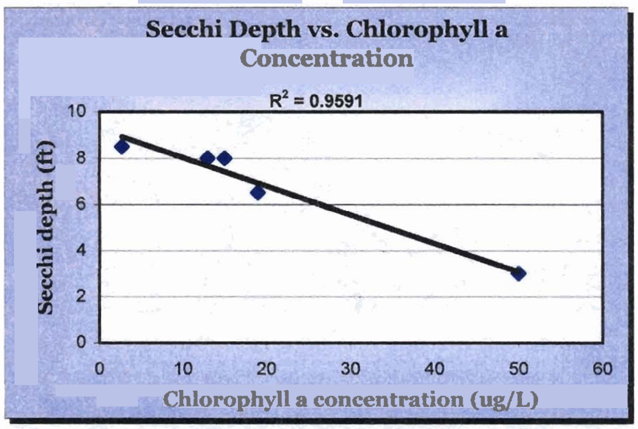


Figure 19: *Correlation between Secchi depth and Chlorophyll a*

TOTAL PHOSPHORUS

In more than 80% of Wisconsin lakes, phosphorus is the key nutrient affecting the amount of algae and aquatic plant growth (Shaw et al, 1996). Phosphorus can promote excessive algal and aquatic plant growth by provoking complex reactions in the production cycle of algae and plants. These reactions lead to eutrophication.

Eutrophication is the natural aging process of lakes, often times accelerated by human activities, and is identified by the increase in biological productivity causing the water to become murky. The easiest and most practical method to control eutrophication is to focus on phosphorus.

Phosphorus originates from a variety of sources, many of which are related to human activities (Shaw et al, 1996). Sources of phosphorus include human and animal wastes, soil erosion, purchased detergents, septic systems, runoff from lawns or gardens, and agricultural fields or barnyards.

Sampling Data

The inflow/outflow sampling data taken in 2001 shows, on average, that the concentration of total reactive phosphorus at the inflow is 32 times greater than at the outflow. The dam traps most of the phosphorus within the lake. Therefore, Largon Lake acts as a phosphorus sink.

Dredge samples were analyzed and show high phosphorus concentrations in the sediment at the center or the lake, as well as the stream inflow (Appendix D). The largest concentration was found in the center of the lake, approximately halfway between the outlet and the intermittent stream inflow from Little Largon Lake.

If Largon Lake acted as an engineered sediment basin, the highest phosphorus concentrations would be expected to be near the outlet. The high concentration near the center are likely the result of high phosphorus sediments that were carried with runoff and did were not able to exit the lake.

Boat Traffic Effect on Phosphorus

The most likely cause of the central location of phosphorus in the lake is the boat traffic, as well as the engine's ability to churn up the lake

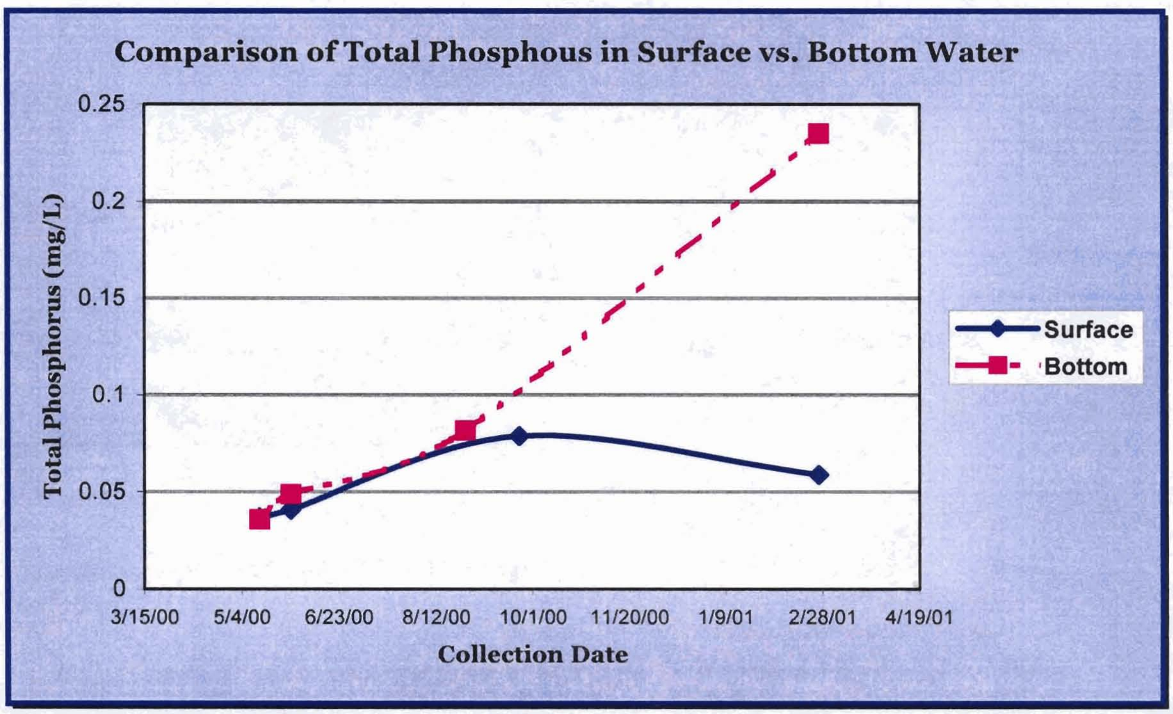


Figure 20: *Total phosphorus in surface and bottom water at Largon Lake*

lake bottom. Yousef et.al. (1980) studied the effect of boat traffic on shallow and deep lakes. On shallow lakes, significant increases were seen in phosphorus on the lakes that had boat traffic which churned up the lake bottom. The control sites without boat traffic did not show the same increase in phosphorus. Average increases of phosphorus in water samples ranged from 28 to 55% with heavy motor boat usage.

According to the Largon Lake Watershed Property Owner Survey, the total amount of watercraft owned by the 40 respondents is 43. This averages out to one watercraft per household living on or near the lake.

TSI INDEX

The Carlson Trophic State Index (TSI) provides a single quantitative index for the purpose of classifying and ranking lakes. The index is most often utilized for assessing water quality. TSI is a measure of the trophic status of a body of water using several measures of water quality including:

- **Secchi readings** *(transparency or turbidity)*
- **Chlorophyll-a concentrations** *(algal biomass)*
- **Total Phosphorus levels** *(nutrient for plant and algal growth)*

The index can be used to measure the potential for algae to develop (Table 1). Lower TSI values coincide with low algae productivity and high water clarity.

The average TSI for Largon Lake is 63. This information indicates that the current conditions are eutrophic and have the potential for persistent algae, as well as nuisance aquatic plant growth (Figure 21). These symptoms have been noted by the lakeshore occupants.

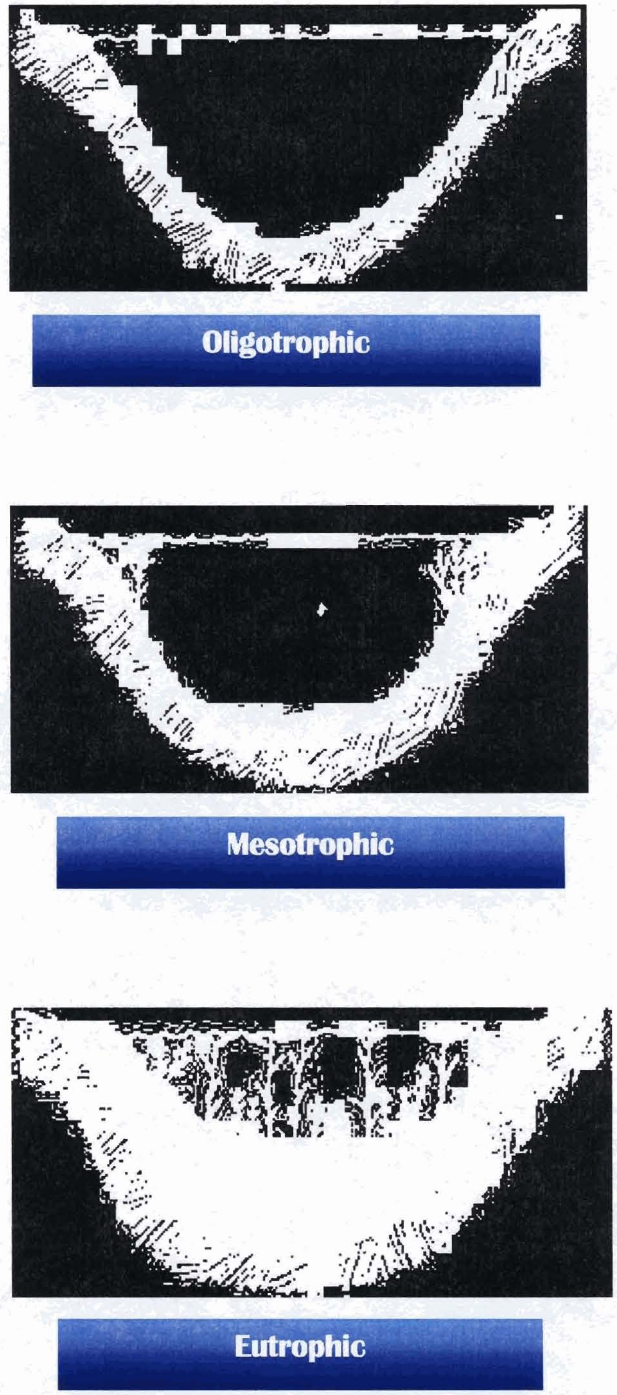


Figure 21: *Different trophic states*

Residents have noted a "pea soup" appearance to the water, as well as an unpleasant odor that occurs during algae blooms. The presence of blue/green algae on the top of the water has also negatively affected the aesthetics of the lake.

Table 1: *Trophic scale including Largon Lake TSI*

TSI	GENERAL DESCRIPTION
< 30	Oligotrophic: clear water, high dissolved oxygen throughout the year in the entire water body.
30 - 40	Oligotrophic: clear water, possible periods of anoxia in the lake bottom (dissolved oxygen =0).
40 - 50	Mesotrophic: moderately clear water, increasing chance of anoxia near bottom in summer, fully acceptable for all
50 - 60	Mildly Eutrophic: decreased water clarity, anoxic near bottom, nuisance aquatic plant growth, warm water fisheries only.
60 - 70	Eutrophic: blue-green algae dominance, scums possible, prolific aquatic plant growth.
70 - 80	Hypereutrophic: heavy algal blooms possible throughout summer; dense beds of aquatic plants.
> 80	Hypereutrophic: algal scums, summer fish kills, few aquatic plants due to algal shading, rough fish dominant.

Largon Lake
TSI = 63

NITROGEN

Nitrogen is an important part of all natural systems, playing an especially important role for plant and algae growth. It enters lakes and streams through sedimentation, groundwater discharge, surface runoff, and rain.

In Wisconsin, nitrogen does not occur naturally in soil minerals, but is a major component of organic matter. Usually, the amount of nitrogen in lake water is directly related to local land use such as septic systems and animal waste. However, the most common source of nitrogen runoff is fertilizers. Although fertilizers can be highly effective for crop fields and lawns, the excess nitrogen flows off during storm events and can make its way to the lake.

Nitrogen is second only to phosphorus in its ability to promote algae growth (Shaw et al, 1996). Aquatic plants and algae can use all inorganic forms of nitrogen (NH_4^+, NO_2^-, and NO_3^-). If these inorganic forms of nitrogen exceed 0.3 mg/L (as N) in spring, there is sufficient nitrogen to support summer algae blooms (Shaw et al, 1996).

The nitrate and nitrite concentrations ranged from the level of detection of 0.01 mg/L to 0.019 mg/L in the lake water. The average nitrate and nitrite concentration for all of the data collected is 0.015 mg/L.

Total kjeldahl nitrogen (TKN) is a measure of both the ammonia and the organic forms of nitrogen. Excess ammonia contributes to eutrophication of water bodies. This results in prolific algal growths that have deleterious impacts on some aquatic life and recreation.

The TKN concentration in Largon Lake ranged from 0.82 to 1.83 mg/L, with an average of 1.09 mg/L. This amount is above the preferred 0.75 mg/L, and therefore, has more than sufficient nitrogen to support algae blooms in the summer.

DISSOLVED OXYGEN

Dissolved oxygen (DO) readings were also taken on Largon Lake. DO affects the water quality in the lake and is a necessary element for fish. It also keeps phosphorus bound to the sediment in the lake. DO concentrations may change dramatically with depth and season.

Oxygen is naturally added to the water through wind mixing and produced in the top portion of the lake during photosynthesis. Respiration consumes some of this dissolved oxygen. Oxygen consumption is greatest near the bottom where settled organic matter decomposes.

The amount of algae present in the lake can influence the DO concentration. Algae produce oxygen during daylight hours, but use up oxygen during the night in respiration and when they die, sink, and decay.

When the amount of oxygen in the water drops below four parts per million (4 mg/L), some species of fish are stressed or killed.

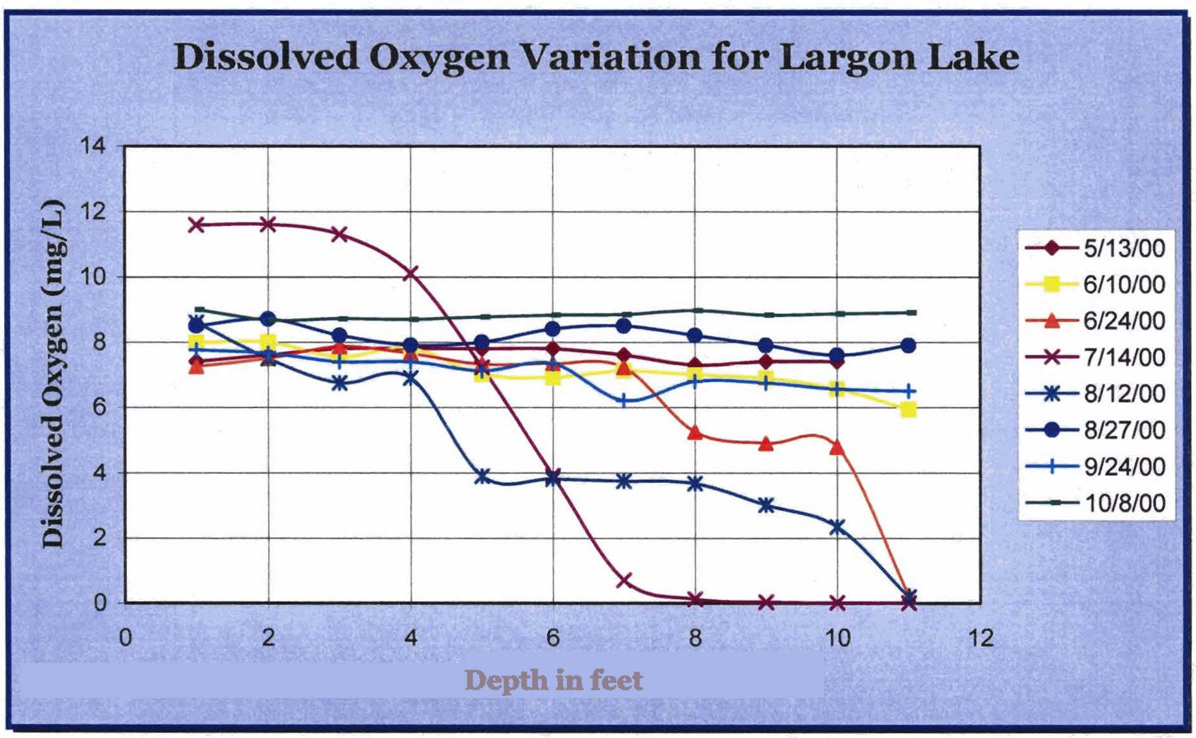


Figure 22: *Graph showing the dissolved oxygen rates for Largon Lake*

Oxygen levels were measured at Largon Lake in 2000 at one foot intervals to the bottom of the lake. This information (Figure 22) illustrates the dramatic change in DO from 1 foot to 10 feet below the surface that occurs from mid June to mid August. While oxygen levels are adequate to support the existing fish, this dramatic change is a critical indicator that the water quality is negatively affected at these times.

As oxygen levels decrease, phosphorus in the sediments become more available for algae blooms in the fall. Phosphorus tends to remain bound to sediment when oxygen levels are high.

ALKALINITY, pH, AND CONDUCTIVITY

Alkalinity

The hardness as $CaCO_3$ ranged from 11 to 12 mg/L with an average concentration of 11.25 mg/L. The alkalinity as mg/L of $CaCO_3$ ranged from 11 to 17 mg/L with an average alkalinity of 15.3 mg/L. Overall, the lake is classified as a soft lake according to Table 2, and has a low sensitivity to acid rain due to its alkalinity (Table 3), which neutralizes the acid rain (Shaw et al., 1996). This is good news considering the threat of air pollution from the twin cities metro area.

Table 2: *Hardness by mg/L of Calcium Carbonate ($CaCO_3$)*

Level of Hardness	Total Hardness as mg/L $CaCO_3$
Soft	0 – 60 mg/L
Moderately Hard	61 – 120 mg/L
Hard	121 – 180 mg/L
Very Hard	> 180 mg/L

*Adapted from Shaw et al., 1996

Table 3: *Sensititvity of Lakes to Acid Rain.*

Sensitivity to Acid Rain	Alkalinity (mg/L $CaCO_3$)
High	0 – 2 mg/L
Moderate	2 – 10 mg/L
Low	10 – 25 mg/L
Not Sensitive	> 25 mg/L

*Adapted from Shaw et al., 1996

pH

The pH is an index of the lake water's acid level and an important component of the carbonate system. A pH of 7 is neutral and water with a pH above 7 is considered to be basic. This means that water with a higher pH will have less hydrogen ions than that of acidic waters. In Wisconsin, pH typically ranges from 4.5 in some acid bog lakes to 8.4 in hard water marl lakes (Shaw et al, 1996).

The pH of Largon Lake in 2000 and 2001 ranged from 6.5 to 7.1, with and average of 6.8. When organic matter at the bottom of the lake breaks down, it consumes oxygen and gives off carbon dioxide, which in the presence of water forms an acid. However, large plant communities will consume carbon dioxide making the water more basic. Water with low alkalinity will have a low pH value (highly acidic) and all of its alkalinity in the bicarbonate (HCO3) form.

A high pH is not necessarily bad because lakes with low pH values have an increase in the movement of metals. In low pH water, aluminum, zinc and mercury concentrations increase if they are present in lake sediment or watershed soils (Shaw et al., 1996). The neutral pH and buffering capacity of Largon Lake insures that toxic metals will not soon be a major factor in lake water quality.

Conductivity

Conductivity or what is sometimes called specific conductance is the measure of the resistance of a solution to electrical flow. This resistance declines with increasing ion content, so the purer the water, the greater its resistance to electrical flow (Wetzel, 2001). The temperature of the solution affects ionic velocities and conductance increases about 2% per °C. According to Wetzel, the international chemical standard reference is 25 °C, which was used in this study.

Because of the local geology, water in Largon Lake generally has relatively low levels of dissolved minerals and a relatively low conductivity. The average for the entire lake is 42 umhos/cm. Urbanization tends to increase conductivity, and increases the presence of dissolved ions potentially from a pollutant source (Interpreting King County Data, 2001).

STREAM WATER QUALITY

Lake volunteers collected water samples from seven stream sample locations in November of 2000 and from April through September in 2001. The sample locations are shown in Figure 24. Samples were analyzed for dissolved reactive phosphorus and total phosphorus. Dissolved reactive phosphorus (DRP) was measured at many of the locations several times during the year, and the averages can be viewed in Figure 23. This form of phosphorus is readily utilized by algae and larger plants, stimulating their growth.

Lake Inflow

The samples collected from the inflows in November of 2000 had dissolved reactive phosphorus concentrations that were greater than any of the samples collected from the

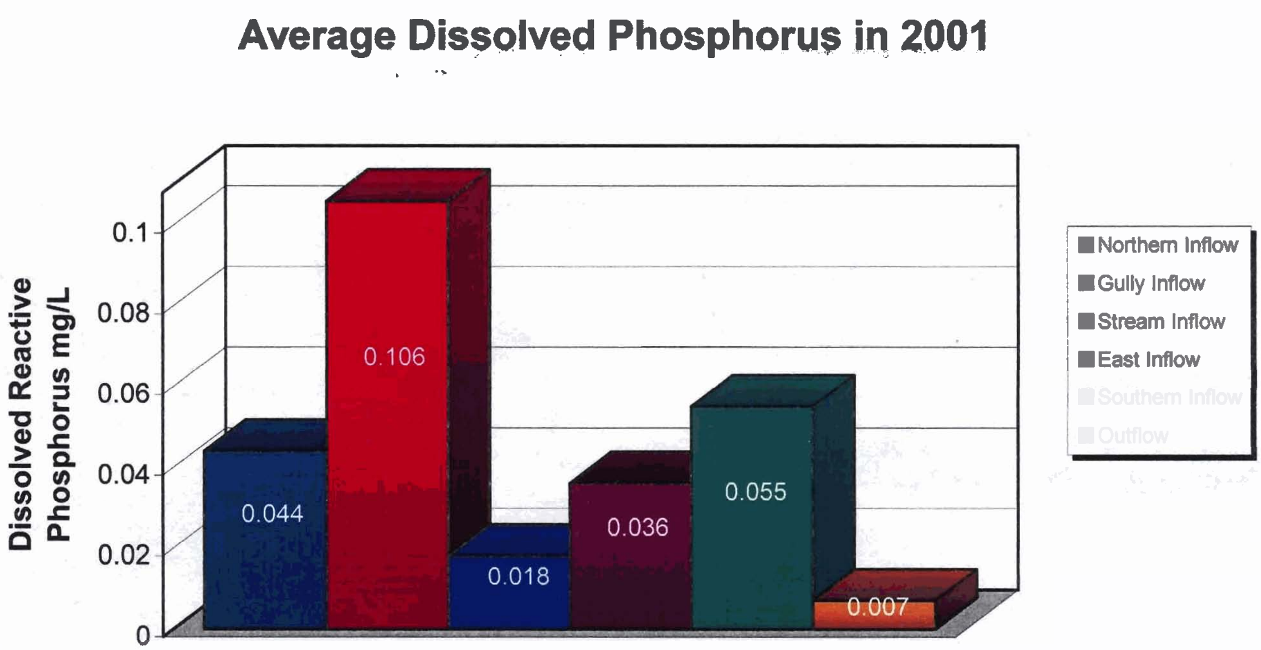


Figure 23: *Average dissolved reactive phosphorus in the inflows and outflow at Largon Lake in 2001*

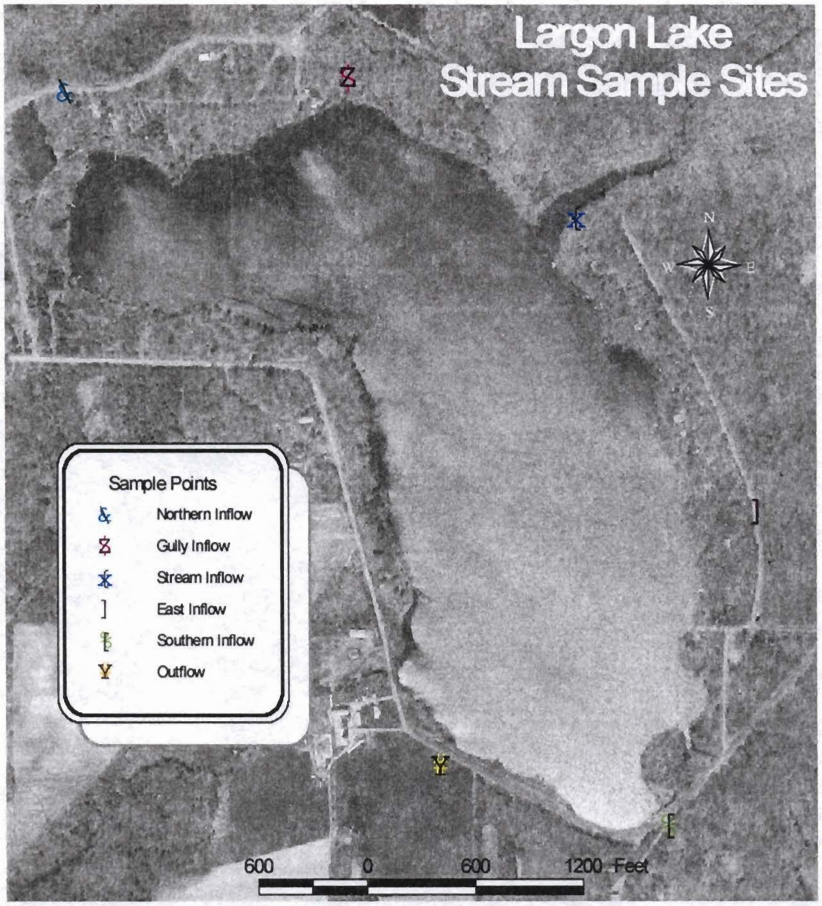


Figure 24: *Stream sample sites at Largon Lake*

streams in 2001. This may reflect the release of phosphorus from decaying vegetation at the end of the growing season and less uptake within the stream. Because there was very little precipitation during the summer of 2000, nutrients may have accumulated for months before being flushed out in November.

Northern Inflow

The northern inflow is located in a low-density residential area and flows into the northwest end of the lake. The northern inflow had the lowest reading of dissolved reactive phosphorus in 2000. This inflow had an average dissolved reactive phosphorus concentration of 0.044 mg/L in 2001.

Gully Inflow

The sampling location that had the highest reading of dissolved reactive phosphorus was the gully inflow. The gully inflow is located on the north, northeast side of the lake with mixed forest and wetlands areas adjacent to the stream channel upstream from the sample site.

In November of 2000, the gully inflow had the second greatest sample concentration of dissolved reactive phosphorus with a reading of 0.279 mg/L. Of the stream samples collected in 2001, the gully inflow had the highest average reactive phosphorus reading of any of the streams. The total phosphorus sample concentration of the gully inflow was more than double any other stream concentration of total phosphorus in April of 2001. Therefore, the gully inflow has significantly greater phosphorus concentrations than any other inflowing stream.

Stream and Eastern Inflow]

The stream inflow and eastern inflow had high levels of dissolved reactive phosphorus at readings of 0.237 mg/L and 0.240 mg/L respectively in November of 2000. The stream inflow receives water from a stream that flows from north in the watershed and a stream flowing from Little Largon Lake.

The stream inflow had the second highest total phosphorus reading at 0.104 mg/L in early April of 2001. However, it also had the lowest average dissolved reactive phosphorus reading of all the inflowing streams sampled in 2001. The water quality at this stream site is expected to be very good considering the lack of adjacent development and the volume of water. The high total phosphorus readings may be attributed to erosion or bank slumpage. Further investigation on the ground is recommended.

The eastern inflow had the second lowest average reactive phosphorus reading in 2001 with a sample concentration of 0.036 mg/L. This inflow also had a total phosphorus reading of 0.083 mg/L, which was the lowest sample concentration of all the streams sampled in April of 2001. The area of the watershed that this stream flows through is primarily forested with some wetland areas, so the water quality of this stream should be very good too.

Southern Inflow

The southern inflow is located on the south end of the lake near a road, and a residential area. This area is mostly forested, with wetland areas and agricultural land adjacent to the forested land along the stream. In November of 2000, the southern inflow had the greatest reading of dissolved reactive phosphorus at a sample concentration of 0.338 mg/L. In 2001, this inflow had the second highest average dissolved reactive phosphorus.

The sample concentrations of total phosphorus in all of the streams are greater than 0.03 mg/l, which is the level that stimulates algae in lakes (Shaw et al. 1996).

Lake Outflow

The concentration of dissolved reactive phosphorus in the outflow from the lake was approximately 0.048 mg/L. The concentrations of phosphorus entering the lake through the five inlets were higher than the outflow concentration. This difference is likely due to the consumption of phosphorus by algae and larger plants and the sediment deposition in the lake. As phosphorus settles to the bottom of the lake, less phosphorus leaves the lake through the outlet where surface water flows over the dam.

Fishing History and Trends

Largon Lake has not always been a quality fishing lake. Prior to the construction of the concrete dam, the lake was subject to partial freeze outs which killed a large portion of the fish population. Today, the fishery in Largon Lake is supported by an aerator and years of stocking. Without the aerator or the dam, the fishery could collapse.

FISHING HISTORY

Historically, Largon Lake suffered partial freeze-outs in the winter, but in the winter of 1974 Largon Lake suffered its worst freeze-out. The following summer lake owners and sport fishermen found the lake over run with bullheads. After vigorous petitioning by the lakeshore owners and an extensive study by the WDNR, the WDNR agreed to poison the lake with Rotenone (1100 gallons) and restock it with the understanding that the lake association would maintain an aeration system that would keep the lake from freezing out again.

The lake was poisoned and restocked by the WDNR with 4000 rainbow trout as a temporary supply for the remainder of the fishing season. Largemouth bass and northern pike fingerlings were stocked the following fall and bluegills the next spring (Appendix A2).

According to the WDNR Research Report 169 in 1995, the northern pike did well after the reclamation; however, an apparent decline in numbers prompted a survey in 1988 (Appendix A3 and A4). The 1988 survey suggested that the decline of northern pike was possibly the result of limited natural reproduction and recommended stocking fingerlings or disease-free transfer fish from other lakes.

Maintenance stocking of northern pike started in 1989 and 1990 when fish researchers transferred "stunted" northern pike into Largon Lake from Island Lake. Northern pike stocking occurred most years in the 1990's (Appendix A7).

Prior to the 2000 fish survey, electrofishing surveys were conducted in 1977, 1979, 1981 and 1988 (Table 1). In addition, fish researchers used fyke nets to estimate the size of the northern pike population in 1992 and in 1998 (Appendix A5). On the evening of September 18, 2000, an electrofishing survey was conducted to update information on the fish population (Appendix A8 and A9).

The following species are **common** in Largon Lake: largemouth bass, northern pike, bluegill, and bullheads. Pictures of these fish, created by Virgil Beck, are shown below in Figures 25-28.

Figure 25: *Largemouth bass*

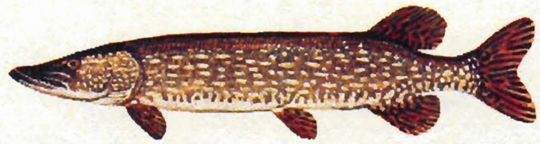


Figure 26: *Northern pike*

Figure 27: *Bluegill*

Figure 28: *Bullhead*

The following species are **present** in Largon Lake: pumpkinseed, black crappie, walleye and yellow perch.

RECOMMENDATIONS BY WDNR

The following conclusions and recommendations have been made by Rick Cornelius, WDNR-Barron:

The largemouth bass population appeared to be in good shape. Panfish populations should improve with decreased predation as the northern pike population declines.

The 1998 fish survey indicated that an abundant northern pike population has developed in Largon Lake. The 2000 fish survey indicated that a moderate largemouth bass population has developed.

The 1998 survey indicated that the average size of panfish has declined (Appendix A6). These facts lead to the conclusion that Largon Lake currently has an unbalanced fish community dominated by a large predator fish population.

There are two basic management options to reduce the northern pike population to a more acceptable level.

Option 1

One option would be to remove the northern pike special regulation (32-inch length limit and 1 bag limit). However, this special regulation has good public acceptance, and in spite of the large northern pike population, growth rates and condition factors of northerns are still good.

Option 2

The second option is to reduce northern pike maintenance stocking, which has occurred almost annually since 1989. Because natural reproduction of northern pike appears to be somewhat limited in Largon Lake, a reduction would be made in northern pike numbers by fish stocking on an alternate year basis at the rate of 2 per acre.

SENSITIVE AREAS

Four sites on Largon Lake have been designated as sensitive areas. These areas offer critical or unique fish and wildlife habitats that provide necessary seasonal or life stage requirements of the associated fisheries. These areas also provide aquatic and shoreline vegetation that offer water quality and erosion control benefits.

The sensitive areas should be retained in a natural and undisturbed state as much as possible. Figure 29 shows the location and relative size of these sensitive areas.

These sensitive areas account for about ¼ of the total lake acreage. In order to ensure a thriving wildlife population, a viable fishery, and good water quality, these areas should be protected from pulling, cutting, herbicides, and pollutants.

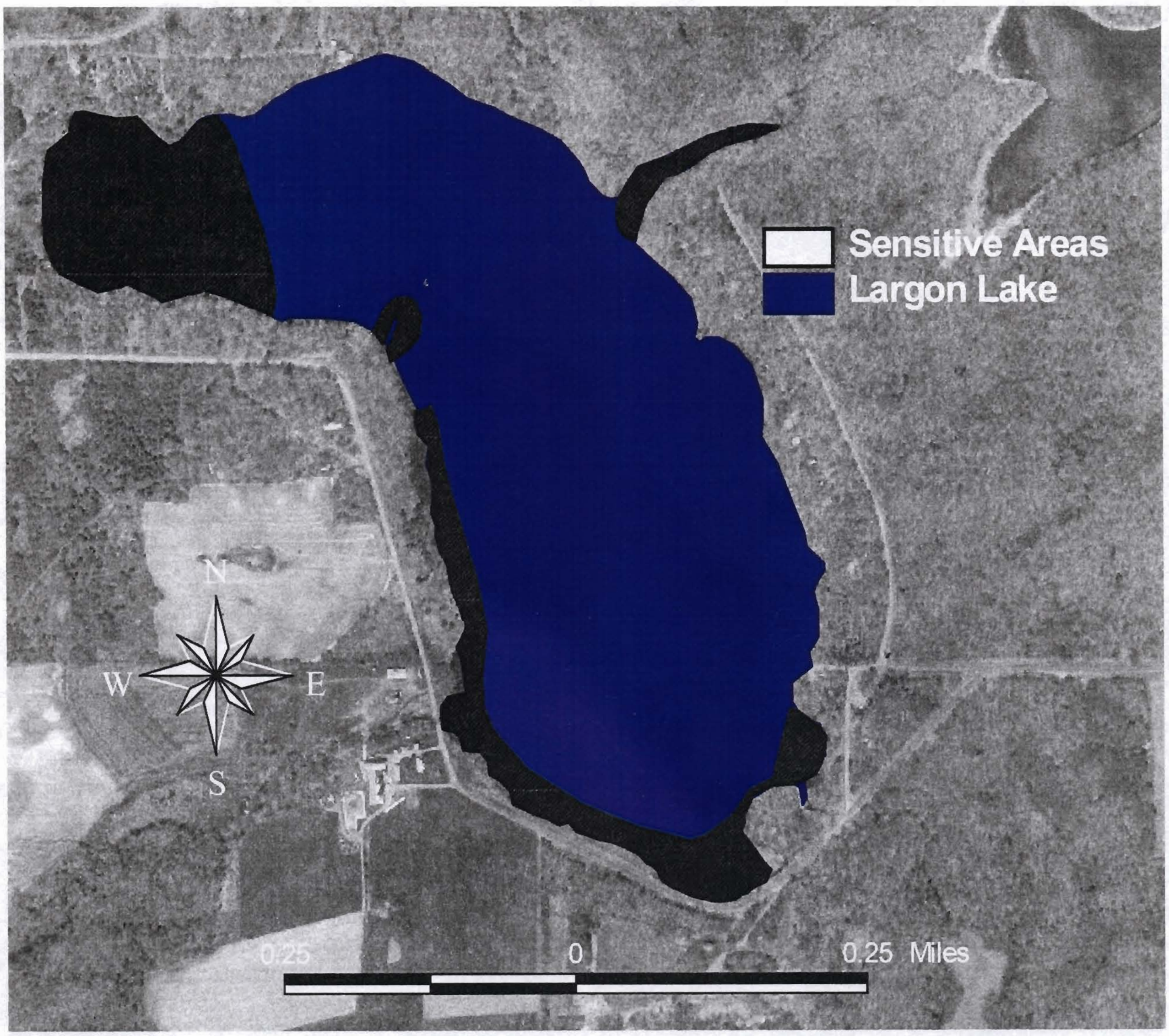


Figure 29: *Map of the Sensitive Areas on Largon Lake*

WILMS Modeling

The Wisconsin Lake Model Spreadsheet (WILMS) Version 2.0 was chosen by the LWRD as a lake-modeling tool for water quality planning. This mathematical lake model was developed by the WDNR. WILMS uses empirical models. These models are developed from statistical research of lake and watershed data. Empirical models use statistical methods to describe the input/output relationship of a system. Since it would be impossible for one lake model to accurately define all types of lakes, WILMS couples 10 models to account for the variables involved (Appendix C).

The empirical lake response models were researched and completed independent of the WILMS model. Each response model was researched independently or semi-independently of the other empirical lake response models used within WILMS. The research for each model was based on data from different lakes and watersheds. The data was used to develop an empirical lake response model.

The 10 empirical lake response models within WILMS use data collected from lakes monitored in North America, Canada, and Northern Europe. The models predict the mean in-lake phosphorus concentrations for two points in time, spring turnover and during the growing season, as well as the annual phosphorus loading. Phosphorus concentrations are an excellent way of interpreting the lake's overall health.

The computer-generated WILMS model was used to describe the phosphorus loading for Largon Lake. This model has helped provide insight into the effectiveness of management actions.

The WILMS model is split into modules, two input modules and seven ouput modules. The data collected from water sampling, the water quality survey, the dredge sampling, landowner surveys, and the watershed land use delineation was needed for the model inputs.

PHOSPHORUS LOADING

To effectively use the WILMS model as a planning tool, it is necessary to determine the amount of phosphorus that will be reduced by implementing recommendations and then re-running the program. Predicted land use changes can also be input into the program. The WILMS model will then provide data on the lake based on the phosphorus reductions and/or changes in land use.

Lake Sampling

Lake samples were taken in 2000 and inflow/outflow samples were taken in 2001. It is desirable for these samples to be taken in the same year for the modeling process to be more accurate. However, it has been assumed that the years are similar and, given that the data is averaged, the inherit error is assumed to be negligible. The lake samples measured mostly total phosphorus whereas the inlet/outlet samples predominately measured dissolved reactive phosphorus. Total phosphorus and dissolved reactive phosphorus do not correlate to each other.

The inflow/outflow sampling data taken in 2001 shows, on average, that the sampled inflow's dissolved reactive phosphorus is 32 times greater than the outflow dissolved reactive phosphorus. As discussed previously in the Water Quality Section, Largon Lake acts as a phosphorus sink, and the highest concentration of phosphorus is found in the center of the lake.

The Origin of Phosphorus

Land Use

The watershed land use is somewhat indicative of the high phosphorus inflow concentrations seen for Largon Lake. The less cover and more impervious surface you have in the watershed, the more sediment rich runoff makes its way into the lake. It is theorized that the soils in the watershed are naturally high in phosphorus, therefore, the sediment and water that reaches the lake is high in phosphorus.

Runoff from Development

On average, four and a half times more phosphorus comes from developed lake lots (21% impervious) than from an undeveloped lakeshore lot (Panuska, 1999). Phosphorus in runoff from the "high ground" in the watershed must also flow across the lakeshore properties to reach the lake. Riparian vegetation not only provides a reduction in phosphorus for the lakshore property in which they are located, but also reduces the phosphorus loading from "back lots". Most of the lake properties on Largon Lake have some riparian vegetation, and most lake lots have less than 21% impervious. However, enhancing the existing buffers is highly recommended, especially where erosion is present. Determining an exact phosphorus reduction for enhancing the riparian vegetation is difficult, and therefore it was not modeled.

Inflows

Many of the intermittent streambeds adjoining Largon Lake are unstable because they are in wooded areas where little under story vegetation grows. As stated before in the Water Quality section, the best method to help alleviate the amount of phosphorus that enters through the inflows would be to thin some trees to encourage under story growth that would stabilize the channel. Also, repairing a private road in the area and armoring the two gullies on the east side of the lake would somewhat reduce the phosphorus inflows.

MODELING LARGON LAKE

20% Phosphorus Reduction

By thinning trees that surround the inflows, repairing a private road, and armoring the two gullies, the inflow phosphorus could be reduced by approximately a fifth (20%). Table 4 represents such a phosphorus reduction. However, one must consider that most of the phosphorus that enters the lake stays in the lake. Therefore, phosphorus reduction strategies may not alleviate algae blooms or nuisance plant growth.

Predicted Land Use Changes

Land use in the Largon Lake watershed is predicted to change within the next 10 to 20 years. Polk County is experiencing increased growth due to its proximity to the Twin Cities. This phenomenon will continue as more people are willing to commute further. The number of tourists and part-time residents will also likely continue to grow with a strong to moderate economy. Largon Lake's location in the northeastern part of Polk County has allowed it to be somewhat protected from some of the major development that is occurring in the southwestern part of the county. However, this will not last indefinitely.

Changing the land use to follow current development trends was done using the WILMS program. An increased development scenario is represented by the following land use totals:

Mixed Agricultural	**128.0 acres**
Pasture/Grass	**191.6 acres**
Medium-Density Urban	**109.0 acres**
Rural Residential	**15.0 acres**
Wetlands	**288.3 acres**
Forest	**1589.8 acres**

Nutrient output from septic systems was changed by changing the total number of capita years to 59.3 to reflect the additional development on the lake. Table 5 shows the lake modeling results with the predicted land use changes.

This scenario is quite likely considering recent development pressure. More development in the watershed would likely result in increased phosphorus loading to the lake. This, in turn, will likely result in increased and more severe algae blooms.

Table 4: *Modeling Largon Lake with a 20% Phosphorus Reduction*

Module	Modeling of Largon Lake 20% Phosphorus Reduction**
Phosphorus Prediction Module	**133 - 327 Kg/Yr**
Uncertainty Analysis Module	**75 mg/m^3 (Predicted growing season phosphorus)**
Parameter Range Module	**51 - 117 mg/m^3 ***
Watershed Load Back Calculation Module	**188 Kg/Yr**

* A 70% confidence interval was used. Therefore, 70% of the time, the observed in-lake phosphorus concentration can be expected to fall within the range shown.

** Reckhow 1977 Anoxic Lake Model

Table 5: *Modeling Largon Lake with Predicted Land Use Changes*

Module	Modeling of Largon Lake Land Use Changes
Phosphorus Prediction Module	**116 - 339 Kg/Yr**
Uncertainty Analysis Module	**74 mg/m^3 (Predicted growing season phosphorus)**
Parameter Range Module	**48 - 119 mg/m^3 ***
Watershed Load Back Calculation Module	**185 Kg/Yr**

* A 70% confidence interval was used. Therefore, 70% of the time the observed in-lake phosphorus concentration can be expected to fall within the range shown.

Management Options

The primary reason this lake study was originally initiated was due to landowners concern over the frequency and severity of algae blooms that occur on Largon Lake. The blue-green algal blooms that occur with an unpleasant odor are actually not an algae, but rather a type of bacteria called cyanobacteria. There is no simple method that will rid the lake of cyanobacteria, although it may be possible to reduce the frequency and severity of the blooms.

Goal A: REDUCE PHOSPHORUS LOADING

Reducing the phosphorus that enters the lake should limit the nutrients that algae and cyanobacteria require for growth.

Figure 30: *Algae bloom*

Action 1: *Re-vegetate inlets/gullies*

Many of the streambeds or channels adjoining Largon Lake are unstable, because they are in wooded areas where little under story vegetation grows. It is unlikely that expensive sedimentation basins will significantly reduce the phosphorus enough to justify their cost. However, small projects could be completed that would reduce the phosphorus inflows into the lake.

There are two gullies on the east side of the lake. One of them was used as a sample site. These two gullies could be armored to stabilize them. The north central inflow was also sampled and showed extremely high phosphorus concentrations. repairing a private road in the area would also help to keep some of the sediment out of the lake.

Thinning some trees at the inlets would encourage under story growth by allowing more light to reach the grasses and shrubs below. The new under-story growth would capture sediments and help to decrease phosphorus input to the lake by stabilizing the channel. These actions could possibly reduce the inflow phosphorus by approximately one fifth.

The cost would be very minimal. Thinning the trees by the inlets and gullies could be completed by the landowner(s) with guidance from a WDNR forester.

Action 2: *Lobby for stronger enforcement of zoning laws*

By restricting the amount of impervious surfaces that are built near the lake and in the watershed, the amount of polluted or nutrient-rich runoff would be reduced. Impervious surfaces are areas that do not allow water to flow through such as asphalt, paved sidewalks, houses, garages, etc.

By attending township and county meetings regarding zoning and development, community members will become more actively involved in the decisions to build in critical areas. This could limit the amount of impervious surfaces and new developments being built in the area. Involvement may also influence the type of development and lead to more watershed friendly zoning. In the future, the decision to become involved with future zoning could leave a positive future impact on Largon Lake.

Goal B:
LIMIT EXISTING PHOSPHORUS

Phosphorus appears to be the limiting nutrient affecting the growth of algae and aquatic plant growth. This nutrient promotes algae growth by provoking complex reactions and creates excessive aquatic plant growth. Therefore, by limiting phosphorus availability, it may be possible to limit the amount of algae development on the lake.

Action 3: *Alum Treatment*

Non-toxic aluminium salts, especially aluminium sulphate (also known as alum), and sodium aluminate often are added to lakes to reduce the amount of phosphorus within the water (Olem and Flock, 1990). Phosphorus reacts with the aluminium salts to form aluminium phosphate over a wide range of environmental conditions, including at low oxygen concentrations, when other compounds have a tendency to release phosphorus.

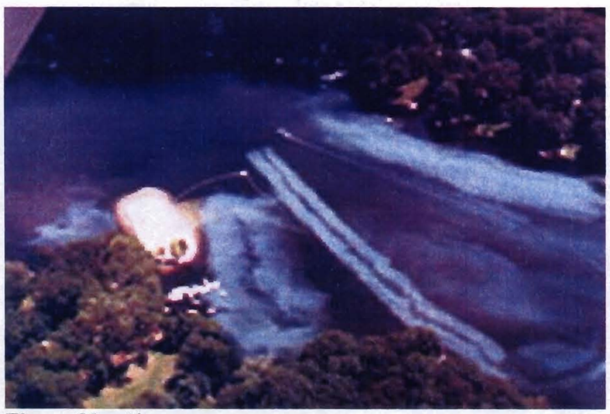


Figure 31: *Alum treatment*

In Figure 31, there is a cloud temporarily formed by treatment of a lake with alum. This settles to the bottom of the lake, binding phosphorus to the alum and cutting back plant growth.

When added to lake water, the aluminium salts form small aggregates of aluminium hydroxide to which phosphorus is adsorbed. The aluminium hydroxide and phosphorus particles precipitate. In some lakes where large quantities of alum have been added, a layer comprised mainly of aluminium hydroxide up to 5cm thick has formed. This layer effectively seals the lake sediments and retards the release of any phosphorus from the sediments, which otherwise may contribute to the phosphorus load in the water column.

The alum is sometimes mixed with lake water via an air diffuser. This delays the settling of aluminum hydroxide precipitate to the lake bottom, which provides a greater opportunity for reaction with phosphorus.

This treatment has been successfully applied in smaller lakes and ponds. However, the long term effects of the treatment are unclear.

Approximate Costs:	**$84.50 per 40 lb pail**
Application Rates:	**1 pail per 1 acre-foot**

Treating Largon Lake with alum would cost approximately $10,900. This product is able to be spread by hand or made into a slurry to be sprayed over the lake surface. The disadvantage of this method is that some of the phosphorus precipitated is not bound permanently in the sediments and thus it could contribute to a later internal loading.

Largon Lake has a short hydraulic retention time and this would work against the alum treatment. This treatment may be too expensive given that the result will likely only be temporary.

Action 4: *Microorganisms*

Bacta-Pur bacteria were developed for use in lakes to get rid of the water of unwanted solid and soluble pollutants. In the presence of oxygen, these bacterial strains will out-compete algae to clear green water.

When added to lakes in sufficient numbers, the bacteria will utilize the available nitrogen and phosphorous, making them less available to support algae blooms. A treatment plan begins before the onset of heavy algae growth and prevents odors and improves water clarity for an entire season. Another use is to extend the effectiveness of an algaecide treatment.

This product is safe for the environment and provides a more natural alternative. It also reduces phosphorus and organic sludges in the lake.

Approximate Cost: **$8.75 per liter**
Application Rate: **1 liter per 2.5 acres per week**

One application per week from Memorial Day through Labor Day, the approximate cost would be $5,915 for Largon Lake.

Action 5: *Circulation System*

A circulation system would draw water from the bottom of the lake and spread it across the top of the lake for continuous surface renewal. The mixing action accelerates the normal purification process in the lake through surface re-aeration (Figure 32).

The system encourages the beneficial diatom and green algae to out-compete the blue-green algae for phosphorus. The lower phosphorus availability prevents the cyanobacteria from becoming a significant nuisance to the lake community.

According to company representatives, the surface renewal also helps to control the algae growth by producing small lapping waves at the surface of the lake. This limits the amount of phosphorus available by continuously mixing the nutrient-rich surface water.

By diffusion, even the water at the bottom of the lake has higher dissolved oxygen and a higher pH. This keeps more phosphorus tied up with iron and calcium at the silt-to-water interface, and enhances digestion of organic substances.

The Solar Bee pond circulator is silent and solar powered, so there are no electrical costs or power wires. The only maintenance that needs to be completed is changing the filters once per year.

There is an option to rent the equipment before you purchase it. Seventy-five percent of the rent that you pay on the equipment will go to the purchase of it in the future. The cost of renting the equipment is:

Approximate Cost: **$860/unit per month**
Application Rate: **1 unit per 2,000 acre-feet**

Largon Lake is approximately 800 acre-feet and would only require one unit. The approximate cost, including the $2,183 installation fee, is $12,503 for one year and $19,383 for five years.

The cost of purchasing the equipment is:

Approximate Cost: **$24,900 per unit**
Application Rate: **1 unit per 2,000 acre-feet**

The total initial cost for purchasing one unit, including the $2,183 installation fee, is $27,083. During additional years of operation, the filters will

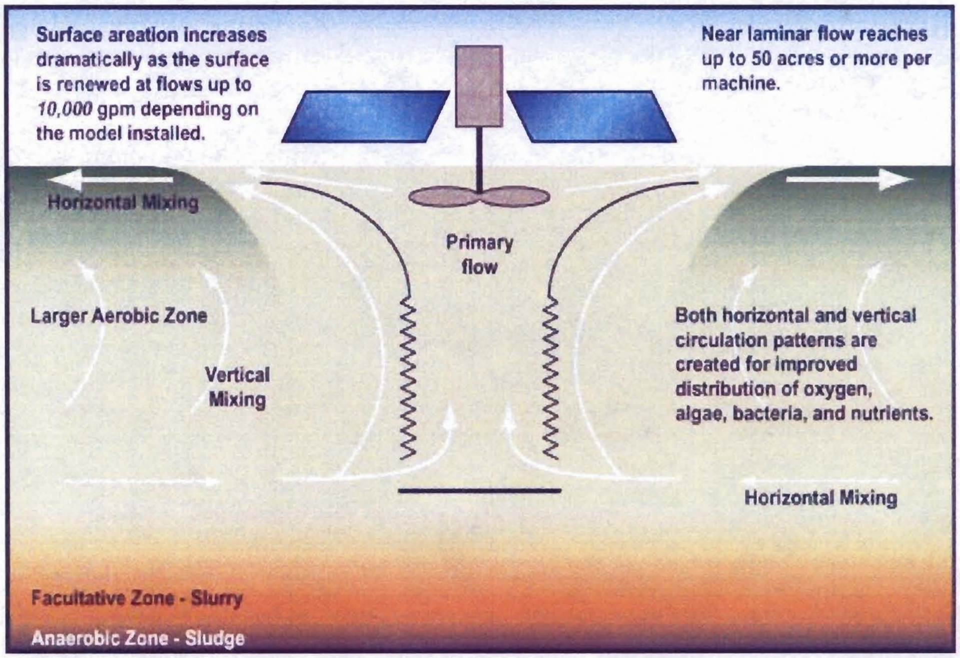


Figure 32: *Solar Bee Circulation System*

need to be changed. The filters are changed once a year in the spring and will cost about $20/year.

The current aeration system on Largon Lake works similar to a circulation system, although it does not produce the lapping waves which mix the surface water. It may be possible to achieve similar benefits by running the aerator year-round.

Goal C:
REDUCE ALGAE GROWTH

There many ways to decrease algae abundance, other than limiting the nutrients that algae need to grow. We can also affect them directly using chemicals or biological control agents. An integrated management plan would be best.

Action 6: *Barley Straw*

How it Works

When barley straw is put into water, it starts to rot and during this process a chemical is released which inhibits the growth of algae. As a rough guide, it may take 6-8 weeks for straw to become active when the water temperatures is below 10°C but only 1-2 weeks when the water is above 20°C. During this

Figure 33: *Barley Straw*

period, algal growth will continue unchecked. Once the straw has started to release the chemical it will remain active until it has almost completely decomposed. Straw is likely to remain active for approximately six months, after which its activity gradually decreases.

The chemical does not appear to have any effect on higher plants (IACR, 1999). In several shallow lakes where straw was used, algae were replaced by higher plants which suppressed the subsequent growth of algae, so eliminating the need for further straw treatments.

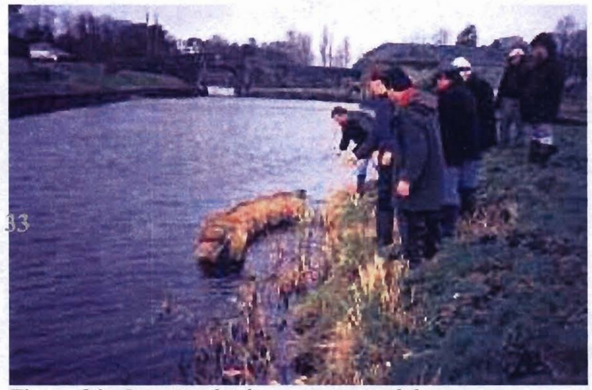


Figure 34: *Inserting barley straw into a lake*

Using Barley Straw

In still waters such as lakes, the minimum quantity of straw needed to control algae is about 10g straw per m^2 of water surface (IACR, 1999). However, when a water body with a history of severe algal problems is first treated, a higher dose is preferable (25 g per m^2) and quantities up to 100 g per m^2 have been used. Once the algal problem has been controlled, and further additions of straw are being made to prevent a recurrence of the problem, the dose can be reduced.

Bales should not normally be used as they are too tightly packed and do not allow adequate water movement through the straw. It is preferable to apply the straw in a loose form retained in some form of netting or cage. One of the simpler ways of wrapping large quantities of loose straw is to use one of the various forms of tubular netting normally sold for wrapping Christmas trees, constructing onion sacks and for other agricultural purposes.

In order to ensure that there are no areas within the water body unaffected by the straw, it is necessary to calculate how much straw is needed, how many nets should be employed and how far apart each net should be. Nets or sausages of straw should then be placed so that each net is roughly equidistant from its neighbors and from the bank.

There are two methods for using the barley straw: treat the entire lake or treat the inlets only. Treating the entire lake in spring before the algae becomes abundant would show the most immediate effects. The steps involved in the calculation for the amount of barley straw to be used are listed in Appendix B.

Approximate Cost:	**$35 per bale**
Application Rate:	**656 bales (about 2 bales / acre)**

The cost for treating the entire lake would be $22,960.

Treating only the inlets would reduce the amount of algae from developing at the three locations that have the highest amounts of phosphorus flowing into the lake. The cost for treating the Northern, Gully, and Southern Inflow would be significantly less than treating the entire lake.

Approximate Cost:	**$35 per bale**
Application Rate:	**60 bales**

The cost for treating the area surrounding the inlets would be $2,100.

A disadvantage to using barley straw is that it is very labor intensive. Also, preliminary discussions with people who are familiar with the barley straw method think that Largon Lake may be too large to reap the same benefits as a smaller pond might.

Action 7: Chemical Treatments

Large blooms of algae can be difficult to handle. If the situation is severe, there are a number of chemical options available for treating the surface water. However, no chemical treatment is completely effective for long term control. Cyanobacteria (blue-green algae) can build up tolerance to repeated chemical applications. It is recommended that chemical application should only be used as a last resort, not as routine maintenance (Scott, 2002).

Copper Sulphate

Copper sulphate, also known as bluestone, kills cyanobacteria (blue-green algae). This treatment, however, is only marginally effective on the typical green and filamentous algae. This treatment should be applied at the first signs of a cyanobacteria algal bloom. Following the treatment, the dead cells settle to the bottom of the lake.

Approximate Cost:	**$10 - $15 per 5 lbs.**
Application Rates:	**0.8 lbs – 1.75 lbs / acre-foot**

The total cost range for Largon Lake would be $1,032 to $3,386 per year, depending on the frequency and severity of algae blooms during the year of treatment. This would not permanently remove the algae, but temporarily control the density of algae blooms in the lake.

Chelated Copper

Chelated copper, also known as K-Tea and Cutrine, is elemental copper from copper triethanolamine. Most planktonic algae can be controlled with chelated copper. Control is best achieved when the algaecide is applied in water temperatures of at least 65° at the first signs of an algal bloom.

Approximate Cost:	**$26.50 per gallon**
Application Rates:	**1 – 2 gallons per acre-foot**

The total cost range for Largon Lake would be $3,180 to $6,837. Even distribution of the algaecide over the lake is desired. This may be accomplished by applying as a spray solution with water or by simply pouring the mixture throughout the lake using a boat. No more than 1/3 of the lake should be treated at any one time, allowing a 7 day interval between applications.

Risks associated with using copper-based algicides include:

- The mass release of toxins from the algal cells may harm wildlife, pets, and humans
- the accumulation of copper in the sediments may have effects for years to come
- the growth of species of blue-green algae that are resistant to the algicide may cause greater water quality problems
- copper based products may kill other aquatic flora and fauna. It also causes the death of fish through reducing the concentration of oxygen in the water when the algae die.

Action 8: *Biomanipulation*

Biomanipulation includes lake improvement procedures that alter the food web to favor grazing on algae by zooplankton that eliminate fish species that recycle nutrients.

Lake biomanipulation theory is based on the prediction that increased piscivore (predator fish) abundance will result in decreased planktivore (small fish) abundance, increased zooplankton abundance, and increased zooplankton grazing pressure leading to reductions in phytoplankton (algae) abundance and improved water clarity (Benndorf & Miersch 1991).

Biomanipulation is relatively new to the lake management community. This approach is becoming increasingly popular due its low cost, and the absence of machinery and toxic chemicals (in some cases), and to its effectiveness.

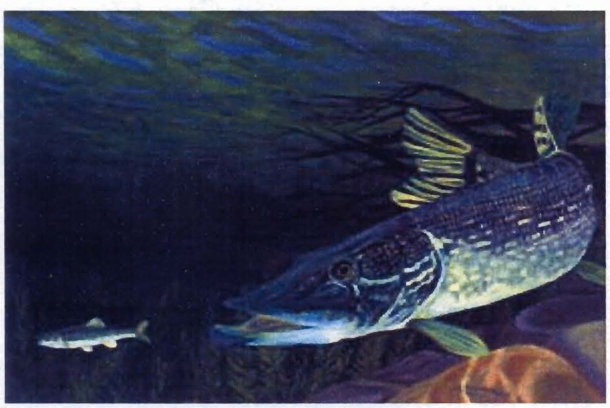


Figure 35: *Pike feeding on planktivorous minnow*

Biomanipulation involves eliminating certain fish species or restructuring the fish community to favor the dominance of piscivorous fish instead of planktivorous fish (DeMelo et al 1992).

The cost for biomanipulation would be minimal. To advance this control method, new fishing regulations would be implemented that would change the amount of northern pike that are removed from the lake.

Goal D:
REMOVING SEDIMENT

Action 9: *Hypolimnetic Withdrawal*

Phosphorus recycling rates could dramatically decline if phosphorus is removed from the lake using bottom water (hypolimnetic) withdrawal (FDLSK, 2002). This is a technique that has a proven track record of success in other lakes (Nournberg 1987). Hypolimnetic withdrawal may increase water clarity by restricting the growth of algae.

Flushing the water out of the lake would not be as efficient as hypolimnetic withdrawal, because much of the phosphorus in the lake is released from the sediments in the bottom throughout the summer. By withdrawing the water from the bottom of the lake, nutrient-rich bottom waters are removed.

The pipe system to remove the water would be installed in the spring. The withdrawal process would take place for three years in a row, with consistent testing after each to ensure progress. The system would remain installed for future use as needed.

This technique is more expensive than the other alternatives. A siphon withdrawal system would need to be purchased, as well as subcontracting an engineer to complete the pipe system design. No accurate costs for hypolimnetic withdrawal for Largon Lake are currently available, but this technique has cost between $80,000 to $150,000 for similar lakes.

Table 6: *Management Options Overview*

#	Action	Approx. Cost	Timeline	Advantages	Drawbacks
1	Re-vegetate inlets/gullies and continue testing	minimal	Thin trees around inlets and gullies first year, annual monitoring	Reduces the amount of nutrients and sediments entering the lake	Finding volunteers to thin trees. Not likely to have an immediate impact on water quality
2	Lobby for stronger enforcement of zoning laws	minimal	Continuous support at township and county meetings regarding shoreland zoning and backlot development	Community members become more involved in the watershed. Less impervious surface is developed.	No immediate effects, and is supported only if the community participates.
3	Alum Treatment	$10,140 per year	Single treatment occurs during first year in summer, possible treatment in years following	Lowers lake phosphorus content. Inhibits release of phosphorous from sediment. Increases water column transparency immediately.	Likely a temporary measure. Potential toxic impacts during application. Increased aquatic plant growth due to water clarity.
4	Microorganisms	$5,915 per year	One application per week during summer	Non-toxic, "natural" alternative to chemical treatments	Frequency of application that is required
5	Circulation System	$27,083 to purchase,$12,503 per year to rent	Intall equipment first year, replace filters every year afterwards	Minimal maintenance, quiet. Lowers available phosphorus for blue-green algae. Increases oxygen.	Expensive to purchase equipment as opposed to renting. May be nuisance to boaters and affect aesthetics.
6	Barley Straw	$2,100 to $22,960 per year	One application every 6 months as needed	Only one application required per season. Prevents algae growth, instead of only treating blooms.	High costs if treated on the entire lake. Difficult to remove. May not be practical.
7	Chemical Treatments	$1,032 to $6,837 per year	Applied once a year at the first sign of algae blooms	Controls the density of the algae blooms, only needs to be applied at first signs of blooms.	Temporary measure. Would not permanantly remove the algae. Difficult to time the application. Possible long-term toxic build-up in sediments.
8	Biomanipulaton	mimimal	Change fishing limits for northern pike to be adjusted as needed every year	Encourages growth of zooplankton, which eat algae.	Considered experimental. Not as effective where blue-green algae dominate.
9	Hypolimnetic Withdrawal	$95,000 to $160,000 for installation and first 3 years	Withdrawal bottom water each year, amount depending on severity	Removes nutrient rich bottom water, improves clarity, limits in-lake phosphorus cycling	High costs. Low water level after first year of removal. May warm water to a point that harms the ecosystem.

APPENDIX A

Fishing History Data

Appendix A1:

Electrofishing Catch Per Effort

Number/Hour		
Date	Largemouth Bass	Northern Pike
Oct-77	<1/hr	15/hr
May-79	1/hr	12/hr
May-81	2/hr	21/hr
Sep-88	64/hr	3/hr

Appendix A2:

Fish Stocking Since 1977

Year	Species	Number	Size
1977	Northern Pike	352,800	Fry
	Largemouth Bass	9,850	3"
	Rainbow Trout	4,000	9"
1978	Northern Pike	130,200	Fry
	Largemouth Bass	5,000	1"
	Bluegill	600	5"
1979	Largemouth Bass	3,000	Fry
1988	Largemouth Bass	12,500	1"

Appendix A3:

Age-Length Relationships of Game fish and Pan fish, 1981 & 1988

Age	Number	Average	NWD Average	Range
LARGEMOUTH BASS				
2	6	6.9	6.1	6.0-8.3
3	6	9.7	8.4	9.0-10.0
4	10	11.8	10.7	10.5-13.0
5	27	13.4	12.8	12.4-14.2
6	5	14.5	14.5	14.0-14.8
7	3	15.9	16.1	15.6-16.3
9	1	18	18.8	---
10	2	19.2	---	18.9-19.5
NORTHERN PIKE				
2	2	12.5	13.3	12.0-13.0
3	6	18.5	16.8	16.0-20.0
4	16	20.3	19.6	17.0-24.0
5	2	23.8	21.6	22.5-25.0
BLUEGILL				
1	1	2.5	1.9	---
2	6	3.2	3.3	3.0-3.5
3	13	4.3	4.4	3.5-5.4
4	17	5.5	5.3	5.1-6.6
5	13	6.4	6.1	6.0-7.0
6	12	7	6.8	6.7-7.5
7	1	8	7.5	---
9	1	10	8.1	---
PUMPKINSEED				
2	1	4	2.9	---
3	3	5.3	4.3	5.0-5.7
4	4	5.9	5.2	5.7-6.0
YELLOW PERCH				
1	2	4.5	3.1	4.5
4	1	8	6.9	---

Largemouth bass collected on 9/20/88, other species collected on 5/14/81.

Appendix A4:

Game Fish Length and Frequency, 9/20/88

Size Range (Inches)	Species		Size Range (Inches)	Species	
	Largemouth Bass	Northern Pike		Largemouth Bass	Northern Pike
<5.9			18.5-18.9	1	
6.0-6.4	2		19.0-19.4		
6.5-6.9			19.5-19.9	1	
7.0-7.4	3		20.0-20.4		
7.5-7.9			20.5-20.9	1	
8.0-8.4			21.0-21.4		
8.5-8.9	1		21.5-21.9		
9.0-9.4	1		22.0-22.4		
9.5-9.9	3		22.5-22.9		
10.0-10.4	2		23.0-23.4		
10.5-10.9	2		23.5-23.9		
11.0-11.4	2		24.0-24.4		
11.5-11.9	1		24.5-24.9		
12.0-12.4	3		25.0-25.4		1
12.5-12.9	8		25.5-25.9		1
13.0-13.4	8		26.0-26.4		
13.5-13.9	10		26.5-26.9		
14.0-14.4	7		27.0-27.4		
14.5-14.9	3		27.5-27.9		
15.0-15.4	1		28.0-28.4		
15.5-15.9	2		28.5-28.9		
16.0-16.4	1		29.0-29.4		1
16.5-16.9			29.5-29.9		
17.0-17.4			>30.0		
17.5-17.9					
18.0-18.4	1		**Total**	64	3

Effort: 1.4 hours, 2 miles, AC Shocker

Appendix A5:

Largon Lake Northern Pike, 1998

Length	Sexes Combined	Males	Females
9.9	0	0	0
10.9	0	0	0
11.9	0	0	0
12.9	8	8	0
13.9	16	14	2
14.9	28	24	4
15.9	32	29	3
16.9	34	24	10
17.9	56	47	9
18.9	71	63	8
19.9	63	53	10
20.9	67	50	17
21.9	48	33	15
22.9	45	26	19
23.9	33	9	24
24.9	16	2	14
25.9	16	0	16
26.9	22	0	22
27.9	19	1	18
28.9	16	0	16
29.9	2	0	2
30.9	7	1	6
31.9	7	1	6
32.9	2	0	2
33.9	2	0	2
34.9	2	0	2
35.9	0	0	0
36.9	1	0	1
37.9	0	0	1
38.9	0	0	0
39.9	0	0	0
40.9	0	0	0
Total	614	385	229

Appendix A6:

Gill Net Catch of Forage Fishes in Largon Lake, Polk County

** number/450ft/8 hours, 1990 to 1998

Inch Group	Yellow Perch		Centrarchids		Cyprinids	
	1990	1998	1990	1998	1990	1998
2	0	0	0	4.1	0	0
3	0	25.5	0	21.3	0	0
4	0	37.9	3.5	116.1	0	14.8
5	2.2	4.7	6.2	1.8	1.8	42.7
6	71.8	14.8	11.4	5.9	29.5	33.2
7	35.7	8.9	33.9	0	23.8	16.6
8	1.3	1.2	1.3	1.2	0.9	1.8

➔Centrarchids includes black crappie and bluegill.
➔Cyprinids include golden shiner.

Appendix A7:

Recent Northern Pike Stocking

Year	Number	Size
1989	124	10"-18" from Island Lake
1990	320	10"-18" from Island Lake
1991	170	14"
1992	650	4"-8"
1994	645	6"
1996	273	2"-3"
1997	372	5"
1998	645	4"-5"
2000	645	3"-4"

Appendix A8:

Age-Length Relationships of Game Fish and Pan Fish, 2000

Age	Number	Average Length	Range in Length	*NW WI Average*
LARGEMOUTH BASS				
2	3	6.2	5.6-6.6	6.3
3	2	8.9	8.7-9.0	8.8
4	14	11.2	9.0-11.8	11.2
5	2	13.3	12.5-14.0	13
6	2	13.5	13.2-13.8	15
7	4	15	14.3-15.5	16.2
8	3	14.7	14.2-15.2	17.5
9	3	17.8	16.8-18.3	18.5
NORTHERN PIKE				
5	5	21.8	18.7-24.0	21.7
6	3	26.2	24.5-28.2	24.3
BLUEGILLS				
3	5	4.5	3.9-5.0	4.5
4	5	5.1	4.1-5.9	5.4
5	8	7.2	5.3-7.6	6.2
6	9	7.1	6.2-8.1	6.8

Appendix A9:

Fishing Results, 2000

Fishing Results			
Species	Number	Size Range	Catch/Unit
Largemouth Bass	36	5.5-18.4	41/hour
Northern Pike	9	18.5-28.4	10/hour
Bluegill	171	3.0-8.1	329/hour
Yellow Perch	1	6.8	2/hour
Black Crappie	10	3.0-8.7	19/hour
Pumpkinseed	1	4.8	2/hour

Boomshocker: 0.88 hours (gamefish) and 0.52 hours (panfish).

APPENDIX B

Barley Straw Calculations for Inlets

Decision Step	Calculation
#1 Estimate the surface area requiring treatment	**24,000 m^2**
#2 Decide on the dose rate of straw required	**50 g/m^2**
#3 Multiply #1 by #2 to obtain the total weight of straw required	24,000 m^2 x 50 g/m^2 = **1,200,000 g**
#4 Convert the total weight from grams to kilograms	600,000 / 1000 = **1,200 kg**
#5 To obtain the number of bales to be purchased, divide #3 by the weight of bales (about 20 kg)	1,200 kg / 20 kg = **60 bales**
#6 Decide on the weight of straw to be placed in each net. Nets should normally contain between 1kg (in small lakes) to 40kg (in very large lakes).	**25 kg**
#7 Calculate the number of nets which will have to be constructed. Divide the total quantity of straw required (#4) by the weight in each net (#6).	1,200 / 25 = **48 nets**
#8 Calculate the area of water which will be treated by each net at the dose rate decided in 2 (above).	25kg / 50(g/m^2) = **500 m^2**
#9 Calculate the radius of a circle with an area of the size calculated in 6 (above) using r^2.	$r^2 = 500$ r = 500 **r = 22.4 m**
#10 The diameter of a circle of 1,000 m^2 is r x 2.	diameter = **44.8 m**
#11 Decide on the most appropriate placement of the nets of straw in the lake so that each one is approximately 35m from its neighbour and 17m from the bank.	**Regular square grid pattern with centres at 45 m**

Barley Straw Calculations for the Entire Lake

Decision Step	Calculation
#1 Estimate the surface area requiring treatment	**525,000 m^2**
#2 Decide on the dose rate of straw required	**25 g/m^2**
#3 Multiply #1 by #2 to obtain the total weight of straw required	525,000 m^2 x 25 g/m^2 = **13,125,000 g**
#4 Convert the total weight from grams to kilograms	13,125,000 / 1000 = **13,125 kg**
#5 To obtain the number of bales to be purchased, divide #3 by the weight of bales (about 20 kg)	13,125 kg / 20 kg = **656 bales**
#6 Decide on the weight of straw to be placed in each net. Nets should normally contain between 1kg (in small lakes) to 40kg (in very large lakes).	**25 kg**
#7 Calculate the number of nets which will have to be constructed. Divide the total quantity of straw required (#4) by the weight in each net (#6).	13,125 / 25 = **525 nets**
#8 Calculate the area of water which will be treated by each net at the dose rate decided in 2 (above).	25kg / 25(g/m^2) = **1,000 m^2**
#9 Calculate the radius of a circle with an area of the size calculated in 6 (above) using r^2.	r^2 = 1,000 r = $\sqrt{1000}$ **r = 31.6 m**
#10 The diameter of a circle of 1,000 m^2 is r x 2.	diameter = **63.2 m**
#11 Decide on the most appropriate placement of the nets of straw in the lake so that each one is approximately 35m from its neighbour and 17m from the bank.	**Regular square grid pattern with centres at 65 m**

APPENDIX C

Choosing an Empirical Model

Phosphorus Prediction Module

Using the Phosphorus Prediction Module data, WILMS first predicts the total phosphorus loading using each of the 10 empirical models. The empirical models predict either a spring turnover mean phosphorus concentration or a growing season mean phosphorus concentration. The observed spring or growing season mean total phosphorus concentrations are then compared to the predicted concentrations.

Uncertainty Analysis Module

The Uncertainty Analysis Module helps the user decide on which empirical model best describes the lake in question. It also gives a range of predicted phosphorus loadings for a user specified confidence interval. The confidence interval means that at a user specified percent of time the average in-lake phosphorus concentration can be expected to be within the range shown in the model. A seventy percent confidence interval was chosen, to facilitate in determining a representative WILMS model for Largon Lake.

Parameter Range Module

The parameter range module determines whether the lake's input data parameters fall within each of the empirical models' specific ranges. If the input data satisfies this, then the parameter or variable range for the empirical model of the program displays <FIT>. If it does not, then <NO FIT> is displayed. Also, the number of lakes used to develop each of the models is shown. Largon Lake does not fit two of the ten empirical models, and one of the models will not calculate and displayed N?A.

Watershed Load Back Calculation Module

The Watershed Load Back Calculation Module uses the lake's spring and/or growing season mean in-lake phosphorus concentrations to back calculate an annual phosphorus load in Kg/Yr. The back calculation is done for each of the empirical models. Using the spring and growing season mean in-lake phosphorus the back calculation was completed. One of the models would not calculate and returned an N/A.

Using Module Data to Choose an Empirical Model

Using the data in the previous modules, an empirical model that best represents Largon Lake must be chosen. The two most important things considered when making this determination, was that the empirical model matched the Largon Lake data, and the model that matched used similar lakes to Largon Lake in its development. Using these criterions, two models were found to fit. It is desirable to choose a single model to facilitate in the planning portion of the model. However, both models are consistent with the Largon Lake data. The models that fit are the Canfield-Bachmann, 1981 Artificial Lake Model and the Reckhow, 1977 Anoxic Lake Model. See Table 1 for comparisons between Largon Lake and the Reckhow Model.

Table 1: *Comparisons between Largon Lake, Canfield-Bachmann and the Reckhow Model*

Module	Largon Lake	Canfield-Bachmann Model	Reckhow Model
Phosphorus Prediction Module	41 mg/m3* (SPO)	47 mg/m3 (SPO)	92 mg/m3 (GSM)
	81 mg/m3* (GSM)		
Uncertainty Analysis Module	41 mg/m3* (SPO)	15 - 136 mg/m3***	63 - 143 mg/m3**
	81 mg/m3* (GSM)		
Parameter Range Module		<FIT>****	<FIT>****
Watershed Load Back Calculation Module	165 - 395 Kg/Yr	150 Kg/Yr	203 Kg/Yr

* Obtained from sampling data

** A 70% confidence interval was used. Therefore, 70% of the time, the observed in-lake phosphorus concentration can be expected to fall within the range shown.

*** Canfield-Bachmann Model is predicting a single estimate. 95% of the time, the observed in-lake phosphorus concentration can be expected to fall within the range shown.

**** The key parameters of the model fit Largon Lake.

SPO = Spring Overturn P Concentration
GSM = Growing Season P Concentration

Empirical Models

Canfield-Bachmann Models

The Canfield-Bachmann models are different from the other models used in WILMS. They predict a single point estimate of the in-lake phosphorus as opposed to a mean. Predicting a mean is more certain, so the confidence interval for the Canfield-Bachmann models is set at 95%. When using the Canfield-Bachmann models there is greater uncertainty. The comparisons made between the three models from the table are not completely accurate; the model predicts a single point estimate, which is compared to a mean.

The Canfield-Bachmann model was developed using a highly diversified data set of lakes. The Canfield-Bachmann 1981 Artificial Lake Model is based on a data set from the EPA-National Eutrophication Survey, which included 33 lakes. In most cases, a model based on an exceptionally diversified data set can show more biases, unless the lake being modeled is rather "general".

Reckhow Model

Four Reckhow models are used in WILMS. Three models are based on a lake classification system. Lakes were classified into three groups. Two of the models are based on oxic (oxyen) lakes' data and one was based on anoxic (without oxygen) lakes' data. The EPS-National Eutrophication Survey and the Reckhow 1977 Anoxic Lake Model classifies anoxic lakes as those with at least one measurement of zero dissolved oxygen during summer stratification. Monitoring data that was collected for 2000, shows the dissolved oxygen was at or close to zero from June 24, 2000 through August 27, 2000. This is consistent with the anoxic classification; therefore, Largon Lake fits that part of the Reckhow anoxic model.

The statistics for the data sets used to develop the model can be found in Engineering Approaches for Lake Management. Since the models are empirical, it is necessary for the modeled lake's variables to be within the boundaries, between the minimum and maximum of the variables used to develop the model. Beyond the constraints of the minimum and maximum, the empirical model may no longer apply. The constraints exist because there is no evidence or research to support that the model is an effective tool and accurate outside the minimums and maximums. Each variable for Largon Lake was within the data set for the Reckhow, 1977 Anoxic Lake Model. Therefore, the model fits Largon Lake. The model also has no significant biases, which is important when using the model as a planning/prediction tool.

The Reckhow 1977 Anoxic Lake Model was based on 21 north temperate lakes. Given the information regarding each model, the Reckhow Model was selected as the planning/prediction tool for Largon Lake.

Additional Modules

Three modules remain to be used in the WILMS model. They provide information about the lake independent of the 10 empirical models.

Lake Condition Module

In WILMS, the module following the Watershed Load Back Calculation Module is the Lake Condition Module. This module has the user input, the average in-lake spring turnover phosphorus, and the average growing season chlorophyll. Using these inputs, the module uses a regression equation to predict secchi depths for mixed and stratified, natural and impoundment lakes. The modeled secchi depth for the mixed impoundment was 0.69 meters, and 1.05 meters for the stratified impoundment. The average secchi depth from the sampling data was 0.8 meters. The Lake Condition Module also determines the Trophic State Indicies (TSI) for total phosphorus (TSI = 62), chlorophyll (TSI = 64), and secchi disc depth (TSI = 63). Based on the Carlson TSI, the lake is eutrophic, which is indicated by the TSI being greater than 50. This is consistent with the sampling data.

Steady State Response Time Module

The Steady State Response Time Module estimates the amount of time it takes for 95% of the steady-state phosphorus concentration to occur. Steady state is the point where the system comes to equilibrium. It theoretically takes an infinite amount of time to reach steady state; therefore, 95% of steady state is used. It should be noted that a lake environment is very dynamic and always in a state of flux. The steady state response time should be used as a planning tool to determine the time it would take to see a change in the lake after something in the system has changed. Keep in mind that before the steady state is reached other things will change in the system, causing the system to try to come to a new steady state. The estimated steady state response time for Largon Lake is 0.8 years approximately.

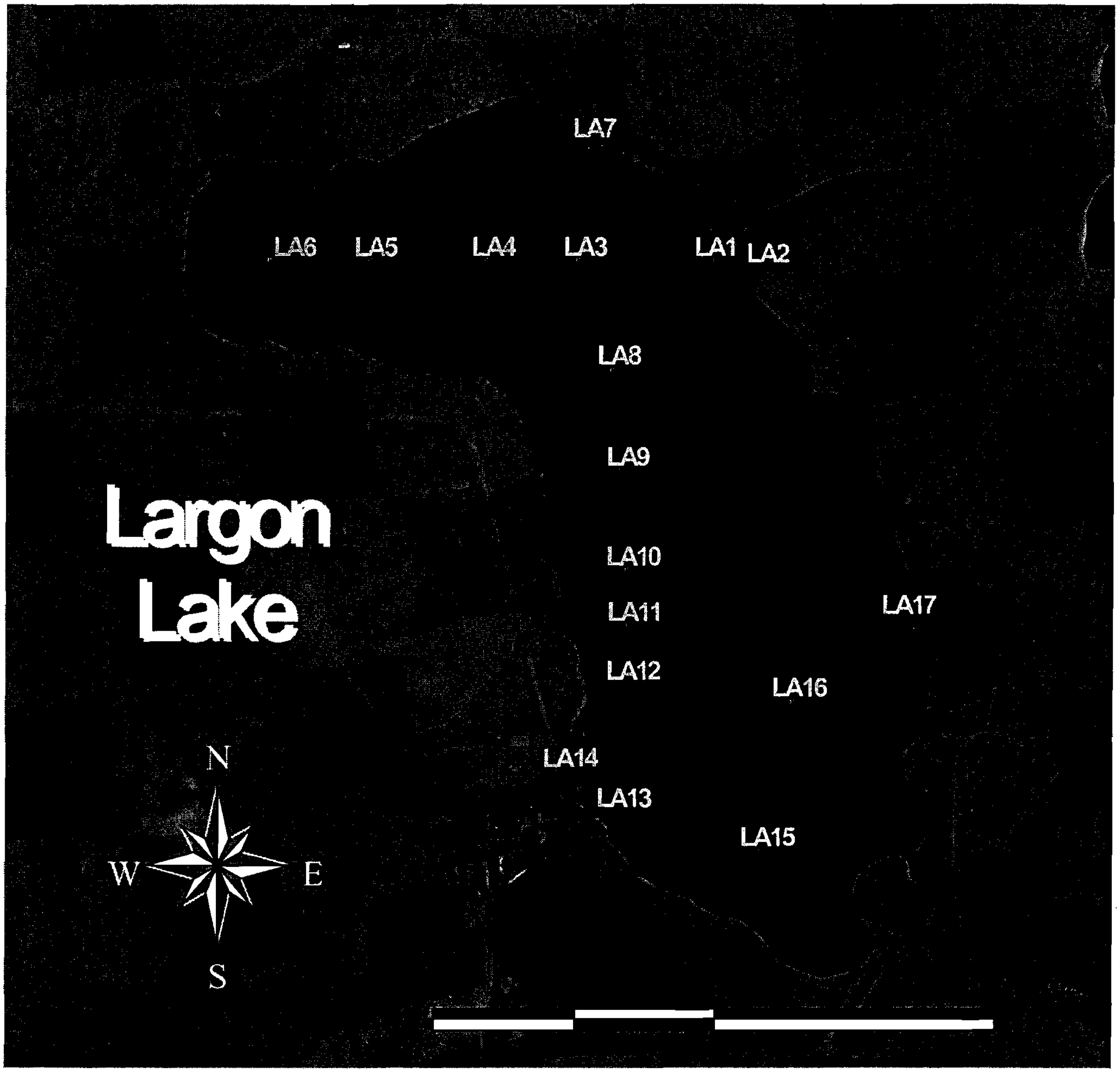
Water and Nutrient Outflow Module

The Water Nutrient Outflow Module was not used. The module's intended use is for modeling multiple lakes connected in series. The annual outflow loading is calculated as 96% of the average annual in-lake phosphorus flows out the outflow. Based on the sampling data, this module would not provide accurate outflow data.

APPENDIX D

Largon Lake Dredge
9/12/00

Test			pH (S.U.)	% Solids	Total Kjeldahl Nitrogen (mg/Kg)	Total Phosphorus (mg/Kg)
		Date Analyzed	*Jan. 2*	*Oct. 3*	*Dec. 22*	*Dec. 22*
ID	Latitude	Longitude				
LA 1	45°37'01 N	092°11'43 W	6.31	33.6	3677	392
LA 2	45°37'01 N	092°11'44 W	5.9	56.5	1532	368
LA 3	45°37'00 N	092°11'47 W	5.86	8.6	34368	148
LA 4	45°37'00 N	092°11'51 W	5.77	6.4	56596	154
LA 5	45°37'01 N	092°11'58 W	5.9	5.7	67077	221
LA 6	45°37'01 N	092°12'11 W	5.99	5.9	66841	138
LA 7	45°37'03 N	092°11'55 W	5.82	6	70728	189
LA 8	45°36'59 N	092°11'51 W	5.55	5.1	19830	274
LA 9	45°36'53 N	092°11'50 W	5.75	6.2	17439	432
LA 10	45°36'47 N	092°11'49 W	5.83	4.5	11270	184
LA 11	45°36'43 N	092°11'51 W	5.79	6.9	10080	214
LA 12	45°36'41 N	092°11'52 W	5.41	6.2	10433	161
LA 13	45°36'39 N	092°11'55 W	5.25	9	11582	267
LA 14	45°36'39 N	092°11'54 W	5.26	12.1	7642	200
LA 15	45°36'39 N	092°11'46 W	4.92	5.8	9065	200
LA 16	45°36'42 N	092°11'43 W	5.4	6	11938	186


LA7
LA6
LA5
LA4
LA3
LA1
LA2
LA8
LA9
Largon Lake
LA10
LA11
LA17
LA12
LA16
N
LA14
LA13
LA15
W
E
S

APPENDIX E

Well Data

Owner	pH	Conductivity (umhos)	Alkalinity (mg/L)	Total Hardness (mg/L)	Nitrate + Nitrite (mg/L)	Chloride (mg/L)
James Batt	7.4	254	150	140	0.1	3
Donald Lazarus	7.16	220	136	118	0.2	1
Robert Leafgren	7.1	262	162	140	<.1	1.5
Marvin Marshall	7.35	286	183	136	<.1	1.5
Steve Friendt	7.77	258	137	136	<.1	8.5
Robert Crowder	7.36	235	137	138	<.1	<.5
Carol Halverson	7.23	223	124	116	0.1	0.5
Mary Daul	7.21	222	119	112	0.1	<.5
Charles Elling	7.32	234	130	120	0.1	0.5
Bonnie Singh	7.18	227	126	112	0.1	<.5
Kay Behling-Potter	7.23	232	124	120	<.1	1
Robert Behling	7.58	264	150	132	0.1	0.5
Jim Behling						
Warren Gladitsch	7.45	244	133	120	0.1	<.5
Ronald Germain	7.18	283	156	148	<.1	1
Irven Peterson	7.91	401	214	212	<.1	<.5
Helen Stecklein	7.77	261	131	128	1.3	<.5
Patrick Horan	7.45	231	123	120	0.1	1

List of Contacts

For further information, please use the following contacts:

QUESTIONS ABOUT	OFFICE TO CALL	PHONE #	CONTACT PERSON
Aquatic plants management	Wisconsin Dept. of Natural Resources	(715)537-5900	Jim Cahow
Cutting trees and shrubs	Polk County Zoning	(715)485-8279	Gary Spanel or staff
Fisheries	Wisconsin Dept. of Natural Resources	(715)537-5900	Staff
Lake Association contacts	Polk County Assoc. of Lakes & Rivers	(715)485-8637	Brook Waalen
Lake management options	Polk Co. Land & Water Resources Dept.	(715)485-8637	Brook Waalen
Sanitary and septic requirements	Polk County Zoning	(715)485-8279	Gary Spanel or staff
Shoreland buffers and restoration	Polk County LWRD	(715)485-8639	Jeremy Williamson
Wildlife	Wisconsin Dept. of Natural Resources	(715)485-3518	Mike Johnson
Yard care and the shoreline	Polk Co. Land & Water Resources Dept.	(715)385-8639	Jeremy Williamson

ON-LINE RESOURCES FOR	PROVIDED BY	WEBSITE ADDRESS
Polk County shoreland zoning ordinance	Polk County Government	http://www.polkshore.com
Shoreland restoration and lake protection	Wisconsin Lakes Partnership University of Wisconsin Extension	http://www.uwsp.edu/cnr/uwexlakes http://www.uwex.edu/ces/shoreland
Water quality and resource education	University of Wisconsin Extension	http://clean-water.uwex.edu
Wisconsin lake issues	Wisconsin Association of Lakes	http://www.wisconsinlakes.org
Wisconsin's natural resources	Wisconsin Dept. of Natural Resources	http://www.dnr.state.wi.us