2001 SUMMARY REPORT
of
LAKE BARRINGTON

Lake County, Illinois

Prepared by the

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Lake Barrington, located in Cuba Township, was originally created in 1925 and passed through the hands of several owners before being sold for development in 1972. Construction of the Lake Barrington Shores condominiums began in 1973 and by 1990, over 1,300 units were built. The lake is an elongated impoundment with a surface area of 90.3 acres and a mean depth of 7.8 feet (Appendix A). The lake is located entirely within the village limits of Lake Barrington and is used by Lake Barrington Shores residents for swimming, fishing, and aesthetics, with a boat launch, beach and walking path on and around the lake.

Water quality parameters, such as nutrients, suspended solids, oxygen, temperature and water clarity were measured and the plant community was assessed each month from May-September 2001. Phosphorus levels started out very low in May and June, with no planktonic algae present and Secchi depth (water clarity) was to the lake bottom. This changed dramatically in July when phosphorus concentrations quadrupled, a dense algae bloom appeared and Secchi depth dropped to 1.7 feet. It is hypothesized that this huge pulse of phosphorus was coming from the sediment and was being released via a stratification-destratification cycle. It appears that Lake Barrington stratifies for short periods of time and that phosphorus increases as dissolved oxygen is depleted in the bottom waters. Stratification is then broken by air temperature changes or wind or rain event and the phosphorus is distributed throughout the water column. This cycle occurs several times throughout the summer, sending large pulses of phosphorus to surface waters and resulting in large algae blooms.

Algae blooms were wide-spread and continuous from July through September in Lake Barrington. The blooms largely consisted of planktonic blue-green algae, but mats of filamentous algae were also present on the lake, concentrated in the North Bay. Besides high phosphorus concentrations, a lack of aquatic vegetation contributed to the algae-dominated state of the lake. Lake Barrington had a relatively dense curly leaf pondweed plant population which was spot-treated along the shorelines early in the summer. *Chara* was the only plant (macroalgae) that became established to replace the pondweed. Therefore, the benefits provided by a highly diverse plant community, such as sediment stabilization, fish habitat and competition with algae were not fully realized and contributed to a decline in water quality. Another water quality problem related to high algae density and low plant density was poor water clarity, which served to prevent native aquatic plants from becoming established. Poor clarity also reduced the aesthetics of the lake and may have deterred residents from participating in recreational activities such as swimming.

Buckthorn, purple loosestrife and reed canary grass were present along 65.5% of the shoreline of Lake Barrington. These are exotic plant species that out-compete native vegetation and provide poor habitat for wildlife.

Recommendations and options for lake management techniques to address these problems are described in the report.

LAKE IDENTIFICATION AND LOCATION

Lake Barrington is located in unincorporated Cuba Township, west of Route 59 and north of Miller Road (T 43N, R 9E, S 11) and is entirely within the village limits of Lake Barrington. The lake was created in 1925 by damming the inflow to a depressional area and allowing it to fill up with runoff and groundwater. Lake Barrington is an elongated lake with a surface area of 90.3 acres, mean and maximum depths of 7.8 feet and 13.0 feet, respectively, and a volume of 701.4 acre-feet (Appendix A). Lake Barrington receives its water input from numerous storm pipes during rain events, a small inlet on the Forest Preserve land, and from controlled deep well injection. Deep well injection will be discontinued beginning in 2002. It is located in the Tower Lake sub basin, within the Fox River Watershed. Water exits the lake over a spillway on the northwest shore and eventually flows into the Fox River.

BRIEF HISTORY OF LAKE BARRINGTON

Lake Barrington was originally created in 1925 and passed through the hands of several owners before being sold to Mr. Bartlett in 1946. He changed its name from Indian Lake to Lake Barrington, and sold the lake and surrounding area to the J.S. James Co. and Amoco Reality in 1972. In 1973, development of the Lake Barrington Shores condominiums began and was ongoing for 17 years. Eventually, over 1,300 units were built. As a result, the immediate watershed of Lake Barrington (146 acres) has changed from being dominated by agricultural and forested land to being dominated by residential land (81%). The entire watershed of the lake, which includes surrounding residential, commercial and wetland areas is approximately 415 acres in size and is also dominated by residential land use (70%). Currently, the lake is owned and managed by the Lake Barrington Shores Homeowners Association.

SUMMARY OF CURRENT AND HISTORICAL LAKE USES

Access to Lake Barrington is open to Homeowners Association members only. The lake's main uses are swimming, fishing, aesthetics and irrigation for the Barrington Shores golf course. A walking path was built around the lake and is heavily utilized by Barrington Shores' residents. No gas motors are permitted on the lake, but many residents fish off the shore or from small boats. The swimming beach is also utilized by residents, but on a lesser scale, due to algae blooms that persist during the summer months and the presence of a pool just up the hill. In 2001, the beach was closed by the Lake County Health Department on three occasions due to high fecal coliform counts. These high counts can be caused by a number of things, including a large number of waterfowl, rain and high wind and wave events. The presence of a large number of waterfowl in the vicinity of the beach area could cause problems because their wastes contain fecal coliform. When these wastes make their way into the water, they can cause high fecal coliform counts. Rain events can increase fecal coliform counts because as rain runs over the land, it picks up high numbers of fecal coliform which are then washed into the lake. Fecal coliform bacteria can rest in large numbers on or in lake sediment at the beach area and will not be detected unless they are resuspended into the water column. This can occur if wind and waves resuspend sediment at the beach. On two consecutive days in July 2001, the high fecal coliform numbers appear to have been caused by rain. The closing in June may have been due to a high number of geese or ducks along the beach area. Despite the beach closings this year, since testing began in 1988, the beach at Lake Barrington has only been closed on nine occasions and fecal contamination is not a serious problem. The Lakes and Ponds Commission of the Lake Barrington Shores Homeowners Association meets once a month to address lake management issues, and each homeowner on the lake is required to pay a fee of between $300-500 per month (based on unit size), a portion of which goes towards maintenance of the lake. Currently, the biggest management concerns include algae and aquatic plant control, as well as the health of the fish community.

LIMNOLOGICAL DATA – WATER QUALITY

Water samples collected from Lake Barrington were analyzed for a variety of water quality parameters (See Appendix B for methodology). Samples were collected at 3 foot and 8-11 foot depths (depending on water level) from the deep hole location in the lake (Figure 1). Lake Barrington was thermally stratified only on the July 2001 sampling date. Thermal stratification occurs when a lake divides into an upper, warm water layer (epilimnion) and a lower, cold water layer (hypolimnion). When stratified, the epilimnetic and hypolimnetic waters do not mix, and the hypolimnion typically becomes anoxic (dissolved oxygen= 0 mg/l) by mid-summer. A lake that remains thermally stratified all summer is considered dimictic. Conversely, a polymictic lake stratifies and destratifies many times during the summer. Stratification may occur after several calm, hot days. However, this stratification may be broken by a storm or high wind event and the lower water layer will mix with the upper water layer. This may result in changes in phosphorus concentrations in the epilimnion that affect many aspects of water quality. Due to a fetch of nearly ¾ of a mile (fetch is defined as the farthest distance across which wind blows unobstructed by land, and can strongly affect mixing within a lake), Lake Barrington appears to be polymictic, and the consequences of this with regard to water quality will be discussed below. A 1991 study by Harza Engineering found very similar results with regard to thermal stratification. They found that Lake Barrington did not produce a distinct thermal boundary between the upper and lower water layers and that stratification was very unstable throughout the summer.

Near surface dissolved oxygen (DO) concentrations did not fall below 5.0 mg/l (a level below which aquatic organisms become stressed) at any time during the study period. Near-bottom DO concentrations fell below 5.0 mg/l during June, July and August, and the bottom waters became hypoxic (DO<1.0 mg/l) below seven and eight feet in July and August, respectively (Table 1, Appendix A). This hypoxic layer included approximately 31% of the lake volume during these months. This left the majority of the lake oxygenated. However, as the water temperature rose and the blue-green algae bloom became more dense and began to decompose from June through September, the

biological oxygen demand (BOD) also increased in surface waters. This, most likely, put additional stress on the fish community. A high BOD means that regardless of the amount of oxygen present, the demand for that oxygen by living organisms (especially bacteria that decompose organic matter) is very high and there may not be enough to go around. As a result, the oxygen in the warm, upper water layer may have been temporarily depleted to a level below that which would support most fish species. Approximately seven pike and nine bluegill were found floating along the western shore during the plant survey conducted on August 2nd, and a much larger fish kill (hundreds of fish) occurred on August 17th. It is hypothesized that the kill was the result of very high BOD from the decomposition of blue-green algae in the epilimnion. Additionally, the Harza Engineering study in 1991 determined that early morning DO concentrations were only about 4.0 mg/l from the surface to two feet off the lake bottom. Photosynthesis does not occur during the night to replace oxygen being taken up by respiration, and oxygen levels often decline overnight and are not replenished until mid-morning. This is especially true in nutrient enriched lakes with large amounts of algae and plant matter and a high BOD.

Phosphorus is a nutrient that can enter lakes through runoff or be released from lake sediment, and high levels of phosphorus typically trigger algal blooms or produce high plant density. The average surface phosphorus concentration in Lake Barrington was 0.096 mg/l, but ranged from 0.023 mg/l in June to 0.157 mg/l in September. The phosphorus concentration quadrupled from June to July in surface waters and increased by five-fold in bottom waters (Table 1, Appendix A). This was followed by a very dense lake-wide blue-green algae bloom and a large drop in Secchi depth that persisted through September (Figure 2). Based on historical data, this sequence of events occurs every summer, resulting in dense algae blooms and low water clarity. The source of this pulse of phosphorus into the water column each year appears to be internal. Although sampling was not frequent enough to prove it, the data supports the idea that the polymictic nature of Lake Barrington lead to a large release of phosphorus from the sediment during the summer. As mentioned above, a polymictic lake will stratify and de-stratify several times during the summer. During calm, hot periods, the lake will become weakly stratified and bottom waters will lose oxygen very quickly. As a result, phosphorus is released from the sediment and builds up in the hypolimnion. Stratification is then broken by air temperature changes or a wind or storm event and the phosphorus is distributed throughout the water column, often producing algae blooms. In June 2001, phosphorus concentrations between the epilimnion and hypolimnion were very similar, indicating that the lake was still mixing. By the end of July, the phosphorus concentration had increased six-fold in the epilimnion and five-fold in the hypolimnion and the lake was stratified. In August, the lake was no longer stratified and phosphorus concentrations were, once again, very similar between surface and bottom waters. It is hypothesized that this stratification-destratification cycle occurred throughout the month between the June and July sampling dates. A greater volume of the bottom water was becoming anoxic throughout that month, as the top of the anoxic zone moved from a depth of 12 feet in June to a depth of 7 feet in July. Phosphorus would have continued building in bottom waters. During this time, the depth of thermal stratification may not have coincided with the anoxic boundary or may not have been very strong at the anoxic

boundary. This would have lead to the release and distribution of phosphorus throughout the water column before strong thermal stratification isolated the anoxic water from surface waters. This may have occurred several times during the month of July, pumping large amounts of phosphorus into the entire water column and accounting for the huge jump in phosphorus concentrations between June and July and the resulting blue-green algae bloom in July. Based on limited data collected between 1996 and 2000 by Aron and Associates, Inc., it appears that this has been the primary mechanism of phosphorus release and subsequent algae blooms in Lake Barrington for several years. In general, average epilimnetic and hypolimnetic phosphorus concentrations have remained relatively stable (but high) since 1996 (Figure 3). Additionally, Harza Engineering, using a phosphorus loading model, found that 68% of the total phosphorus loading to the lake was internal loading, recycled from the lake sediments.

A secondary mechanism of phosphorus release in Lake Barrington may be occurring through the death and decomposition of curly leaf pondweed in late June and early July. Rooted aquatic plants take most of their nutrients up from the sediment and store these nutrients in plant tissue. When these plants are chemically treated in late spring each year, they begin to decompose as water temperatures increase, and the stored nutrients are released into the water column. This internal recycling of phosphorus from the sediment to the water column provides a readily available source of phosphorus for algae and may contribute to planktonic algae blooms each summer.

Although rain data did not coincide with pulses in phosphorus concentrations in the lake, Harza Engineering found that the Lake Barrington Shores common property was the second-most important source of phosphorus (after internal loading) to Lake Barrington, contributing approximately 19% of the total. Much of this was originating from fertilized lawns around the lake. Harza performed soil tests on cores of soil from the common area between the rec center and construction office, roadside lawn off of Pine Crest, lakeside lawn off Mallard Point, forest preserve property, and a steep lawn near the west shore. The forest preserve property was considered the standard by which to compare the other cores since this is a relatively undisturbed area with no manicured lawn. The forest preserve had 13 lbs P/acre, while the other cores ranged from 21-87 lbs P/acre, with the common area being the highest. All of the areas tested drain into the lake, bringing with them relatively large amounts of phosphorus from the soil. These soil tests indicate that these areas do not need additional phosphorus-rich fertilizer in order to maintain green lawns. Typically, soils in this geographical area need nitrogen additions, not phosphorus. It is strongly suggested that the Lake Barrington Shores lawn maintenance department begin using phosphorus-free fertilizer on the manicured areas of the complex. These fertilizers are typically available from the same distributors as other fertilizers and are no more expensive than other fertilizers. Runoff from the Barrington Shores Golf Course does not drain into Lake Barrington and is, therefore, not a concern at this time.

High phosphorus concentrations also resulted in a high density of filamentous algae, especially in North Bay. Phosphorus concentrations were not determined in this relatively isolated area of the lake, but were higher than concentrations in the main lake during the 1991 Harza study. Large mats of surface algae covered nearly the entire cove

in May and June and a large amount of algae was observed lying on the lake bottom, waiting to rise to the surface. The mats had been chemically treated several times by July and surface coverage had been reduced. However, most of the surface mats had simply sunk to the bottom and were, likely, releasing phosphorus during their decomposition. This phosphorus was available to the living filamentous algae resting on the sediment, which then floated to the water surface to create another mat of algae. This cycle continued through the summer, but by the end of July, the density of surface algae had been decreased by herbicide treatment. As a side note, large numbers of curly leaf pondweed turions (structures released from the plant which sink to the lake sediment, overwinter, and give rise to new plants in the spring) were found tangled in the filamentous algae mats around the lake. When the algae mats sunk to the lake bottom, the turions were taken with them, remaining dormant over the winter and possibly contributing to the curly leaf pondweed problem the next spring.

It appears that the chemical treatment of filamentous algae is successfully reducing its density in North and Mallard Bays by the middle of the summer. This treatment should continue as needed. However, because the chemical treatment of the filamentous algae mats is simply leading to continued algal decomposition and phosphorus release, it is also recommended that these algae mats be removed manually from the lake surface, if possible. This could be carried out with a pontoon or flat-bottomed boat and large metal garden rakes, and if manual removal is conducted early in the summer and continued each week, the density of algae should not become too heavy to physically remove. With manual removal, curly leaf pondweed turions would also be removed from the lake, and decomposition of chemically treated algae (which strips surface waters of oxygen) would be reduced or eliminated. In addition, if the Homeowners Association could recruit volunteers to provide the labor for this task, algae management costs could be significantly reduced.

Total suspended solids (TSS) is a measure of the amount of suspended material, such as algae or sediment, in the water column. High TSS values are typically correlated with poor water clarity and can be detrimental to many aspects of the lake ecosystem such as the plant and fish communities. A large amount of material in the water column can inhibit successful predation by sight-feeding fish, such as bass and pike, or settle out and smother fish eggs. High turbidity caused by sediment or algae can shade out native aquatic plants, resulting in their reduction or disappearance from the littoral zone. This eliminates the benefits provided by plants, such as habitat for many fish species and stabilization of the lake bottom. A sharp increase in TSS was observed between June and July, coinciding with the sharp increase in TP (Figure 4). Since total volatile solids (TVS), a measure of organic solids such as algae, also coincided with TSS concentrations, the majority of detectable TSS in the water column likely consisted of algae. TSS concentrations in Lake Barrington ranged from 0.2 mg/l in June (the lowest among County lakes with detectable concentrations from 1995-2001) to 18.0 mg/l in July. Although the average TSS concentration of 9.6 mg/l was slightly lower than the County average of 10.0 mg/l, it was almost twice as high as the majority of the County lakes studied since 1995 (5.7 mg/l).

The decrease in Secchi depth (water clarity) coincided very closely with the increase in both TP and TSS (Figures 2 & 5). Clarity plunged from 12.67 feet in June to 1.72 feet in July as a result of an increase in TP and the resulting algae bloom. Throughout the summer, Secchi depth ranged from the lake bottom in May to just 1.51 feet in September, and averaged 4.41 feet from June through September. This huge reduction in water clarity by mid-summer is likely preventing the establishment of a native plant community after the curly leaf pondweed has been reduced through herbicides. A volunteer lake monitoring program (VLMP) has been in place on Lake Barrington since 1986. This Illinois Environmental Protection Agency (IEPA) program, organized and run by the Northeastern Illinois Planning Commission (NIPC), involves the collection of data by a volunteer in the same place and along the same time scale each year. Although the amount of data collected is often limited, it can provide valuable historical information on water clarity and, therefore, water quality on many Lake County lakes. Volunteer lake monitors consistently collected Secchi depth data at four sites on Lake Barrington, one of which corresponded with the sampling site used by the Lakes Management Unit in 2001 and Aron and Associates from 1996-2001. Average Secchi depth has remained relatively consistent each year since 1986 (Figure 6), and VLMP measurements typically matched with measurements collected from other (Aron and Assoc., LCHD-LMU) sources during the same year. Lower than average measurements were recorded in the early 1990's; however, the cause of these low Secchi depths is not apparent from the data provided and may have resulted from several factors.

Historically, planktonic algae along the shoreline of Lake Barrington was being treated with Hydrothol 191®, Clearigate® and Cutrine Plus®. Although very little of this chemical was used, it is recommended that the use of Hydrothol 191® be discontinued. This chemical is highly toxic to fish, especially pike and especially if a large area is treated. In addition, Hydrothol 191® is, first and foremost, an herbicide. The application of this chemical after curly leaf pondweed plants have disappeared (in July and August) may be killing potentially beneficial plants along the shoreline. The application may also be reducing the density of *Chara*, a low-lying macroalgae that often aids in maintaining water clarity. Clearigate® and/or Cutrine Plus® should provide adequate control of shoreline planktonic algae without the additional use of Hydrothol 191®.

Most of the other variables measured during the 2001 study (average total dissolved solids (TDS), total volatile solids (TVS), alkalinity, conductivity, nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_3-N) and pH) were below their respective County averages (Table 1, Appendix A) and did not contribute to the poor water quality of Lake Barrington.

Typically, lakes are either phosphorus (P) or nitrogen (N) limited. This means that one of these nutrients is in short supply relative to the other and that any addition of phosphorus or nitrogen to the lake might result in an increase of plant or algal growth. Other resources necessary for plant and algae growth include light or carbon, but these are typically not limiting. Most lakes in Lake County are phosphorus limited, but to compare the availability of nitrogen and phosphorus, a ratio of total nitrogen to total phosphorus (TN:TP) is used. Ratios less than or equal to 10:1 indicate nitrogen is limiting. Ratios

greater than or equal to 15:1 indicate that phosphorus is limiting. Ratios greater than 10:1, but less than 15:1 indicate that there are enough of both nutrients to facilitate excess algal or plant growth. Lake Barrington had a TN:TP ratio of 19:1. This indicates that the lake is phosphorus limited and is the reason that the increase in phosphorus in July resulted in the occurrence of algae blooms. High nitrogen concentrations during July, August and September were the main cause of this high ratio. Total nitrogen levels in Lake Barrington during these three months were double the County average. Nitrogen can come from many sources, including septic systems, watershed runoff, soils and the atmosphere, and is very difficult to control. One source of nitrogen to Lake Barrington may be lawn fertilizer used on the manicured lawns surrounding many of the condominiums. If these lawns are heavily fertilized, rain will eventually wash excess fertilizer into the lake. This leads to an increase in both nitrate and total nitrogen concentrations in surface water and could contribute to the phosphorus limitation in the lake. Additionally, sediment cores analyzed in 1989 by the Lakes Management Unit indicated elevated to highly elevated total nitrogen levels in four areas of the lake. This suggests that nitrogen may also be coming from the lake sediment.

Phosphorus concentrations can also be used to indicate the trophic state (productivity level) of a lake. The Trophic State Index (TSI) uses phosphorus, chlorophyll *a* (algae biomass) and Secchi depth to classify and compare lake trophic states using just one value. The TSI is set up so that an increase in phosphorus concentration is related to an increase in algal biomass and a corresponding decrease in Secchi depth. A high TSI value indicates eutrophic (TSI=50-69) to hypereutrophic (TSI $\geq$70) lake conditions, typically characterized by high nutrient concentrations, high algal biomass, low DO levels, a rough fish population, and low water clarity. Lake Barrington had a phosphorus TSI (TSIp) value of 70, indicating hypereutrophic conditions. This means that the lake is a highly enriched system with poor water quality. Although Lake Barrington ranks 81st out of 102 lakes in Lake County (TSIp averaged over several years), it is not extremely unusual, as most man-made lakes in this geographical area fall into the eutrophic and hypereutrophic categories (Table 2, Appendix A).

Most of the water quality parameters just discussed can be used to analyze the water quality of Lake Barrington based on use impairment indices established by the Illinois Environmental Protection Agency (IEPA). According to this index, Lake Barrington provides *Full* support of aquatic life, and *Partial* support of swimming and recreation as a result of a high TSI value and low percent plant coverage.

LIMNOLOGICAL DATA – AQUATIC PLANT ASSESSMENT

Aquatic plant surveys were conducted every month for the duration of the study (See Appendix B for methodology). Shoreline plants of interest were also recorded. However, no quantitative surveys were made of these shoreline plant species and these data are purely observational. Lake Barrington currently has a plant management plan in place. Harvesting began approximately 20 years ago when curly leaf pondweed covered 20-30 acres of the lake. Approximately 15 years ago, the curly leaf had spread to cover the entire lake surface and Eurasian watermilfoil was prevalent. Seven years ago, the application of Sonar™ was incorporated into the plant management program. Approximately 150 truckloads of plants were removed each year during harvesting until 2000 (more in 1999). In 2000, only 4 truckloads of plants were removed and it was not necessary to harvest in 2001. Because the harvester was unable to cut very close to shore and in the shallow bays, the application of Aquathol-K® and Sonar™ to treat curly leaf pondweed was incorporated into the management plan in 1996. Sonar™ treatments were carried out in North Bay and Turtle Bay in 1996, North Bay, Turtle Bay, Herons Cove and Mallard Bay in 1997, Mallard Bay in 1998, Mallard Bay and North Bay in 1999 and 2000, and North Bay and Turtle Bay in 2001. According to Aron and Associates, the early season treatment of Sonar™ in North and Mallard Bays has dramatically reduced the turion density in these areas, resulting in the return of a lower density of curly leaf pondweed each year. Aquathol-K® was applied early in the summers of 1997, 1999, 2000 and 2001 along a 20 foot wide band of the shoreline. In 1996, plantings of *Elodea*, wild celery, white water lilies and pickerel weed were conducted by Aron and Associates. In 1997, sago and large leaf pondweed were planted in addition to wild celery and white water lilies. In 1998, plantings included sago pondweed, coontail, wild celery and white water lilies. No plantings were conducted in 1999, 2000 or 2001. The plants were placed along the shoreline in Turtle Bay and North Bay. In 1996, the water lilies and pickerel weed appeared to have become established, but there was no sign of growth from the wild celery or *Elodea*. In 1997 and 1998, the only plantings that appeared to have survived in large numbers were the white water lilies. Small, sporadic areas of coontail, sago pondweed and wild celery were reported by residents in 1998. In 2001, *Chara* appeared in the lake in very high densities for the first time since approximately 8-10 bushels were planted. It is recommended that plantings not be conducted again until it is determined whether other lake management techniques can increase water clarity. Additionally, in 1997, the lake level was increased by three inches in order to reduce the acreage of the littoral zone and limit the area that curly leaf pondweed could grow.

In 2001, curly leaf pondweed and *Chara* dominated the plant community. Very small amounts of coontail, horned pondweed, small pondweed, sago pondweed, duckweed, and watermeal were observed throughout the summer, and white water lily was observed in small pockets in the northern part of the lake (Tables 3 & 4). During our study, light level was measured at one-foot intervals from the water surface to the lake bottom. When the light level falls below 1% of the level at the water surface, plants are no longer able to grow. Using this information, it can be determined how much of the lake has the potential to support aquatic plant growth. Based on 1% light level, Lake Barrington could have supported plants over approximately 55% of the lake, but plants were observed, on average, over only 40% of the lake surface area during 2001. In May plants could have and did grow throughout the entire lake, as light levels were above 1% at the lake's deepest point. Curly leaf pondweed was found growing at a depth of 12 feet in May. Light levels were also above 1% at the bottom in June, but plants were found in no deeper than 7 feet of water. From July through September, 1% light levels did not exist deeper than 5 feet and some plants were observed growing at this depth. However, most plants were found in only 2-3 feet of water. The inability of aquatic plants to grow in all areas as determined by percent light level may be explained by shading by filamentous algae mats in certain areas or the presence of inadequate substrate in various parts of the lake.

While *Chara* was present throughout the summer, curly leaf pondweed was chemically treated in late spring and was no longer present by the end of July. This is the first year (2001), in recent years, that *Chara* appeared in relatively high densities. The establishment of this macroalgae may have helped to delay the shift to algae domination, which occurred in late July of this year, as compared to other years when the algae bloom appeared as early as late June. After increasing from May to June, *Chara* density dropped throughout the rest of the summer. The combination of reduced water clarity and monthly algae treatments is thought to be the cause of this reduction in density. The virtual lack of plants in the lake by August (Table 4, Appendix A), contributed to algae dominance and low water clarity during the latter part of the summer, preventing the establishment of native plants from previous years' plantings.

The plant management plan for Lake Barrington appears to be successfully treating the curly leaf pondweed and reducing turion density each year. We recommend that Sonar™ treatments in the Bays continue as needed but that harvesting not be removed from the lake management budget. As with chemical treatment of the filamentous algae, the chemical treatment of curly leaf pondweed results in the death and decomposition of the plant material, which then releases phosphorus back into the water column to be utilized by planktonic algae. The removal of this plant material through harvesting would better serve to reduce the phosphorus concentrations in the lake. The Harza study in 1991 determined that with the harvesting of curly leaf pondweed, approximately 1,400 pounds of phosphorus were removed from the lake (nearly double the estimated mean annual load that year). Additionally, if the plants are cut before they reach a height of approximately four feet, they will not yet have produced turions and will not produce new plants the following year. This may have been the reason that curly leaf pondweed densities did not decline in the past after many years of harvesting. If the curly leaf pondweed plants are not harvested before forming turions, plant density will remain the same or increase through turion growth the following year. Additionally, the turions were likely distributed by the harvester into areas not originally infested with curly leaf pondweed, increasing the acreage covered by the plant. Because curly leaf pondweed naturally dies back by July (due to high water temperatures), early harvesting should be carried out so that by the time regrowth began to occur, water temperatures would prevent the re-establishment of the curly leaf. Since boat traffic is light on the lake, the presence of curly leaf pondweed in isolated areas such as Turtle Bay and along some shorelines should not pose a navigational problem if the harvester is not able to get into these areas. Herbicide spot treatments could still be carried out near the boat launch and along the beach, and Sonar™ treatments should still be considered for North and Mallard Bays. However, a plant management plan that continues to include harvesting in the main body of the lake is recommended.

Of the six emergent plant and trees species observed along the shoreline of Lake Barrington, three (purple loosestrife, reed canary grass, and buckthorn) are invasive species that do not provide ideal wildlife habitat and have the potential to dominate the emergent plant community.

FQI (Floristic Quality Index) is a rapid assessment tool designed to evaluate the closeness of the flora of an area to that of undisturbed conditions. It can be used to: 1) identify natural areas, 2) compare the quality of different sites or different locations within a single site, 3) monitor long-term floristic trends, and 4) monitor habitat restoration efforts (Nichols, 1999). Each floating or submersed aquatic plant is assigned a number between 1 and 10 (10 indicating the plant species most sensitive to disturbance). An FQI is calculated by multiplying the average of these numbers by the square root of the number of plant species found in the lake. A high FQI number indicates that there are a large number of sensitive, high quality plant species present in the lake. Non-native species were also included in the FQI calculations for Lake County lakes. The average FQI for 2000-2001 Lake County lakes is 14.0. Lake Barrington has an FQI of 16.3, and an average plant community, by Lake County standards at this time.

Table 3: Aquatic and shoreline plants on Lake Barrington, May-September 2001.

Aquatic Plants	
Coontail	*Ceratophyllum demersum*
Chara	*Chara* sp.
Small Duckweed	*Lemna minor*
White Water Lily	*Nymphaea tuberosa*
Curlyleaf Pondweed	*Potamogeton crispus*
Small Pondweed	*Potamogeton pusillus*
Sago Pondweed	*Stuckenia pectinatus*
Horned Pondweed	*Zannichellia palustris*
Watermeal	*Wolffia columbiana*
Shoreline Plants	
Tall Bur Marigold	*Bidens coronata*
Bull Thistle	*Cirsium vulgare*
Purple Loosestrife	*Lythrum salicaria*
Reed Canary Grass	*Phalaris arundinacea*
Common Buckthorn	*Rhamnus cathartica*
Common Cattail	*Typha latifolia*

LIMNOLOGICAL DATA – SHORELINE ASSESSMENT

A shoreline assessment was conducted at Lake Barrington on June 28, 2001. The shoreline was assessed for a variety of criteria (See Appendix B for methods), and based on these assessments, several important generalizations could be made. Approximately 74% of Lake Barrington's shoreline is developed and the majority of the developed shoreline is comprised of rip rap (72.8%) (Figure 6). The remainder of the developed shoreline consists of manicured lawn (12.4%), buffer (10.6%) and wetland (4.2%). The undeveloped portions of the lake (located mostly along the northern shores) consist primarily of woodland. Although rip rap is not an ideal shoreline type with regard to wildlife habitat, it does help to prevent shoreline erosion. Only 32.3% of Lake Barrington's shoreline exhibited erosion, and the majority of the erosion (29.2%) was only slight erosion (Figure 7). Moderate erosion was occurring on approximately 3% of the shoreline. The types of shorelines exhibiting the most erosion included woodland (100%) and manicured lawn (81%), with buffer and rip rap making up the rest (37%). Manicured lawn is considered undesirable because it provides a poor shoreline-water interface due to the poor root structure of turf grasses. These grasses are incapable of stabilizing the shoreline and typically lead to erosion. Woodland is a more desirable shoreline type and although woodland-dominated lots may seem to provide the ideal shoreline, if the slope is steep or if these lots are not maintained, erosion can occur. Deciduous trees present along these shorelines have very large roots that are unable to stabilize soil as well as native grasses and plants. If these trees become so large that they shade out all understory plants (whose roots provide the best stabilization) beneath them, the shoreline will become eroded.

Dramatic water level fluctuation can increase shoreline erosion, especially if the fluctuations occur over short periods of time. The water level in Lake Barrington dropped nearly ½ foot from June to July and another ½ foot from July to August, mostly due to the removal of water for irrigation of the Barrington Shores Golf Course. The level then increased nearly 1.0 foot from August to September as a result of deep well injection in mid-August. These are relatively dramatic changes that occurred over a short period of time (1 month). Shoreline erosion observed during 2001 was minimal. However, continuous water level fluctuations over a long period of time will increase shoreline erosion, especially along areas not protected by buffer strips containing native vegetation. Erosion occurs when water levels drop and newly exposed soil, which may not support emergent plant growth, is subjected to wave action. The Association may want to consider filling the lake throughout the summer to supplement water being taken for irrigation instead of refilling the lake all at once at the end of the summer. This will help prevent erosion along the shoreline in the future. As a side note, data collected by Aron & Associates during 2001 suggest that water level fluctuations may not have been as high as were measured by the Lakes Management Unit.

Although very little erosion was occurring around Lake Barrington, invasive plant species, including reed canary grass, buckthorn and purple loosestrife were present along 65.5% of the shoreline. These plants are extremely invasive and exclude native plants

from the areas they inhabit. Buckthorn provides very poor shoreline stabilization and may lead to increasing erosion problems in the future. Reed canary grass and purple loosestrife inhabit mostly wetland areas and can easily outcompete native plants. Additionally, they do not provide the quality wildlife habitat or shoreline stabilization that native plants provide. Since the relative density of these three invasive plants was not extremely high along Lake Barrington, steps to eliminate these plants around the lake should be carried out before they become a nuisance.

LIMNOLOGICAL DATA – WILDLIFE ASSESSMENT

Fish surveys have been performed on Lake Barrington by the IDNR since 1957. In 1957, a large fish kill was investigated. Prior to that time, the fishery had been very healthy and diverse. From 1973 through 1982, the fish population was in good condition. In 1982, a fish survey indicated a subtle deterioration of the bass population and a slight decrease in the average length of sunfish. In 1989, large mouth bass were still relatively small, but the sunfish population was in better condition than in 1982. In accordance with recommendations made by the IDNR, large mouth bass and northern pike were stocked in the lake for many years. The most recent fishing survey was performed in 1997. Compared to the 1982 survey, species number remained the same, while species composition had changed with the absence of yellow perch and the addition of northern pike. Bluegill and golden shiner remained the dominant species, followed by warmouth, largemouth bass and pumpkinseed sunfish. The remainder of the fish community consisted of green sunfish, sunfish hybrid, black crappie, northern pike, and brown bullhead. Conclusions from the survey were that the lake maintained exceptional bluegill and warmouth populations, but had low bass abundance due to intense competition from the bluegill and warmouth. Recommendations included (1) maintenance of an aquatic vegetation control program directed at reducing curly leaf pondweed and Eurasian watermilfoil, (2) establishment of a 15 inch minimum length limit and 1 per day catch limit on largemouth bass, (3) initiation of a five-year largemouth bass stocking program and an annual or biennial northern pike stocking program. The first two recommendations are being carried out through herbicide treatment and (until recently) harvesting, and current fish stocking activities are based on the third recommendation. Another IDNR fish survey is scheduled to be carried out during the summer of 2002.

Wildlife observations were made on a monthly basis during water quality and plant sampling activities (See Appendix B for methodology). Although wildlife habitat in the form of wetland and woodland areas was limited around Lake Barrington, a good number of waterfowl and song birds were observed (Table 5). Dead trees were also found along some of the shoreline in Turtle Bay. These trees can serve as excellent habitat for birds like herons and cormorants. In addition, once a tree falls into the water, it provides excellent habitat for many wildlife species (i.e., turtles, fish, birds). It is, therefore, very important that some of the wetland and hardwood forest buffer areas around the lake be maintained to provide the appropriate habitat for these bird species in the future. It is also important that areas with manicured lawns down to the shoreline, such as those in

North Bay, establish a buffer strip of native plants to provide additional habitat and reduce erosion.

Table 5: Wildlife species observed at Lake Barrington, May-September 2001.

Birds	
Double Crested Cormorant	*Phalacrocorax auritus*
Mute Swan	*Cygnus olor*
Canada Goose	*Branta canadensis*
Mallards	*Anas platyrhnchos*
Great Blue Heron	*Ardea herodias*
Green Heron	*Butorides striatus*
Red-bellied Woodpecker	*Melanerpes carolinus*
Barn Swallow	*Hirundo rustica*
American Crow	*Corvas brachyrhynchos*
Blue Jay	*Cyanocitta cristata*
American Robin	*Turdus migratorius*
Red-winged Blackbird	*Agelaius phoeniceus*
Northern Cardinal	*Cardinalis cardinalis*

EXISTING LAKE QUALITY PROBLEMS

- *Polymixis Leading to Internal Phosphorus Loading*

  Lake Barrington is a polymictic lake, meaning that it stratifies and destratifies many times during a summer. As a result of this stratification cycle, phosphorus was released and built up in bottom waters during stratification and was then distributed throughout the water column during destratification. This resulted in an increase in available phosphorus and the occurrence of a blue-green algae bloom throughout the summer. If high oxygen concentrations could be maintained (destratification) throughout the entire water column via artificial aeration, phosphorus concentrations may not increase as dramatically and algae blooms may be reduced.

- *Lack of Aquatic Vegetation*

  One key to a healthy lake is a healthy plant community. Lake Barrington has a relatively dense curly leaf pondweed plant population early in the summer, and a *Chara* population throughout the summer. However, curly leaf is chemically treated in the spring and is not replaced by native vegetation. The benefits provided by a quality plant community, such as sediment stabilization, fish habitat and competition with algae, are not realized and result in a decline in water quality. The lack of quality aquatic vegetation in Lake Barrington contributed to dense algae blooms, low water clarity, and the failure of native plants to become established. It has been recommended that Sonar™ or Avast™ treatments continue in several of the Bays, but that harvesting remain a possible means by which to manage the curly leaf pondweed.

- *Excessive Planktonic and Filamentous Algae Blooms*

  Algae blooms were wide-spread and continuous from July through September in Lake Barrington. The blooms largely consisted of planktonic blue-green algae, but mats of filamentous algae were also present in the lake, and were concentrated in North Bay. High phosphorus concentrations and a lack of quality aquatic vegetation are thought to be the cause of these algae blooms, which have occurred every summer in the recent past. The filamentous mats and planktonic algae are currently being chemically treated. It is recommended the chemical treatment of the filamentous algae continue as needed and that attempts be made to manually remove the filamentous algae from North Bay. This will reduce decomposition and phosphorus release from the treated algae and will remove a large number of curly leaf pondweed turions that are caught in these mats. It has also been recommended that the use of Hydrothol 191® be discontinued. This chemical has a high fish toxicity and may be killing beneficial plants along the shoreline (since it also serves as a herbicide).

- *Poor Water Clarity*

  Due to the high phosphorus levels and the low density and diversity of aquatic plants, which provide sediment stability and compete with planktonic algae for resources, the water column of Lake Barrington was choked with blue-green algae blooms from July through September. This kept water clarity low and prevented any aquatic plants (that had been planted in prior years) from becoming established. Poor water clarity also reduced the aesthetics of the lake and may have deterred lake residents from participating in recreational activities such as swimming.

- *Invasive Shoreline Plant Species*

  Numerous exotic plant species have been introduced into our local ecosystems. Some of these plants are aggressive, quickly out-competing native vegetation and flourishing in an environment where few natural predators exist. The outcome is a loss of plant and animal diversity. Purple loosestrife is responsible for the “sea of purple” seen along roadsides and in wetlands during summer. It can quickly dominate a wetland or shoreline. Reed canary grass is another exotic plant found in wetland habitat. It spreads very quickly, does not provide adequate shoreline stabilization and is not well utilized by wildlife. Buckthorn is an aggressive shrub species that grows along lake shorelines as well as most upland habitats. It shades out other plants and is quick to become established on disturbed soils. Purple loosestrife, reed canary grass and buckthorn are present along 65.5% of the shoreline of Lake Barrington and attempts should be made to control their spread before they become a large problem.

POTENTIAL OBJECTIVES FOR THE LAKE BARRINGTON MANAGEMENT PLAN

I. Maintain High Dissolved Oxygen Levels Through Continuous Destratification to Reduce Phosphorus Concentrations and Algae Blooms
II. Eliminate or Control Invasive Species

OPTIONS FOR ACHIEVING THE LAKE MANEMENT PLAN OBJECTIVES

Objective I. Maintain High Dissolved Oxygen Levels Through Continuous Destratification to Reduce Phosphorus Concentrations and Algae Blooms

Fish and other aquatic organisms need oxygen to live. As water moves past their gills (or other breathing apparatus), microscopic bubbles of oxygen gas in the water, called dissolved oxygen (DO), are transferred from the water to their blood. Like any other gas diffusion process, the transfer of DO to aquatic organisms can only occur above certain concentrations. In other words, oxygen can be present in the water, but at too low a concentration to sustain aquatic life. Oxygen also is needed by virtually all algae and all aquatic plants, and for many chemical reactions that are important to lake functioning. Lake DO concentrations naturally vary and are controlled by several biological, chemical and physical processes.

Dissolved oxygen concentrations in a lake can vary greatly depending on the time of day. This is mainly due to oxygen being produced during photosynthesis and consumed during respiration and decomposition. Because it requires light, photosynthesis occurs only during the daylight hours. Respiration and decomposition, on the other hand, occurs 24 hours a day. This difference alone can account for large daily variations in DO concentrations. During the night, when photosynthesis cannot counter balance the loss of oxygen through respiration and decomposition, DO concentration may steadily decline. DO concentrations are generally lowest just before dawn, when photosynthesis resumes.

Ice-covered (nutrient-enriched) lakes may also develop variations of DO dependent on depth. If there is little or no snow cover to block sunlight, algae and some plants may continue to photosynthesize, resulting in a small increase in DO just below the ice. But as microorganisms continue to decompose material in the lower water column and in the sediments, they consume oxygen, and the DO is depleted. No oxygen input from the air occurs because of the ice cover, and, if snow covers the ice, it becomes too dark for photosynthesis. This condition can cause high fish mortality during the winter, know as “winter kill.” Lakes in this area that do not have at least 25% of their surface area with a depth of at least 10 feet are prone to winter kill. Lake Barrington has 43.2% of its surface area at a depth of at least 10 feet and should, therefore, not experience frequent winter fish kills.

Temperature effects can also cause reduced DO in deeper lakes (usually greater than 10 feet deep) as thermal stratification may cut-off all oxygen sources from reaching the lower depths. DO concentrations drop as organisms continue to respire and consume oxygen. The bottom layer of the lake may eventually become anoxic, that is, totally devoid of oxygen. Oxygen losses can also occur in summer if large amounts of plants or algae quickly die naturally, or as a result of an application of fast acting aquatic herbicides or algicides. Decomposition is more rapid in the summer due to warmer water temperature, which uses a large amount of DO very quickly, causing a DO crash. The anoxia causes chemical reactions which result in the release of phosphorus in this bottom layer. If the phosphorus is then distributed to the surface layer through frequent mixing of the water column, algae blooms could result. This appears to be occurring in Lake Barrington each summer. If the entire water column remained oxygenated throughout the summer, internal phosphorus release should decrease or be eliminated and should result in a decrease of planktonic (and possibly filamentous) algae.

Option 1. No Action

Lakes that experience low DO concentrations either during the summer or winter are almost always nutrient-enriched or eutrophic lakes that are very productive biologically. Lakes such as Lake Michigan that are deep, but nutrient-poor rarely have problems with low DO. Therefore, DO measurements should be collected at least monthly in summer and winter to determine if low DO is a problem for the specific lake. If low DO is a problem, then the underlying cause should be investigated and additional tests conducted prior to taking management actions. As stated previously, lakes have natural variations of DO dependent on physical processes and the amount of biological and chemical activity. With a no action management plan for lakes with low DO, nothing would be done to improve the DO concentrations. The DO concentrations would continue to vary and fluctuate dependent on time and lake condition.

Pros

If no efforts are made to increase DO concentrations, there are no DO management expenses. Although, equipment costs and other management options may increase in price over time. In most cases, low DO in the lower water layer of a thermally stratified, productive lake is a natural, physical and chemical phenomenon and is not necessarily bad. In many cases, the amount of total volume that has low DO is relatively small (sometimes less than 30% in Lake County). Thus, ample volume can exist with sufficient DO for aquatic organisms to survive. Generally, nutrients released from sediment, due to low DO in a thermally stratified lake, are contained in the lower water and are not available for additional growth of plants and algae until fall turnover. As stated above, this is not the case in Lake Barrington. The phosphorus released from bottom sediment appears to be making its way into the epilimnion many times during the summer. No action may also be warranted in cases of productive, shallow lakes that regularly experience fish kills as it may not be cost effective to maintain suitable conditions (year-round) for gamefish populations. In some cases, DO management options such as aeration (artificial circulation) have increased phosphorus concentrations and/or exacerbated algae blooms.

Cons

If no action is taken, fish in lakes that experience DO concentrations of less than 3.0 mg/l (bass/bluegill/pike) or 5.0 mg/l (trout) throughout the water column can suffer severe oxygen stress. Under severe DO depletion in summer or winter, fish kills can occur. Lakes that frequently experience low DO concentrations throughout the water column usually can only support tolerant fish species such as carp and green sunfish. Also, some lakes have a small amount of the lake volume that has sufficient oxygen (<30%) which is entirely in the sunlit zone. Fish are squeezed into a smaller volume and can be easily seen, which may cause increased predation leading to an unbalanced fish population. A high quality fishery will be difficult to sustain or achieve under these circumstances. Other aquatic organisms such as invertebrates require 4.0 mg/l to avoid severe oxygen stress. Besides the direct effects to aquatic organisms, low DO levels (<1 mg/l) can lead to increased release of phosphorus from the sediment that can fuel algal blooms when mixed into the sunlit zone. It also leads to the buildup of chemically reduced compounds such as ammonium and hydrogen sulfide (H_2S, rotten egg gas) which can be toxic to bottom dwelling organisms. In extreme cases, sudden mixing of H_2S into the upper water column can cause fish kills. These gases are released causing potential odor problems and reduced enjoyment for lakeside residents. Since aerobic (with oxygen) decomposition breaks down organic matter faster than anaerobic (without oxygen), organic matter may buildup faster in the sediment due to low DO concentrations.

Cost:
There is no cost associated with the no action option.

Option 2: Aeration via Artificial Circulation

Artificial circulation of lakes has been employed as a management technique since at least the early 1950s. Initially it was used to prevent fish kills during winter in shallow, ice-covered lakes. Since the 1960s it has also been used as a technique to obtain additional water quality improvements and control nutrient enrichment. Artificial circulation is probably the most widely used lake management technique for lake rehabilitation.

The principal, and probably most reliable if properly sized, effect of artificial circulation is to raise the DO content throughout the lake. In fact, artificial circulation should be called stratification prevention, as the mixing process prevents thermal stratification. This lack of stratification allows water undersaturated with oxygen to come in contact with the air at the surface permitting oxygen diffusion to occur. While the vertical movement of water is usually achieved by entraining water through releasing compressed air at some depth, little oxygen increase is achieved through direct diffusion from bubbles (King, 1970; Smith et al. 1975). In order to vertically move the entire water volume, the system must be sized properly. A recommended air flow rate for a typical disk diffuser aeration system is equivalent to 1.33 standard cubic feet per minute (scfm) per lake surface acre (Lorenzen and Fast, 1977). Case studies have shown that artificial circulation can be achieved at a flow rate as low as 0.7 scfm/acre (Kortmann, personal communication 2001). Our Unit recommends that the minimum sizing flow rate should be 0.9 scfm/acre, but to ensure success to use 1.33 scfm/acre as finances allow. The higher flow rate per acre should be chosen for lakes that strongly stratify thermally and that have very high relative thermal resistance to mixing. The physical shape of the lake should also be considered. Mixing a lake that is shaped like a “martini glass” is a lot easier than mixing a big “spaghetti” bowl. Lakes shaped like a martini glass that have a single deep hole may only require one diffuser that can handle the required flow rate. Whereas, a lake with multiple holes and bays may require several diffusers and a flow manifold to properly distribute the required airflow. Lakes that are less than 6 feet deep rarely stratify in the summer and usually do not benefit from this option as they are already circulated. These shallow lakes may benefit from this option in the winter months.

There are several types and manufacturers of electrical compressors and blowers on the market and even windpowered systems that force the required airflow through submersed tubing to a diffuser or air stone that releases the air and circulates the water column. The most commonly used electrical compressor is a carbon vane compressor. This compressor operates at low pressure (usually below 10 pounds per square inch or PSI) and produces a large volume of airflow. This type of compressor is designed for continual operation, low maintenance and has the average lifespan of 15-25 years. This type of compressor works well in lakes that are less than 25 feet deep as water pressure effects performance. These compressors do not require oil for lubrication and thus, no oil will move into the lake with the compressed air. Some rotary vane compressors only operate at 5 PSI and thus would not work well in lakes deeper than 11 feet. For these deeper lakes, or for large airflow requirements, electrical high-pressure units such as piston or rotary screw compressors are utilized. These compressors can operate at or higher than 100 PSI, which can easily overcome lake water pressure effects for all lakes in Lake County. Some of the piston compressors, like the rotary vanes are oil-free, whereas the rotary screw compressors all require oil for lubrication. Special biodegradable oils are a must as miniscule quantities of oil are carried in the air to the lake. Both compressors are also for continuous operation, although the rotary screws do require more maintenance than the oil-free piston and rotary vane compressor. Additionally, the higher operating pressure does reduce the amount of airflow generated by the compressor and more horsepower may be required than a low-pressure system.

There are several types and manufacturers of diffusers. They are generally subdivided into fine and coarse bubble units. All diffusers are rated for a specific minimum and maximum flow rate. It is very important to properly size the diffusers with the amount of compressed airflow to ensure performance. Most fine bubble units are either a membrane air diffuser or an air stone. The major advantages of the membrane air diffuser are low maintenance, ease of installation and higher oxygen transfer efficiency. Air stones tend to produce a medium bubble and may need to be removed and cleaned with acid if clogging occurred. Coarse bubble diffusers are also low maintenance, easy to install, but may provide less oxygen transfer efficiency. However, they are able to transfer more oxygen to the water since they can operate at much higher gas flow rates with less required pressure than the fine bubble units. Line diffusers (soaker hoses) consist of porous hose lines that distribute small bubbles over a large area near the water bottom. They, like fine bubble units, produce high oxygen transfer efficiencies. However, if high gas flow rates are required, the length of hose must be extended. Simple slits in the air tubing can also cause mixing to occur. This is usually used in winter aeration strategies to open specific areas of lake ice.

Pros

When properly sized for the lake, these systems can improve DO concentrations in the water column to help prevent fish kills and increase habitat for aquatic life. Zooplankton and warmwater fish such as bass and bluegill can inhabit a larger volume of the lake, due to higher DO concentrations throughout the lake.

Algal blooms may be controlled, possibly through one or more of these processes: 1) mixing to the lake’s bottom will increase an algae cell’s time in darkness, leading to reduced net photosynthesis due to light limitation; 2) introduction of dissolved oxygen to the lake’s bottom may inhibit phosphorus release from sediments; 3) rapid contact of water with the atmosphere, as well as the introduction of carbon dioxide-rich water during the initial period of mixing, can lower pH, leading to a shift from blue-greens to less noxious green algae; and 4) when zooplankton are mixed to the lake’s bottom, they are less vulnerable to sight-feeding fish, resulting in the increase of consumption of algal cells by the zooplankton (Olem & Flock, 1990; Lorenzen and Fast, 1977; Vandermeulen, 1992).

Internal loading of phosphorus can theoretically be decreased through increased circulation. By aerating the sediment-water interface of lakes where iron is controlling phosphorus solubility, phosphorus would be prevented from migrating into the water column.

Artificial circulation in winter can help alleviate low oxygen conditions when the systems are able to keep about 2.3% of the lake's surface free from snow and ice cover (Wirth, 1988). Usually, critically low DO concentrations do not appear until late in winter. Weekly DO measurements may be necessary to determine the need for operating an aeration system. If the lake's DO was found to be 4.0 mg/L less than 2 to 3 feet below the ice, operation of the aeration system should begin.

Cons

Mixing anoxic water from the hypolimnion (deep water) with oxygen poor surface waters can cause DO concentrations in the entire water column to fall below the amount needed for fish survival. Aeration systems should be started just after spring/fall turnover to avoid this situation. Also if artificial circulation is only used during the winter and the DO concentration is well below 4.0 mg/l near the surface, it may be too late to activate the aeration system. Mixing the anoxic water near the bottom with marginally oxygenated water near the surface can cause the entire water column to have DO concentrations below what is needed for fish survival.

Calcium may control phosphorus solubility in most of the hardwater Lake County lakes or the iron/phosphorus ratio may be too low, in which case the phosphorus release rate could be largely a function of aerobic decomposition of organic matter (Kamp-Nielsen, 1975). In that event, internal phosphorus loading may actually increase as temperature at the sediment-water interface is raised in the circulation process. Also, some sediments have a high organic and water content and are very flocculent, and may have a high loosely bound phosphorus fraction (Bostrom, 1984) which may be disturbed causing increased loading. If nutrient-rich waters are brought to the surface by the circulating water, algae and plant growth can become a greater nuisance. For shallow lakes where light is not a limiting factor, algae populations may not decrease. In some lakes, they may actually increase, as explained above.

Depending on the size and type of the compressor(s), seasonal or annual electrical costs may run in the hundreds or thousands of dollars. Some Lake Associations utilize the entire annual budget on electrical costs and maintenance of the aeration system. Therefore, proper sizing and monitoring of the aeration system's performance is requisite.

Costs

After a 1991 lake study by Harza Engineering, it was recommended that a high pressure artificial aerator with 10 diffusers be installed in North Bay, Turtle Bay and the channel between these two bays and the main lake. This recommendation was carried out by J.S. James Co., the original developers of Lake Barrington Shores. The main compressor was located on border of the Forest Preserve property along North and Turtle Bays. The following year, the lake was turned over to the Lake Barrington Shores Homeowners Association. Due to problems with the harvester cutting the aeration lines and noise complaints from residents, the aerators were shut down and removed prior to 1996. In 1997, the Homeowners Association installed four small aerators in the lake and have been maintaining them for the past four years. Three are located in North Bay and one is located in Mallard Bay. These are 1 HP turbo motors which are mounted on floats. The systems work by taking air from the water surface and blowing it down into the water column. All three aerators in North Bay are pointed toward the west, attempting to create flow in that area. The aerators were installed in order to increase oxygen concentrations and to break up filamentous algae mats in the Bay. The turbo motor in Mallard Bay works in the same manner and was also installed to break up and redistribute filamentous algae that was blown into the Bay during the summer.

Another aerator for the main body of the lake should be located in or near the deep hole (Figure 1). The recommended aerator for the main lake is a rotary screw unit, requiring 17.1-24.0 HP at a cost of $6,377-$7,668. Since the main body of Lake Barrington is so elongated, a long pipe diffuser should be attached to the rotary screw unit. A 1 ¼ inch 1.25 psig polyethylene pipe with ½ inch holes drilled every 2-3 feet should be run the length of the lake. This design will most closely resemble a course bubble diffuser in terms of bubble size. Approximately 3,600 feet of weighted pipe, at a cost of $6,264-$7,272 will be needed to reach the entire length of the lake (with the exception of North Bay). If a 20 HP unit is used, electricity usage is approximately 13.3 kw/hr. If the system is run from mid-May (before stratification begins) through the end of August, electricity costs will be approximately $3,550 per summer (if the residential electricity rate of $.08/kwh applies). Additional costs will be incurred for housing the compressor and miscellaneous installation costs. The total cost for the installation of an adequate aeration unit for Lake Barrington could be as high as $20,000. As mentioned above, yearly electricity and maintenance costs of approximately $3,500 will be incurred after the unit has been installed. However, if aeration of the lake reduces or eliminates algae blooms and leads to an increase in native aquatic plants, the costs incurred for herbicide treatments each year may be eliminated.

Option 3. Reduce Lake Phosphorus Concentrations

If a lake has an overabundance of plants and algae, severe oxygen losses can occur if they rapidly die and decompose. Reducing phosphorus can decrease algal populations and (possibly) plant populations. In-lake phosphorus can be reduced by using alum (aluminum sulfate). Alum does not directly kill algae as copper sulfate does. Instead, alum binds phosphorus, making it unavailable, thus reducing algal growth. Alum binds water-borne phosphorus and forms a flocculent layer that settles on the bottom. This floc layer can then prevent sediment bound phosphorus from entering the water column through internal loading. Phosphorus inactivation using alum has been in use for 25 years. However, cost and sometimes unreliable results deterred its wide spread use. Currently, alum is commonly being used in ponds and small lakes, and its use in larger lakes is increasing. Alum treatments typically last 1 to 20 years depending on various parameters. Lakes with low mean depth to surface area ratio benefit more quickly from alum applications, while lakes with high mean depth to surface area ratio (thermally stratified lakes) will see more longevity from an alum application due to isolation of the flocculent layer. Lakes with small watersheds are also better candidates because external phosphorus sources can be limited. Alum treatments must be carefully planned and carried out by an experienced professional. If not properly done, there may be many detrimental side effects. One of the most serious side effects has to do with pH. The application of alum can dramatically reduce the pH of a lake, resulting in the formation of toxic, soluble forms of aluminum and the death of many aquatic organisms.

In 1991, Harza Engineering performed alum dose tests on the sediments of Lake Barrington to determine how much alum would be necessary to reduce water column phosphorus concentrations and inactivate internal phosphorus loading throughout the lake. Jar tests and drum tests indicated that an alum dose of 20 ppm would remove more than 80% of total phosphorus, while keeping the pH at a safe level. It was determined that the alkalinity of Lake Barrington was high enough and that buffered alum would not be required. The total amount of alum necessary to reach a concentration of 20 ppm was between 215 and 240 dry tons. A rough estimate of the cost of an alum application of this magnitude at $0.35-$0.60/pound is $150,000-$288,000. If liquid alum was used, it was determined that approximately 38,000-44,000 gallons would be needed. Using phosphorus concentrations from the 2001 study, rough calculations indicated that the alum dose calculated by Harza was reasonable. However, if an alum application were carried out in the near future, it is recommended that new jar and drum tests be performed to ensure that an adequate amount of alum is applied to the lake. An alum application would probably dramatically reduce the amount of phosphorus in Lake Barrington and prevent internal phosphorus loading for several years. However, due to the shallow, polymictic nature of Lake Barrington, the longevity of an alum application may not be more than 3-5 years. Given the high cost of the treatment, it may be financially risky to consider alum as an algae management option at this time.

Objective II: Eliminate or Control Invasive Species

Numerous exotic plant species have been introduced into our local ecosystems. Some of these plants are aggressive, quickly out-competing native vegetation and flourishing in an environment where few natural predators exist. Plants such as purple loosestrife (*Lythrum salicaria*), buckthorn (*Rhamnus cathartica*), and reed canary grass (*Phalaris arundinacea*) are three examples. The outcome is a loss of plant and animal diversity. This section will address terrestrial shoreline exotic species.

Purple loosestrife is responsible for the "sea of purple" seen along roadsides and in wetlands during summer. It can quickly dominate a wetland or shoreline. Due in part to an extensive root system, large seed production (estimates range from 100,000 to 2.7 million seeds per plant), and high seed germination rate, purple loosestrife spreads quickly. Buckthorn is an aggressive shrub species that grows along lake shorelines as well as most upland habitats. It shades out other plants and is quick to become established on disturbed soils. Reed canary grass is an aggressive plant that if left unchecked will dominate an area, particularly a wetland or shoreline, in a short period of time. Since it begins growing early in the spring, it quickly out-competes native vegetation that begins growth later in the year. Control of purple loosestrife, buckthorn, and reed canary grass are discussed below. However, these control measures can be similarly applied to other exotic species such as garlic mustard (*Allilaria officianalis*) or honeysuckle (*Lonicera* spp.) as well as some aggressive native species, such as box elder (*Acer negundo*).

Presence of exotic species along a lakeshore is by no means a death sentence for the lake or other plant and animal life. If controlled, many exotic species can perform many of the original functions that they were brought here for. For example, reed canary grass was imported for its erosion control properties. It still contributes to this objective (offering better erosion control than commercial turfgrass), but needs to be isolated and kept in control. Many exotics are the result of garden or ornamental plants escaping into the wild. One isolated plant along a shoreline will probably not create a problem by itself. However, problems arise when plants are left to spread, many times to the point where treatment is difficult or cost prohibitive. A monitoring program should be established, problem areas identified, and control measures taken when appropriate. This is particularly important in remote areas of lake shorelines where the spread of exotic species may go unnoticed for some time. Although exotic species were found along over 60% of the shoreline of Lake Barrington, the density of these plant species was not extremely high. Therefore, control measures should be carried out before these exotics reach nuisance levels.

Option 1: No Action

No control will likely result in the expansion of the exotic species and the decline of native species. This option is not recommended if possible.

Pros

There are few advantages with this option. Some of the reasons exotics were brought into this country are no longer used or have limited use. However, in some cases having an exotic species growing along a shoreline may actually be preferable if the alternative plant is commercial turfgrass. Since turfgrass has shallow roots and is prone to erosion along shorelines, exotics like reed canary grass or common reed (*Phragmites australis*) will control erosion more effectively. Native plants should take precedent over exotics when possible. Table 6, Appendix A lists several native plants that can be planted along shorelines.

Cons

Native plant and wildlife diversity will be lost as stands of exotic species expand. Exotic species are not under the same stresses (particularly diseases and predators) as native plants and thus can out-compete the natives for nutrients, space, and light. Few wildlife species use areas where exotic plants dominate. This happens because many wildlife species either have not adapted with the plants and do not view them as a food resource, the plants are not digestible to the animal, or their primary food supply (i.e., insects) are not attracted to the plants. The result is a monoculture of exotic plants with limited biodiversity.

Recreational activities, especially wildlife viewing, may be hampered by such monocultures. Access to lake shorelines may be impaired due to dense stands of non-native plants. Other recreational activities, such as swimming and boating, may not be effected.

Costs

Costs with this option are zero initially, however, when control is eventually needed, costs will be substantially more than if action was taken immediately. Additionally, the eventual loss of ecological diversity is difficult to calculate financially.

Option 2: Biological Control

Biological control (bio-control) is a means of using natural relationships already in place to limit, stop, or reverse an exotic species' expansion. In most cases, insects that prey upon the exotic plants in its native ecosystem are imported. Since there is a danger of bringing another exotic species into the ecosystem, state and federal agencies require testing before any bio-control species are released or made available for purchase.

Recently two beetles (*Galerucella pusilla* and *G. calmariensis*) and two weevils (*Hylobius transversovittatus* and *Nanophyes marmoratus*) have offered some hope to control purple loosestrife by natural means. These insects feed on either the leaves or juices of purple loosestrife, eventually weakening or killing the plant. In large stands of loosestrife, the beetles and weevils naturally reproduce and in many locations, significantly retard plant densities. The insects are host specific, meaning that they will attack no other plant but purple loosestrife. Currently, the beetles have proven to be most effective and are available for purchase. There are no designated stocking rate recommendations, since using bio-control insects are seen as an inoculation and it may take 3-5 years for beetle populations to increase to levels that will cause significant damage. Depending on the size of the infested area, it may take 1,000 or more adult beetles per acre to cause significant damage.

Pros
Control of exotics by a natural mechanism if preferable to chemical treatments. Insects, being part of the same ecological system as the exotic (i.e., the beetles and weevils and the purple loosestrife) are more likely to provide long-term control. Chemical treatments are usually non-selective while bio-control measures target specific plant species. This technique is beneficial to the ecosystem since it preserves, even promotes, biodiversity. As the exotic dies back, native vegetation can reestablish the area.

Cons
Few exotics can be controlled using biological means. Currently, there are no bio-control techniques for plants such as buckthorn, reed canary grass, or a host of other exotics. One of the major disadvantages of using bio-control is the costs and labor associated with it.

Use of biological mechanisms to control plants such as purple loosestrife is still under debate. Similar to purple loosestrife, the beetles and weevils that control it are not native to North America. Due to the poor historical record of introducing non-native species, even to control other non-native species, this technique has its critics.

Costs
The New York Department of Natural Resources at Cornell University (607-255-2821) sells overwintering adult beetles (which will lay eggs the year of release) for $2 per beetle and new generation beetles (which will lay eggs beginning the following year) at $0.25 per beetle. Some beetles may be available for free by contacting the Illinois Natural History Survey (217-333-6846).

Option 3: Control by Hand

Controlling exotic plants by hand removal is most effective on small areas (< 1 acre) and if done prior to heavy infestation. Some exotics, such as purple loosestrife and reed canary grass, can be controlled to some degree by digging, cutting, or mowing if done early and often during the year. Digging may be required to ensure the entire root mass is removed. Spring or summer is the best time to cut or mow, since late summer and fall is when many of the plant seeds disperse. Proper disposal of excavated plants is important since seeds may persist and germinate even after several years. Once exotic plants are removed, the disturbed ground should be planted with native vegetation and closely monitored. Many exotic species, such as purple loosestrife, buckthorn, and garlic mustard are proficient at colonizing disturbed sites.

Pros
Removal of exotics by hand eliminates the need for chemical treatments. Costs are low if stands of plants are not too large already. Once removed, control is simple with yearly maintenance. Control or elimination of exotics preserves the ecosystem's biodiversity. This will have positive impacts on plant and wildlife presence as well as some recreational activities.

Cons
This option may be labor intensive or prohibitive if the exotic plant is already well established. Costs may be high if large numbers of people are needed to remove plants. Soil disturbance may introduce additional problems such as providing a seedbed for other non-native plants that quickly establish disturbed sites, or cause soil-laden run-off to flow into nearby lakes or streams. In addition, a well-established stand of an exotic like purple loosestrife or reed canary grass may require several years of intense removal to control or eliminate.

Costs
Cost for this option is primarily in tools, labor, and proper plant disposal.

Option 4: Herbicide Treatment

Chemical treatments can be effective at controlling exotic plant species. However, chemical treatment works best on individual plants or small areas already infested with the plant. In some areas where individual spot treatments are prohibitive or unpractical (i.e., large expanses of a wetland or woodland), chemical treatments may not be an option due to the fact that in order to chemically treat the area a broadcast application would be needed. Since many of the herbicides that are used are not selective, meaning they kill all plants they contact; this may be unacceptable if native plants are found in the proposed treatment area.

Herbicides are commonly used to control nuisance shoreline vegetation such as buckthorn and purple loosestrife. Herbicides are applied to green foliage or cut stems. Products are applied by either spraying or wicking (wiping) solution on plant surfaces. Spraying is used when large patches of undesirable vegetation are targeted. Herbicides are sprayed on growing foliage using a hand-held or backpack sprayer. Wicking is used when selected plants are to be removed from a group of plants. The herbicide solution is wiped on foliage, bark, or cut stems using a herbicide soaked device. Trees are normally treated by cutting a ring in the bark (called girdling). Herbicides are applied onto the ring at high concentrations. Other devices inject the herbicide through the bark. It is best to apply herbicides when plants are actively growing, such as in the late spring/early summer, but before formation of seed heads. Herbicides are often used in conjunction with other methods, such as cutting or mowing, to achieve the best results. Proper use of these products is critical to their success. Always read and follow label directions.

Pros
Herbicides provide a fast and effective way to control or eliminate nuisance vegetation. Unlike other control methods, herbicides kill the root of the plant, which prevents regrowth. If applied properly, herbicides can be selective. This allows for removal of selected plants within a mix of desirable and undesirable plants.

Cons
Since most herbicides are non-selective, they are not suitable for broadcast application. Thus, chemical treatment of large stands of exotic species may not be practical. Native species are likely to be killed inadvertently and replaced by other non-native species. Off target injury/death may result from the improper use of herbicides. If herbicides are applied in windy conditions, chemicals may drift onto desirable vegetation. Care must also be taken when wicking herbicides as not to drip on to non-targeted vegetation such as native grasses and wildflowers. Another drawback to herbicide use relates to their ecological soundness and the public perception of them. Costs may also be prohibitive if plant stands are large. Depending on the device, cost of the application equipment can be high.

Costs
Two common herbicides, triclopyr (sold as Garlon™) and glyphosate (sold as Rodeo® or Round-up™), cost approximately $100 and $65 per gallon, respectively. Only Rodeo® is approved for water use. A Hydrohatchet®, a hatchet that injects herbicide through the bark, is about $300.00. Another injecting device, E-Z Ject® is $450.00. Hand-held and backpack sprayers costs from $25-$45 and $80-150, respectively. Wicking devices are $30-40.