2002 SUMMARY REPORT
of
LAKE LINDEN

Lake County, Illinois

Prepared by the

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EXECUTIVE SUMMARY

Lake Linden, located in Lake Villa Township, was created in the early 1960's by developer, Mort Eagle, and construction of homes began immediately after the lake was created. The lake has a surface area of 31acres and a mean depth of 4.8 feet. It is located entirely within the village limits of Lindenhurst and is used by Lindenhurst village residents for swimming, boating and fishing. It has two beaches, a park and a boat launch on 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 2002. Lake Linden was fully mixed in nearly all parts of the lake and dissolved oxygen levels remained high throughout the water column until September. Phosphorus levels were relatively low throughout the summer, and the most likely source of phosphorus was tied to filamentous algae. Filamentous algae was treated with copper sulfate twice per month from May-September. Filamentous algae utilizes phosphorus from the lake sediment before it rises to the water surface. When this algae is chemically treated and begins to decompose, the accumulated phosphorus is released into the water column, where it can be utilized by other algae. Secchi depth was relatively high all summer. Historical VLMP data indicates that Secchi depth reached a low of 2.25 feet in 1995, before increasing and finally leveling off in the past few years. Conductivity levels have increased since our last study, conducted in 1996. Factors contributing to this increase may include cumulative road salt loads to the lake, some environmental factor such as bacteria levels in the lake and/or a change in soil chemistry in the watershed.

Chara dominated the plant community in 2002. Very small amounts of curly leaf pondweed, small pondweed, sago pondweed, horned pondweed, water star grass and wild celery were also observed. Filamentous algae was treated throughout the summer with copper sulfate, and Sonar™ was used to treat curly leaf pondweed, sago pondweed and leafy pondweed. The plant management plan for Lake Linden appears to be successfully treating the target plant species. However the village may want to reconsider the biweekly treatment of filamentous algae, as it (or environmental factors) may also be negatively impacting the *Chara* present in the lake. Reducing the health of *Chara*, may actually increase algae density, requiring more frequent algaecide treatments over the course of the summer. Additionally, the Sonar™ concentration could be reduced and, by utilizing FasTEST, lake managers could ensure that the desired concentration is maintained throughout the application period.

Although very little erosion was occurring around Lake Linden, buckthorn, purple loosestrife, bull thistle, multiflora rose and reed canary grass were present along 26% of the shoreline. These are exotic plant species that out-compete native vegetation and provide poor habitat for wildlife. A relatively large number of waterfowl and bird species were observed during the summer, despite the dominance of residential shoreline.

LAKE IDENTIFICATION AND LOCATION

Lake Linden is located in Lake Villa Township, north of IL State Rte. 132 and west of U.S. Hwy 45 (T 46N, R 21E, S 35), and is entirely within the village limits of Lindenhurst. Lake Linden has a surface area of 31 acres, mean and maximum depths of 4.8 feet and 11.0 feet, respectively, and a volume of 147.4 acre-feet (Figure 1, Appendix A). The lake receives its water input from numerous storm pipes that drain residential land during rain events. It has no natural inlet. The lake is located in the North Mill Creek sub basin of the Des Plaines River watershed. Water exits via a dam on the southwest shore and runs along the edge of a wetland area before flowing into Hastings Lake from the southeast.

BRIEF HISTORY OF LAKE LINDEN

Lake Linden was created in the early 1960's by placing the current dam across a narrow section of marshland. The creator and original owner of the lake was Mort Eagle, a residential developer who began development around the lake as soon as it was created. The Lindenhurst Lakes Commission was formed in the early 1990's to manage the lake.

SUMMARY OF CURRENT AND HISTORICAL LAKE USES

Access to Lake Linden is open to residents of the Village of Lindenhurst and their guests. Three general access points exist around the lake. Linden's Landing is located on the south end of the lake and provides a beach and boat launch. Meyers Beach is located on the northwest side of the lake and Beck Basin (a picnic area) is located on the northeast side of the lake (Figure 2). The lake's main uses are swimming, boating and fishing in the summer, and ice skating in the winter. Gas motors (even on transom in locked position) are not permitted on the lake. The Lindenhurst Lakes Commission currently meets every other month or on special call. The annual budget for management of the lake is approximately $16,000, and currently, the biggest management concerns include filamentous algae and problems with the emergent plantings and seeding program, such as grazing by muskrats and/or raccoons.

Linden's Landing Beach and Meyers Beach were sampled every two weeks (from May to September) by the Lake County Health Department to test for the presence of high *E. coli* counts. *E. coli* bacteria is found virtually everywhere, but is in very high numbers in the feces of animals and humans. The bacteria may indicate the presence of other pathogens such as *Giardia*, which can cause serious illness in humans. In 2002, Linden's Landing Beach was closed on June 18th, July 3rd, July 16th, and July 30th due to *E. coli* concentrations that exceeded 235 colonies/100 mL. Meyers Beach was not closed during 2002. In the past five years, Linden's Landing Beach has been closed three other times (once in 1997 and twice in 2000), but Meyers Beach has not been closed a single time in the past five years. The high counts at Linden's Landing can be caused by a number of things, including a large number of waterfowl, stormwater inflow, 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 *E. coli*. When these wastes make their way into the water, they can cause high *E. coli* counts. Rain events can increase *E. coli* counts because as rain runs over the land, it picks up high numbers of *E. coli* which are then washed into the lake. On both dates that Linden's Landing Beach was closed in 2000 and on two of the four dates the beach was closed in 2002, the high *E. coli* numbers appear to have been caused by rain. Ten stormwater pipes flow into Lake Linden at different locations. Linden's Landing Beach is flanked on either side by storm pipes that drain ditches and grass swales, while Meyers Beach is has a large stormwater pipe entering along the south end that drains curb and gutter areas. The higher volume of storm water entering Lake Linden at Linden's Landing and the fact that those storm pipes drain grass swale areas goes a long way in explaining the higher number of closures at Linden's Landing vs. Meyer's Beach. Animal waste and other organic substances are typically more abundant along grass swales than along curbed areas. As storm water flows along these swales, it is probably picking up a relatively large amount of bacteria and other materials. Bacteria is picked up by storm water flowing along curb and gutter areas as well, but the amount is probably lower when compared to grassy areas. Additionally, the amount of residential land drained by the storm pipes that enter Linden's Landing is much larger than the amount of land drained by the pipe entering Meyer's Beach, providing more bacteria laden water to the Linden's Landing Beach area during rain events.

LIMNOLOGICAL DATA – WATER QUALITY

Water samples collected from Lake Linden were analyzed for a variety of water quality parameters (See Appendix B for methodology). Samples were collected at 3 foot and 6 foot depths from the deep hole location in the lake (Figure 2). Lake Linden was weakly thermally stratified in the deepest area of the lake on the June and August 2002 sampling dates. 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 in nutrient-enriched lakes.
A lake that remains thermally stratified all summer is considered dimictic. This is typical of deep lakes. Conversely, a polymictic lake stratifies and destratifies many times during the summer. This is more commonly seen in shallow lakes. Based on the data collected in the deep bay on the eastern side of the lake, Lake Linden appears to be undergoing intermittent stratification at a depth of 6.0 feet. Since nearly all of Lake Linden is shallower than 6.0 feet, the lake as a whole can be considered monomictic (does not thermally stratify). Near surface dissolved oxygen (DO) concentrations remained above 5.0 mg/l (a level below which aquatic organisms become stressed) until September, when DO fell to 2.7 mg/l at the water surface. Near-bottom DO concentrations fell below 5.0 mg/l during August and September, but bottom waters did not become anoxic (Table 1, Appendix A).

As a side note regarding DO concentrations, there are discrepancies between several of the DO measurements reported by McCloud Aquatic Services during their algaecide and herbicide applications and DO measurements obtained by the Lakes Management Unit (LMU) during our study (Table 2, Appendix A). Although the differences that occurred during May, June and July were not substantial and probably did not have an impact on aquatic life, the differences in August and September could have resulted in detrimental impacts to the fish community, especially in September. The LMU measurement of 2.17 mg/l on September 3 (versus the measurement of 7.0 mg/l by McCloud on September 4) is far below the concentration limit of 5.0 mg/l mentioned above. If the DO concentration remained this low the following day and a copper sulfate treatment was conducted, the ensuing oxygen decline that always accompanies such a treatment could have resulted in a significant fish kill. Although this was not the outcome, the Village may want to investigate the methodology being used by McCloud Aquatic Services to measure DO concentrations and determine if instruments are being properly calibrated and maintained and methodology is up to date. Additionally, the Lindenhurst Lakes Commission may want to require that a specific DO concentration be attained before algaecide application is allowed.

Phosphorus (P) 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 total phosphorus (TP) concentration in Lake Linden was 0.042 mg/l, slightly less than most of the lakes in the County studied since 1998 (county median = 0.056 mg/l). The average hypolimnetic TP concentration was 0.053 mg/l, much lower than the hypolimnetic county median of 0.170 mg/l. The hypolimnetic concentration in Lake Linden was so much lower than most lakes in the county because the hypolimnion remained oxygenated throughout the summer. During stratification, TP concentrations typically increase dramatically in the hypolimnion due to chemical reactions that occur when oxygen is depleted. Since stratification was very weak and very little of the water volume was incorporated in the hypolimnion, dissolved oxygen concentrations did not fall below 1.0 mg/l in Lake Linden. As a result, TP concentrations near the sediment were not as high as they might have been in an anoxic environment. Both epilimnetic and hypolimnetic TP concentrations increased gradually each month from May-September, with hypolimnetic concentrations remaining 15-25% higher than epilimnetic concentrations (Table 1, Appendix A). Although anoxic conditions did not exist in Lake Linden during the summer of 2002, the primary source of phosphorus to the lake appears to be internal.

The average epilimnetic TP concentration (0.042 mg/l) has increased slightly since the 1996 study conducted on Lake Linden, when the average TP concentration was 0.034 mg/l. Although this increase (24%) does not appear to be large, it may be an indication that nonpoint sources of phosphorus are increasing or that phosphorus build-up in the sediment is increasing as a result of increased development or poor lawn care and home maintenance practices in the watershed of the lake. Care should be taken and education of homeowners in the watershed should be carried out to ensure that the current phosphorus levels in Lake Linden do not continue to increase in future years.

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. The average epilimnetic TSS concentration (2.3 mg/l) in Lake Linden was less than half of the county median (6.0 mg/l). Typically in eutrophic lakes, TP and TSS concentrations are correlated because high TP levels lead to an increase in planktonic algae and TSS levels rise as a result of the algae bloom. Additionally, if high TSS concentrations result from planktonic algae, TSS and total volatile solids (TVS- a measure of organic solids such as algae) will be correlated as well. These two relationships (TP vs. TSS and TVS vs. TSS) did not exist in Lake Linden. The relationships may not have been apparent due to the very low concentrations of TSS in the epilimnion and hypolimnion. When concentrations are at very low levels, it can often become difficult to detect relationships between TSS concentrations and other variables. The average epilimnetic TSS concentration in 1996 was 2.9 mg/l, suggesting that TSS levels have actually dropped slightly (-21%) over the past six years. There may be many ways to explain this observation including a shift in the plant community, a shift in the algae community, temperature, rainfall, changes in the chemical treatment schedule or difficulty detecting actual differences in TSS over time. Unfortunately, without more historical data over those six years, it is impossible to know if this apparent decrease in TSS is a long term trend.

In addition to difficulties with assessing low TSS concentrations, the lack of any obvious relationship between TSS and TP may also be explained by the fact that Lake Linden is different from some other eutrophic lakes in that it is dominated by filamentous algae (vs. planktonic algae) and it is treated with copper sulfate throughout the summer. Phosphorus is being released into the water column under oxic conditions in this lake. This means that the phosphorus is not coming directly from the bottom sediment and is tied more closely with organic materials in the water column. The positive relationship between TP and TVS is a good indication of this (Figure 3). One likely organic source of TP to the water is filamentous algae in Lake Linden. This type of algae begins its life cycle on the sediment surface, acquiring nutrients from the sediment before floating to the water surface as water temperature warms. Chemical treatments were conducted on Lake Linden for algae control at least twice per month from May-September 2002. These treatments kill the algae floating on the surface, and the stored phosphorus is released from the algae into the water as it decomposes. The amount of algae present in Lake Linden increased as the summer progressed, resulting in the gradual increases in epilimnetic concentrations of TP and TVS observed throughout the summer (Figure 3). The higher TP concentrations near the lake bottom likely resulted from a combination of phosphorus release from algae on the sediment and release from resuspension in the lower water column.

Secchi depth (water clarity) in Lake Linden was relatively high throughout the summer, reaching the lake bottom (approximately 8.7 feet) in June and declining to 4.82 feet in August. Decreases in Secchi depth coincided with increases in TSS as the summer progressed (Figure 4). As algae density increased and was continually treated throughout the summer, a general increase in TSS was also observed. The decomposition of the algae cells and increase in TSS lead to a general decrease in Secchi depth from June to August. A volunteer lake monitoring program (VLMP) has been in place on Lake Linden since 1993. 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. Average Secchi depth in Lake Linden was very high in 1993, declined to a low in 1995 and gradually increased throughout the late 1990's. Average Secchi depth was above average in 2000 due to a cool, rainy summer, but has remained relatively constant throughout the past 5-6 years (Figure 5). Because a rotenone treatment had been conducted in 1991, killing most of the carp in the lake and allowing dense plant growth, the average Secchi depth in 1993 was very high. Spot treatments of herbicide began in 1992 to treat several different species of plants. A combination of high algae densities as a result of above average air temperatures and the first whole-lake application of Sonar™ in 1995 was most likely the cause of the low Secchi depth that year. The gradual increase and leveling off of Secchi depth since 1996 may be a reflection of the stabilization of the lake ecosystem since the rotenone treatment and the start of whole-lake herbicide treatments.

Conductivity is the measure of different chemical ions in solution. As the concentration of these ions increases, conductivity increases. The conductivity of a lake is dependent on the lake and watershed geology, the size of the watershed flowing into the lake, the land uses within that watershed, and evaporation and bacterial activity. Conductivity has been shown to be highly correlated (in urban areas) with chloride ions found in road salt mixtures. Water bodies most subject to the impacts of road salts are streams, wetlands or lakes draining major roadways. Average 2002 epilimnetic and hypolimnetic conductivities (0.9772 mS/cm and 0.9777 mS/cm, respectively) in Lake Linden had increased since sampling in 1996 when averages were 0.836 mS/cm and 0.834 mS/cm, respectively. The 2002 levels were also much higher than the county averages (0.7570 mS/cm and 0.7994 mS/cm, respectively) throughout the summer (Table 1, Appendix A). Chloride concentrations tested in September water samples were not extremely high (205 mg/l and 203 mg/l, respectively). However, in a study by Environment Canada (equivalent to our USEPA), it was estimated that 5% of aquatic species such as fish, zooplankton and benthic invertebrates would be affected at chloride concentrations of about 210 mg/l. Additionally, shifts in algae populations in lakes were associated with chloride concentrations as low as 12 mg/l. Epilimnetic total dissolved solids (TDS) concentrations, which have also been shown to be correlated with conductivity, were above the county average (449 mg/l) in Lake Linden during every month of the study (Table 1, Appendix A).

Conductivity changes can occur seasonally and even with depth, but over the long term, increased conductivity levels can be a good indicator of potential watershed or lake problems or an increase in pollutants entering the lake if the trend is noted over a period of years. High conductivity levels (which often indicate an increase in sodium chloride) can eventually change the plant community, as more salt tolerant plants take over. Sodium and chloride ions can bind substances in the sediment, preventing their uptake by plants and reducing native plant densities. Additionally, juvenile aquatic organisms may be more susceptible to high chloride. The general increase in conductivity levels observed in Lake Linden in the six years since the lake was last sampled may be the cumulative result of years of salt laid down on surrounding roads and the widening of some of the roads in the watershed. However, the seasonal increase in conductivity between May and September does not support the suggestion that road salt is the only variable playing a role. Typically, when road salt is the cause of an increase in conductivity, levels will be very high in May and June, when spring runoff brings a large amount of salt-laden water into the lake and then decreases throughout the summer. In Lake Linden, conductivity decreased from May-July, but then increased in August and September, to a high of 1.037 mS/cm on September 4, 2002. This suggests that some other factor in the lake or watershed is affecting conductivity. It is impossible to know what that factor is, but it could be related to any number of things, including a shift in soil chemistry, a change in land use within the watershed, algae treatments of copper sulfate or bacterial activity in the lake. Although the increasing conductivity levels are cause for concern, there may not be much that can be done about it. Non-point runoff, such as that which picks up road salt and enters the lake during rain events, is very difficult to control and it may be unlikely that any control could be placed on the amount of road salt dispersed along surrounding roads each winter without policy changes in quantity or type of de-icer by the Illinois Department of Transportation. Additionally, if another factor besides road salt is contributing to high conductivity, an in-depth study would have to be performed in order to isolate this factor and determine if conductivity could be reduced by changing the factor in some way.

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 Linden had an average TN:TP ratio of 28:1. This indicates that the lake is phosphorus limited and that a small increase in the phosphorus concentration could result in more filamentous algae in the future. In highly nutrient-enriched lakes, phosphorus levels have often reached the point where either very large increases or very large decreases in phosphorus would be necessary to trigger changes in algae density. On the other hand, less enriched lakes, such as Lake Linden, are typically more sensitive to increases or decreases in phosphorus, and planktonic algae, as well as filamentous algae could become a problem with relatively small increases in TP. Care should be taken to ensure that no unnecessary sources of P are created around the lake. This may mean decreasing the amount of fertilizer applied to lawns around the lake, or changing to the use of phosphorus-free fertilizer.

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 moderate TSI value (TSI=40-49) indicates mesotrophic conditions, typically characterized by relatively low nutrient concentrations, low algae biomass, adequate DO concentrations and relatively good water clarity. High TSI values indicate 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 Linden had an average phosphorus TSI (TSIp) value of 58.1, indicating eutrophic conditions (this is up slightly from the 1996 TSIp of 55.0). Lake Linden has relatively good water quality compared to many other lakes that fall into the eutrophic category, and does not have many of the characteristics of eutrophic lakes (listed above). This is most likely the result of frequent algae treatments and relatively high percent plant coverage (of *Chara*). Typically, a lake is either plant or algae dominated and the TSIp index does not always apply when a lake is plant dominated, or when chemical treatments keep algae density very low. When the Secchi depth TSI (TSIsd) for Lake Linden (50.3) is used, the lake is classified as just slightly eutrophic, indicating a less enriched system. As a result of its relatively low average phosphorus concentration, Lake Linden ranks 40th out of 103 lakes studied in Lake County. This is a very high ranking among man-made lakes, which typically fall into the eutrophic and hypereutrophic categories in this geographic area (Table 3, Appendix A). In fact, of the top 40 lakes on the TSI ranking, Lake Linden is one of only 8 man-made lakes. The remainder are either of glacial origin or were originally borrow pits.

Most of the water quality parameters just discussed can be used to analyze the water quality of Lake Linden based on use impairment indices established by the Illinois Environmental Protection Agency (IEPA). According to this index, Lake Linden provides *Full* support of aquatic life, and *Partial* support of swimming and recreation. The lake has *Full* overall use.

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. Copper sulfate was periodically applied to Lake Linden from the early 1970's to the late 1980's for treatment of blue-green and filamentous algae. The lake currently has a plant and algae management plan in place. After the rotenone treatment in 1991 to remove carp, water clarity increased dramatically and the lake was dominated by *Chara* and *Nitella.* Aquathol-K® was applied in 1992 for control of curly leaf pondweed. This is a contact herbicide that only works on submersed plants with which the chemical comes in contact. It is fast-acting, but does not always provide long-term control. Copper sulfate treatments were carried out as needed throughout the summer. In 1993, Aquathol-K® was again applied for control of curly leaf pondweed, *Elodea,* and coontail, and copper sulfate was applied throughout the summer. In 1994 a different contact herbicide, Reward®, was applied for control of curly leaf pondweed, *Elodea,* and coontail and copper sulfate was used to treat filamentous algae. During the summer of 1994, a fish kill occurred in Lake Linden as a result of low dissolved oxygen concentrations. In 1995, the product used for herbicide treatment was changed to the systemic herbicide, Sonar™. This herbicide differs from contact herbicides in that it must be taken up by the plant and kills the entire plant. It takes a longer amount of time to affect the plant, but is a longer lasting treatment that typically does not have to be repeated throughout the summer. In 1995 and 1996, an approximate concentration of 12 ppb was applied. Copper sulfate was also used to treat algae in 1995. Treatments of copper sulfate were carried out each month from May through August 1996 to treat filamentous algae. A single Sonar™ treatment at 12 ppb was applied in April 1996. In 1996, a bathymetric map was created by the Lakes Management Unit and a more accurate application rate could be calculated. From 1997 to the present, Sonar™ has been applied at a "calculated concentration" of 20 ppb in late spring for control of curly leaf pondweed, sago pondweed and leafy pondweed.

The approximate schedule and the types of products used for treatment of aquatic plants and filamentous algae has not changed since 1997. Eleven copper sulfate applications were carried out between May 9, 2002 and September 18, 2002. However, for the past several years, the concentration of Sonar™ has been 20 ppb. In 2002, Sonar™ was applied to treat curly leaf pondweed, sago pondweed and leafy pondweed in early and late May. A whole lake treatment at a calculated concentration of 10 ppb was applied on May 9th and another whole lake treatment of 10 ppb was applied on May 23rd. Based on this information, the amount of Sonar™ placed in the lake totaled 20 ppb, but the concentration of Sonar™ in the lake never reached 20 ppb and should not be reported as such. Sonar™ takes approximately 30 days to be incorporated into plant tissue and begin to kill plants. In that time, Sonar™ can be easily diluted in the water column before it has a chance to begin to affect the target plant species. Although the concentration may start at 10 ppb, it may not remain at that concentration for two weeks until another treatment of 10 ppb is applied.

Although it has not been used in conjunction with the Sonar™ treatments in Lake Linden to date, FasTEST is a product that will quickly and effectively test the concentration of Sonar™ in the water column at different times throughout the application process. It is recommended by SePro, the company who manufactures the product, who indicate on the product label, "When utilizing split or multiple applications of Sonar™ A.S., the utilization of FasTEST is strongly recommended to determine the actual concentration in the water over time." With the use of FasTEST, the actual concentration of Sonar™ could be determined one day after, two weeks after and four weeks after the original application. A check one day after the first application would ensure that the desired concentration was actually achieved, a check two weeks after the first application would allow the applicator to determine if a "bump up" is needed, and, if so, how much product is needed, and a check 4 weeks after the original application would show the actual concentration at 30 days to ensure the Sonar™ concentration is still high enough to remove the target plants. This is very important in determining the degree of dilution occurring in the lake, and will probably save the Village money on herbicide applications. A FasTEST kit costs $100 per sample. It is recommended that a minimum of two locations be sampled each time a FasTEST is conducted. Therefore, the above recommended test schedule would cost approximately $600. This is a small amount of money considering that thousands of dollars could be saved by accurately determining the lowest concentration of Sonar™ that would provide adequate control of the target plant species. It may be that an initial concentration of 10 ppb provides this control as long as an adequate concentration is maintained over a period of 30-40 days, and that the second 10 ppb application is not needed each year. Some Sonar™ may be required for a "bump up" application, but the addition of another 10 ppb application two weeks after the original application may not be necessary. It is recommended that the current "Sonar™ split" treatment method be continued, but that FasTEST be used in the manner outlined above and that the initial target concentration be 10 ppb. The "split" could actually be used as a "bump up" treatment to ensure that an end concentration adequate to remove the target plant species (CLPW) (2-3 ppb) is achieved 30-40 days after the original treatment. The end concentration necessary to remove leafy and sago pondweeds may be higher, and the FasTEST could help determine at what concentration these species are controlled.

In 2002, *Chara* dominated the plant community. Small amounts of curly leaf pondweed, horned pondweed, sago pondweed, small pondweed, wild celery and water star grass were also observed throughout the summer (Tables 4 & 5). During the study, light level was measured at one-foot intervals from the water surface to the lake bottom. When the light intensity 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 Linden could have supported plants over approximately 95% of the lake area, and plants (typically *Chara*) were observed over nearly that surface area during 2002. The inability of aquatic plants to grow in all areas as determined by percent light level may be explained by the presence of inadequate substrate in various parts of the lake or the use of herbicides/algaecides.

The plant and algae management plan for Lake Linden appears to be successfully treating the target plant species of curly leaf pondweed, sago pondweed and leafy pondweed, as very little of these plants were observed in the lake during the summer. However, very few other plant species besides *Chara* existed in the lake. A truly healthy plant community contains a large number of plant species that provide different types of habitat and structure to the lake. As mentioned above, it is recommended that FasTEST be used to determine the lowest possible concentration of Sonar™ that would effectively keep the curly leaf pondweed, sago pondweed and leafy pondweed in check while allowing other beneficial plants such as water star grass and wild celery to thrive. At a lower concentration, native plants should be able to take hold in many areas, providing additional fish structure and sediment stabilization. If the residents are unhappy with the appearance of the lake at a lower Sonar™ concentration, it can always be bumped up the following year. However, education on this matter is important and residents need to understand the beneficial role of plants in a lake ecosystem, so as not to perceive a small increase in plant variety as negative.

Copper sulfate treatments have been successful in keeping the filamentous algae relatively in check throughout the summer, but, as is true of all copper treatments, a large number of applications were necessary. The Lakes Commission may want to reconsider the biweekly application of copper sulfate for algae control. *Chara* a low-lying macroalgae that does not typically reach nuisance levels, currently dominates the plant community. It is likely that the presence of *Chara* is the primary reason that water clarity remains high throughout most of the summer, as *Chara* helps prevent sediment resuspension and competes with filamentous algae in many parts of the lake. However, it may be negatively affected by the copper sulfate treatments used to reduce filamentous algae. Reducing the health and density of *Chara* in Lake Linden through copper sulfate applications may actually increase algae density, requiring more frequent copper treatments over the course of the summer. One alternative to copper sulfate application may be to manually remove the filamentous algae throughout the summer. This can be cumbersome and time consuming, but it is beneficial in two important ways: it will prevent *Chara* from being negatively affected by copper sulfate treatments and it will remove a source of phosphorus from the lake. As mentioned above, phosphorus released from filamentous algae during its decomposition is likely contributing a large portion of the TP to the water column. Additionally, once this decomposing algae settles to the lake bottom, it may continue to release phosphorus back to the sediment and water column, and provide a large amount of organic material back to the lake. Eventually, the breakdown of this organic material can deplete dissolved oxygen concentrations, causing stress in fish and other aquatic organisms. The manual removal of algae from the lake may eventually lead to a decrease in the average TP concentration and algae density in the future. Another alternative would be to reduce the number of copper sulfate treatments to the lake. Fewer treatments could be supplemented by some manual removal of the algae and a healthy population of *Chara* would be maintained throughout the summer.

Of the eight emergent plant and trees species observed along the shoreline of Lake Linden, five (purple loosestrife, reed canary grass, bull thistle, multiflora rose and buckthorn) are invasive species that do not provide ideal wildlife habitat.

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 2000-2002 Lake County lakes is 14.2. Lake Linden has an FQI of 15.1, which is slightly above the county average and relatively high for a man-made lake. However, this number does not reflect the fact that several of the plant species that lead to an increase in Lake Linden's FQI were found only once during the entire summer. Although this gives higher points to the lake for the presence of these particular plant species, it is slightly misleading in this case, as the presence of these plants was very short-lived and, likely, did not provide much ecological benefit to the lake.

Table 4. Aquatic and shoreline plants on Lake Linden, May-September 2002.

Aquatic Plants	
Chara	*Chara* sp.
Water Stargrass	*Heteranthera dubia*
Curlyleaf Pondweed	*Potamogeton crispus*
Small Pondweed	*Potamogeton pusillis*
Sago Pondweed	*Potamogeton pectinatus*
Eel Grass	*Vallisneria americana*
Horned Pondweed	*Zannichellia palustris*
Shoreline Plants	
Marsh Milkweed	*Asclepaias incaruta*
Bull Thistle	*Cirsium vulgare*
Blue Flag Iris	*Iris hexagona*
Purple Loosestrife	*Lythrum salicaria*
Reed Canary Grass	*Phalaris arundinacea*
Multiflora Rose	*Rosa multiflora*
Common Arrowhead	*Sagittaria latifolia*
Wild Grape	*Vitis aestivalis*
Trees/Shrubs	
Dogwood	*Cornaceae* sp.
Common Buckthorn	*Rhamnus cathartica*
Willow	*Salix* sp.

LIMNOLOGICAL DATA – SHORELINE ASSESSMENT

A shoreline assessment was conducted at Lake Linden on July 9, 2002. 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 100% of Lake Linden's shoreline is developed. The majority of the developed shoreline is comprised of a nearly equal amount of rip rap (29.3%) and seawall (28.6%) (Figure 6). The remainder consists of beach (19.8%), manicured lawn (11.8%), shrub (6.9%) and buffer (3.5%). Although rip rap and seawalls are not ideal shoreline types with regard to wildlife habitat, they do, typically, help to prevent shoreline erosion. As a result of the dominance of these two shoreline types around Lake Linden, 92.2% of the shoreline exhibited no erosion, and the erosion that was occurring was only slight (Figure 7). The type of shoreline exhibiting the majority of the erosion was manicured lawn. Other types with erosion included beach, buffer, riprap and seawall. 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 on most lakes. Although rip rap and seawalls are intended specifically to prevent or stop erosion, if improperly installed, these shorelines can exhibit significant erosion. Often, the rip rap consists of very small rocks that simply end up sloughing into the lake as a result of wave action. If they are not replaced, erosion will occur on the exposed soil. The same is true for shorelines with improperly installed seawall. Erosion along all areas of the lake should be addressed.

Several homeowners have already installed buffer strips of emergent vegetation along their shorelines. These buffers are composed of blue flag iris, pickerelweed and arrowhead, and are excellent features for providing erosion control and wildlife habitat and for reducing sediment and nutrient load to the lake. Quart size plant plugs were installed and mesh cloth cages were constructed to cover the plants on three sides. Several residents have had problems keeping muskrats from burrowing under the mesh cages and eating the pickerelweed and arrowhead plugs. Raccoons have also been a problem in some areas. However, predation has not been as great on blueflag iris and an attempt will be made to purchase more of this plant species in the coming year. Although some residents have had predation problems, several have had very good success with their buffer strips, and these should serve as examples to other homeowners. It is recommended that these emergent types of buffer strips, as well as upland buffer strips, be installed along as many shorelines as possible. Seeding of arrowhead, pickerelweed and blueflag iris has also been attempted as a means of establishing buffer strips along the southwest shoreline of Lake Linden. To date, there has been no evidence of plant growth in this area, but these plants may take up to three growing seasons to emerge.

Dramatic water level fluctuation can increase shoreline erosion, especially if the fluctuations occur over short periods of time. The water level in Lake Linden dropped no more than one third of a foot between May and September. Erosion occurs when water levels drop and newly exposed soil, which may not support emergent plant growth, is subjected to wave action. The low water fluctuation in Lake Linden helped to reduce the likelihood of shoreline erosion, as evidenced by the relatively small amount of erosion around the lake.

Although very little erosion was occurring around Lake Linden, invasive plant species, including reed canary grass, buckthorn and purple loosestrife were present along 25.8% 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 wet 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 the invasive species found around Lake Linden was not high (purple loosestrife was observed on only one lot), steps to eliminate these plants should be carried out before they become a nuisance.

LIMNOLOGICAL DATA – WILDLIFE ASSESSMENT

In the early 1970's, fish surveys performed on Lake Linden by the Illinois Department of Natural Resources (IDNR) indicated that the lake was dominated by small black bullheads and pumpkinseed sunfish. By the 1990's carp and stunted panfish dominated the fish community. In 1991, a Rotenone treatment was conducted on Lake Linden, killing nearly all of the fish left in the lake (after electroshocking to remove many of the large game fish). From 1992-1997, largemouth bass, channel catfish, barred musky and tiger musky were stocked each year. Since 1998, blue gill have been stocked each year and musky and channel catfish have been stocked supplementally. In 1997, 1998 and 2001, 32 9-12 inch musky were stocked in the lake and in 2002, 40 18-22 inch musky were stocked. There is a catch and release rule on both musky species and large mouth bass, as the Lakes Commission is attempting to keep panfish in check with larger predators. No live bait is permitted on Lake Linden and protective overflow screens have been installed in various places to prevent European carp from re-entering the lake. While the fishery appears to be healthy and reports from anglers are positive, it is strongly recommended by the Lakes Management Unit that a new fishery assessment be conducted to determine the current status of the fish community. Of particular interest would be the status of the European carp population, the possible presence of stunted panfish and the status of the large predator fish population and the forage base for the predator population. The suggested stocking rate for musky is one fish per acre, and Lake Linden is currently adhering to this suggested rate. However, at the size that these fish are being stocked, they are likely exerting heavy predation pressure on the current forage base. It is, therefore, important that the status of this forage base and the size eventually attained by the musky population be determined.

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 woodland and buffer areas was not abundant around Lake Linden, a relatively large number of songbirds were observed (Table 6). A study done by researchers at the University of Michigan and the Wisconsin Department of Natural Resources showed that birds that eat insects and birds that nest on the ground were less common around developed lakes, while birds that eat seeds and berries were more prevalent. When assessing bird communities using more traditional methods, the researchers found no differences in bird numbers and species around developed and undeveloped lakes. However, the more detailed analysis used in their study suggests that lakeside homeowners' habits of clearing brush, planting lawns, and stocking bird feeders contribute to the differences in bird guilds (ecological groups) and result in the high number of seed and berry eating species. It is also possible that the prevalence of domestic cats and raccoons in more developed areas may threaten ground nesting birds and their eggs.

While an abundance of seed-eating birds is not a problem, the loss of insect-eating birds could be. Without birds to keep them in check, insect larvae such as gypsy moths and tent caterpillars could cause damage to plants and trees. The researchers recommend that shoreline homeowners keep their lawns small, encourage native vegetation, and keep pets away from areas where birds may be nesting or feeding. It is, therefore, very important that the current buffer areas around the Lake Linden be maintained and that additional buffered areas be encouraged to provide the appropriate habitat for a larger variety of bird species in the future.

Table 6. Wildlife species observed at Lake Linden, May-September 2002.

<u>*Birds*</u>	
Mute Swan	*Cygnus olor*
Canada Goose	*Branta canadensis*
Mallard	*Anas platyrhnchos*
Great Blue Heron	*Ardea herodias*
Green Heron	*Butorides striatus*
Sandhill Crane+	*Grus canadensis*
Killdeer	*Charadius vociferus*
Spotted Sandpiper	*Actitis macularia*
Belted Kingfisher	*Megaceryle alcyon*
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Common Flicker	*Colaptes auratus*
Red-bellied Woodpecker	*Melanerpes carolinus*
Downy Woodpecker	*Picoides pubescens*
Barn Swallow	*Hirundo rustica*
Tree Swallow	*Iridoprocne bicolor*
Rough-winged Swallow	*Stelgidopteryx ruficollis*
Chimney Swift	*Chaetura pelagica*
American Crow	*Corvus brachyrhynchos*
Blue Jay	*Cyanocitta cristata*
Black-capped Chickadee	*Poecile atricapillus*
White-Breasted Nuthatch	*Sitta carolinensis*

+Threatened in Illinois

Table 6. Wildlife species observed at Lake Linden, May-September 2002 (cont'd).

Birds	
American Robin	*Turdus migratorius*
Rock Dove	*Columba livia*
Cedar Waxwing	*Bombycilla cedrorum*
Yellow-rumped Warbler	*Dendroica coronata*
Red-winged Blackbird	*Agelaius phoeniceus*
Brown-headed Cowbird	*Molothrus ater*
Common Grackle	*Quiscalus quiscula*
Starling	*Sturnus vulgaris*
House Sparrow	*Passer domesticus*
Northern Cardinal	*Cardinalis cardinalis*
House Finch	*Carpodacus mexicanus*
American Goldfinch	*Carduelis tristis*
Chipping Sparrow	*Spizella passerina*
Song Sparrow	*Melospiza melodia*
Mammals	
Gray Squirrel	*Sciurus carolinensis*
Amphibians	
Bull Frog	*Rana catesbeiana*
Reptiles	
Painted Turtle	*Chrysemys picta*
Insects	
Cicadas	*Cicadae*

EXISTING LAKE QUALITY PROBLEMS

- *Lack of Diverse Aquatic Vegetation*

  One key to a healthy lake is a healthy plant community. *Chara* dominated the plant community throughout the summer and is likely contributing to high water clarity through sediment stabilization. However, algaecide treatments were applied consistently during the summer to suppress the growth of filamentous algae and may be negatively affecting *Chara* as well. Additionally, Sonar™ is being used to treat curly leaf pondweed, but is also affecting native plants, preventing the establishment of a diverse plant community. Recommendations have been made to (1) reduce the number of applications of copper sulfate and supplement chemical treatment with manual algae removal in order to reduce possible effects on *Chara,* and (2) reduce treatment concentration of Sonar™ from a split treatment of 20 ppb (two 10 ppb treatments) to a FasTEST monitored concentration of 10 ppb in order to preserve the growth of native plants such as wild celery and water star grass.

- *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 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, multiflora rose, bull thistle and buckthorn are present along 25.8% of the shoreline of Lake Linden and attempts should be made to control their spread before they become a large problem.

- *Limited Wildlife Habitat and Slight Shoreline Erosion*

  Nearly 100% of Lake Linden's shoreline is dominated by residential homes, which do not always encourage a diverse bird and animal community. Several of the residents along Lake Linden already have either emergent or upland buffer strips in place along their property's shoreline. However, many of the residents have rip rap, seawalls, manicured lawn and beaches along their shoreline. It is recommended that those residents that already have buffer consider widening their strips and do their best to encourage neighboring properties to establish buffers. It is also recommended that those residents that do not have a buffer strip or are experiencing erosion consider planting at least a 10-20 foot wide strip of native plants along their shoreline. This could increase wildlife habitat, reduce the amount of nutrients and soil particles entering the lake and decrease shoreline erosion.

POTENTIAL OBJECTIVES FOR THE LAKE LINDEN MANAGEMENT PLAN

I. Continue Participation in the Volunteer Lake Monitoring Program
II. Eliminate or Control Invasive Species
III. Enhance Wildlife Habitat Conditions
IV. Control Shoreline Erosion
V. Conduct a Fisheries Assessment

OPTIONS FOR ACHIEVING THE LAKE MANEMENT PLAN OBJECTIVES

Objective I: Continue Participation in the Volunteer Lake Monitoring Program

In 1981, the Illinois Volunteer Lake Monitoring Program (VLMP) was established by the Illinois Environmental Protection agency (Illinois EPA) to gather fundamental information on Illinois inland lakes, and to provide an educational program for citizens. Annually, 150-200 lakes (out of 3,041 lakes in Illinois) are sampled by approximately 250 citizen volunteers. The volunteers are primarily lake shore residents, lake owners/managers, members of environmental groups, public water supply personnel, and citizens with interest in a particular lake. Lake Linden has been participating in the VLMP program since 1993.

The VLMP relies on volunteers to gather a variety of information on their chosen lake. The primary measurement is Secchi disk transparency or Secchi depth. Analysis of the Secchi disk measurement provides an indication of the general water quality condition of the lake, as well as the amount of usable habitat available for fish and other aquatic life.

Microscopic plants and animals, water color, and suspended sediments are factors that interfere with light penetration through the water column and lessen the Secchi disk depth. As a rule, one to three times the Secchi depth is considered the lighted or euphotic zone of the lake. In this region of the lake there is enough light to allow plants to survive and produce oxygen. Water below the lighted zone can be expected to have little or no dissolved oxygen. Other observations such as water color, suspended algae and sediment, aquatic plants, and odor are also recorded. The sampling season is May through October with volunteer measurements taken twice a month. After volunteers have completed one year of the basic monitoring program, they are qualified to participate in the Expanded Monitoring Program. In the expanded program, selected volunteers are trained to collect water samples that are shipped to the Illinois EPA laboratory for analysis of total and volatile suspended solids, total phosphorus, nitrate-nitrite nitrogen and ammonia-nitrogen. Other parameters that are part of the expanded program include dissolved oxygen, temperature, and zebra mussel monitoring. Additionally, chlorophyll *a* monitoring has been added to the regiment of selected lakes. These water quality parameters are routinely measured by lake scientists to help determine the general health of the lake ecosystem.

For more information about the VLMP contact the VLMP Regional Coordinator:

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Northeast Illinois Planning Commission
222 S. Riverside Plaza, Suite 1800
Chicago, IL 60606
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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. Although exotic species were found along approximately 26% of the shoreline of Lake Linden, the density of the plant species in these areas was not extremely high. Therefore, control measures should be carried while these exotics would still be relatively easy to control.

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.

<u>Option 2: Control by Hand</u>
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 3: 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.

Objective III: Enhance Wildlife Habitat Conditions

The key to increasing wildlife species in and around a lake can be summed up in one word: habitat. Wildlife need the same four things all living creatures need: food, water, shelter, and a place to raise their young. Since each wildlife species has specific habitat requirements, which fulfill these four basic needs, providing a variety of habitats will increase the chance that wildlife species may use an area. Groups of wildlife are often associated with the types of habitats they use. For example, grassland habitats may attract wildlife such as northern harriers, bobolinks, meadowlarks, meadow voles, and leopard frogs. Marsh habitats may attract yellow-headed blackbirds and sora rails, while manicured residential lawns attract house sparrows and gray squirrels. Thus, in order to attract a variety of wildlife, a mix of habitats are needed. In most cases quality is more important than quantity (i.e.,, five 0.1-acre plots of different habitats may not attract as many wildlife species than one 0.5 acre of one habitat type).

It is important to understand that the natural world is constantly changing. Habitats change or naturally succeed to other types of habitats. For example, grasses may be succeeded by shrub or shade intolerant tree species (e.g., willows, locust, and cottonwood). The point at which one habitat changes to another is rarely clear, since these changes usually occur over long periods of time, except in the case of dramatic events such as fire or flood.

In all cases, the best wildlife habitats are ones consisting of native plants. Unfortunately, non-native plants dominate many of our lake shorelines. Many of them escaped from gardens and landscaped yards (i.e.,, purple loosestrife) while others were introduced at some point to solve a problem (i.e.,, reed canary grass for erosion control). Wildlife species prefer native plants for food, shelter, and raising their young. In fact, one study showed that plant and animal diversity was 500% higher along naturalized shorelines compared to shorelines with conventional lawns (University of Wisconsin – Extension, 1999).

Option 1: No Action

This option means that the current land use activities will continue. No additional techniques will be implemented. Allowing a field to go fallow or not mowing a manicured lawn would be considered an action.

Pros

Taking no action may maintain the current habitat conditions and wildlife species present, depending on environmental conditions and pending land use actions. If all things remain constant there will be little to no effect on lake water quality and other lake uses.

Cons

If environmental conditions change or substantial land use actions occur (i.e.,, development) wildlife use of the area may change. For example, if a new housing development with manicured lawns and roads is built next to an undeveloped property, there will probably be a change in wildlife present.

Conditions in the lake (i.e.,, siltation or nutrient loading) may also change the composition of aquatic plant and invertebrate communities and thus influence biodiversity. Siltation and nutrient loading will likely decrease water clarity, increase turbidity, increase algal growth (due to nutrient availability), and decrease habitat for fish and wildlife.

Costs

The financial cost of this option may be zero. However, due to continual loss of habitats many wildlife species have suffered drastic declines in recent years. The loss of habitat effects the overall health and biodiversity of the lake's ecosystems.

Option 2: Increase Habitat Cover

This option can be incorporated with Option 3 (see below). One of the best ways to increase habitat cover is to leave a minimum 25 foot buffer between the edge of the water and any mowed grass. Allow native plants to grow or plant native vegetation along shorelines, including emergent vegetation such as cattails, rushes, and bulrushes (see Table 7, Appendix A for costs and seeding rates). This will provide cover from predators and provide nesting structure for many wildlife species and their prey. It is important to control or eliminate non-native plants such as buckthorn, purple loosestrife, garlic mustard, and reed canary grass, since these species outcompete native plants and provide little value for wildlife.

Occasionally high mowing (with the mower set at its highest setting) may have to be done for specific plants, particularly if the area is newly established, since competition from weedy and exotic species is highest in the first couple years. If mowing, do not mow the buffer strip until after July 15 of each year. This will allow nesting birds to complete their breeding cycle.

Brush piles make excellent wildlife habitat. They provide cover as well as food resources for many species. Brush piles are easy to create and will last for several years. They should be place at least 10 feet away from the shoreline to prevent any debris from washing into the lake.

Trees that have fallen on the ground or into the water are beneficial by harboring food and providing cover for many wildlife species. In a lake, fallen trees provide excellent cover for fish, basking sites for turtles, and perches for herons and egrets.

Increasing habitat cover should not be limited to the terrestrial environment. Native aquatic vegetation, particularly along the shoreline, can provide cover for fish and other wildlife.

Pros
Increased cover will lead to increased use by wildlife. Since cover is one of the most important elements required by most species, providing cover will increase the chances of wildlife using the shoreline. Once cover is established, wildlife usually have little problem finding food, since many of the same plants that provide cover also supply the food the wildlife eat, either directly (seeds, fruit, roots, or leaves) or indirectly (prey attracted to the plants).

Additional benefits of leaving a buffer include: stabilizing shorelines, reducing runoff which may lead to better water quality, and deterring nuisance Canada geese. Shorelines with erosion problems can benefit from a buffer zone because native plants have deeper root structures and hold the soil more effectively than conventional turfgrass. Buffers also absorb much of the wave energy that batters the shoreline. Water quality may be improved by the filtering of nutrients, sediment, and pollutants in run-off. This has a "domino effect" since less run-off flowing into a lake means less nutrient availability for nuisance algae, and less sediment means less turbidity, which leads to better water quality. All this is beneficial for fish and wildlife, such as sight-feeders like bass and herons, as well as people who use the lake for recreation. Finally, a buffer strip along the shoreline can serve as a deterrent to Canada geese from using a shoreline. Canada geese like flat, open areas with a wide field of vision. Ideal habitat for them are areas that have short grass up to the edge of the lake. If a buffer is allowed to grow tall, geese may choose to move elsewhere.

Cons
There are few disadvantages to this option. However, if vegetation is allowed to grow, lake access and visibility may be limited. If this occurs, a small path can be made to the shoreline. Composition and density of aquatic and shoreline vegetation are important. If vegetation consists of non-native species such as or Eurasian water milfoil or purple loosestrife, or in excess amounts, undesirable conditions may result. A shoreline with excess exotic plant growth may result in a poor fishery (exhibited by stunted fish) and poor recreation opportunities (i.e.,, boating, swimming, or wildlife viewing).

Costs
The cost of this option would be minimal. The purchase of native plants can vary depending upon species and quantity. Based upon 100 feet of shoreline, a 25-foot buffer planted with a native forb and grass seed mix would cost between $165-270 (2500 sq. ft. would require 2.5, 1000 sq. ft. seed mix packages at $66-108 per package). This does not include labor that would be needed to prepare the site for planting and follow-up maintenance. This cost can be reduced or minimized if native plants are allowed to grow. However, additional time and labor may be needed to insure other exotic species, such as buckthorn, reed canary grass, and purple loosestrife, do not become established.

Option 3: Increase Natural Food Supply

This can be accomplished in conjunction with Option 2. Habitats with a diversity of native plants will provide an ample food supply for wildlife. Food comes in a variety of forms, from seeds to leaves or roots to invertebrates that live on or are attracted to the plants. Plants found in Table 7, Appendix A should be planted or allowed to grow. In addition, encourage native aquatic vegetation, such as water lily (*Nuphar* spp. and *Nymphaea tuberosa*), sago pondweed (*Stuckenia pectinatus*), largeleaf pondweed (*Potamogeton amplifolius)*, and wild celery (*Vallisneria americana*) to grow. Aquatic plants such as these are particularly important to waterfowl in the spring and fall, as they replenish energy reserves lost during migration.

Providing a natural food source in and around a lake starts with good water quality. Water quality is important to all life forms in a lake. If there is good water quality, the fishery benefits and subsequently so does the wildlife (and people) who prey on the fish. Insect populations in the area, including beneficial predatory insects, such as dragonflies, thrive in lakes with good water quality.

Dead or dying plant material can be a source of food for wildlife. A dead standing or fallen tree will harbor good populations of insects for woodpeckers, while a pile of brush may provide insects for several species of songbirds such as warblers and flycatchers.

Supplying natural foods artificially (i.e.,, birdfeeders, nectar feeders, corn cobs, etc.) will attract wildlife and in most cases does not harm the animals. However, “people food” such as bread should be avoided. Care should be given to maintain clean feeders and birdbaths to minimize disease outbreaks.

Pros

Providing food for wildlife will increase the likelihood they will use the area. Providing wildlife with natural food sources has many benefits. Wildlife attracted to a lake can serve the lake and its residents well, since many wildlife species (i.e.,, many birds, bats, and other insects) are predators of nuisance insects such as mosquitoes, biting flies, and garden and yard pests (such as certain moths and beetles). Effective natural insect control eliminates the need for chemical treatments or use of electrical “bug zappers” that have limited effect on nuisance insects.

Migrating wildlife can be attracted with a natural food supply, primarily from seeds, but also from insects, aquatic plants or small fish. In fact, most migrating birds are dependent on food sources along their migration routes to replenish lost energy reserves. This may present an opportunity to view various species that would otherwise not be seen during the summer or winter.

Cons

Feeding wildlife can have adverse consequences if populations become dependent on hand-outs or populations of wildlife exceed healthy numbers. This frequently happens when people feed waterfowl like Canada geese or mallard ducks.

Feeding these waterfowl can lead to a domestication of these animals. As a result, these birds do not migrate and can contribute to numerous problems, such as excess feces, which is both a nuisance to property owners and a significant contribution to the lake's nutrient load. Waterfowl feces are particularly high in phosphorus. Since phosphorus is generally the limiting factor for nuisance algae growth in many lakes in the Midwest, the addition of large amounts of this nutrient from waterfowl may exacerbate a lake's excessive algae problem. In addition, high populations of birds in an area can increase the risk of disease for not only the resident birds, but also wild bird populations that visit the area.

Finally, tall plants along the shoreline may limit lake access or visibility for property owners. If this occurs, a path leading to the lake could be created or shorter plants may be used in the viewing area.

Costs

The costs of this option are minimal. The purchase of native plants and food and the time and labor required to plant and maintain would be the limit of the expense.

Option 4: Increase Nest Availability

Wildlife are attracted by habitats that serve as a place to raise their young. Habitats can vary from open grasslands to closed woodlands (similar to Options 2 and 3).

Standing dead or dying trees provide excellent habitat for a variety of wildlife species. Birds such as swallows, woodpeckers, and some waterfowl need dead trees to nest in. Generally, a cavity created and used by a woodpecker (e.g., red-headed or downy woodpecker, or common flicker) in one year, will in subsequent years be used by species like tree swallows or chickadees. Over time, older cavities may be large enough for waterfowl, like wood ducks, or mammals (e.g., flying squirrels) to use. Standing dead trees are also favored habitat for nesting wading birds, such as great blue herons, night herons, and double-crested cormorants, which build stick nests on limbs. For these birds, dead trees in groups or clumps are preferred as most herons and cormorants are colonial nesters.

In addition to allowing dead and dying trees to remain, erecting bird boxes will increase nesting sites for many bird species. Box sizes should vary to accommodate various species. Swallows, bluebirds, and other cavity nesting birds can be attracted to the area using small artificial nest boxes. Larger boxes will attract species such as wood ducks, flickers, and owls. A colony of purple martins can be attracted with a purple martin house, which has multiple cavity holes, placed in an open area near water.

Bat houses are also recommended for any area close to water. Bats are voracious predators of insects and are naturally attracted to bodies of water. They can be enticed into roosting in the area by the placement of bat boxes. Boxes should be constructed of rough non-treated lumber and placed >10 feet high in a sunny location.

Pros

Providing places were wildlife can rear their young has many benefits. Watching wildlife raise their young can be an excellent educational tool for both young and old.

The presence of certain wildlife species can help in controlling nuisance insects like mosquitoes, biting flies, and garden and yard pests. This eliminates the need for chemical treatments or electric "bug zappers" for pest control.

Various wildlife species populations have dramatically declined in recent years. Since, the overall health of ecosystems depend, in part, on the role of many of these species, providing sites for wildlife to raise their young will benefit not only the animals themselves, but the entire lake ecosystem.

Cons

Providing sites for wildlife to raise their young have few disadvantages. Safety precautions should be taken with leaving dead and dying trees due to the potential of falling limbs. Safety is also important when around wildlife with young, since many animals are protective of their young. Most actions by adult animals are simply threats and are rarely carried out as attacks.

Parental wildlife may chase off other animals of its own species or even other species. This may limit the number of animals in the area for the duration of the breeding season.

Costs

The costs of leaving dead and dying trees are minimal. The costs of installing the bird and bat boxes vary. Bird boxes can range in price from $10-100.00. Purple martin houses can cost $50-150. Bat boxes range in price from $15-50.00. These prices do not include mounting poles or installation.

Objective IV: Control Shoreline Erosion

Erosion is a potentially serious problem to lake shorelines and occurs as a result of wind, wave, or ice action or from overland rainwater runoff. While some erosion to shorelines is natural, human alteration of the environment can accelerate and exacerbate the problem. Erosion not only results in loss of shoreline, but negatively influences the lake's overall water quality by contributing nutrients, sediment, and pollutants into the water. This effect is felt throughout the food chain since poor water quality negatively affects everything from microbial life to sight feeding fish and birds to people who want to use the lake for recreational purposes. The resulting increased amount of sediment will over time begin to fill in the lake, decreasing overall lake depth and volume and potentially impairing various recreational uses. Lake Linden has very little erosion occurring along its shoreline, but homeowners should address those areas that are eroded or could become eroded in the future.

Option 1: No Action

Pros

There are no short-term costs to this option. However, extended periods of erosion may result in substantially higher costs to repair the shoreline in the future.

Eroding banks on steep slopes can provide habitat for wildlife, particularly bird species (e.g. kingfishers and bank swallows) that need to burrow into exposed banks to nest. In addition, certain minerals and salts in the soils are exposed during the erosion process, which are utilized by various wildlife species.

Cons

Taking no action will most likely cause erosion to continue and subsequently may cause poor water quality due to high levels of sediment or nutrients entering a lake. This in turn may retard plant growth and provide additional nutrients for algal growth. A continual loss of shoreline is both aesthetically unpleasing and may potentially reduce property values. Since a shoreline is easier to protect than it is to rehabilitate, it is in the interest of the property owner to address the erosion issue immediately.

Costs

In the short-term, cost of this option is zero. However, long-term implications can be severe since prolonged erosion problems may be more costly to repair than if the problems were addressed earlier. As mentioned previously, long-term erosion may cause serious damage to shoreline property and in some cases lower property values.

Option 2: Create a Buffer Strip

Another effective method of controlling shoreline erosion is to create a buffer strip with existing or native vegetation. Native plants have deeper root systems than turfgrass and thus hold soil more effectively. Native plants also provide positive aesthetics and good wildlife habitat. Cost of creating a buffer strip is quite variable, depending on the current state of the vegetation and shoreline and whether vegetation is allowed to become established naturally or if the area needs to be graded and replanted. Allowing vegetation to naturally propagate the shoreline would be the most cost effective, depending on the severity of erosion and the composition of the current vegetation. Non-native plants or noxious weedy species may be present and should be controlled or eliminated.

Stabilizing the shoreline with vegetation is most effective on slopes no less than 2:1 to 3:1, horizontal to vertical, or flatter. Usually a buffer strip of at least 25 feet is recommended, however, wider strips (50 or even 100 feet) are recommended on steeper slopes or areas with severe erosion problems. Areas where erosion is severe or where slopes are greater than 3:1, additional erosion control techniques may have to be incorporated such as biologs, A-Jacks®, or rip-rap.

Buffer strips can be constructed in a variety of ways with various plant species. Generally, buffer strip vegetation consists of native terrestrial (land) species and emergent (at the land and water interface) species. Terrestrial vegetation such as native grasses and wildflowers can be used to create a buffer strip along lake shorelines. Table 7, Appendix A gives some examples, seeding rates and costs of grasses and seed mixes that can be used to create buffer strips. Native plants and seeds can be purchased at regional nurseries or from catalogs. When purchasing seed mixes, care should be taken that native plant seeds are used. Some commercial seed mixes contain non-native or weedy species or may contain annual wildflowers that will have to be reseeded every year. If purchasing plants from a nursery or if a licensed contractor is installing plants, inquire about any guarantees they may have on plant survival. Finally, new plants should be protected from herbivory (e.g., geese and muskrats) by placing a wire cage over the plants for at least one year.

Emergent vegetation, or those plants that grow in shallow water and wet areas, can be used to control erosion more naturally than seawalls or rip-rap. Native emergent vegetation can be either hand planted or allowed to become established on its own over time. Some plants, such as native cattails (*Typha* sp.), quickly spread and help stabilize shorelines, however they can be aggressive and may pose a problem later. Other species, such as those listed in Table 7, Appendix A should be considered for native plantings. Several residents on Lake Linden already have excellent emergent vegetation buffer in place. These can serve as an example to other lakeshore homeowners who should be encouraged to establish their own buffer strips.

Pros

Buffer strips can be one of the least expensive means to stabilize shorelines. If no permits or heavy equipment are needed (i.e., no significant earthmoving or filling is planned), the property owner can complete the work without the need of professional contractors. Once established (typically within 3 years), a buffer strip of native vegetation will require little maintenance and may actually reduce the overall maintenance of the property, since the buffer strip will not have to be continuously mowed, watered, or fertilized. Occasional high mowing (1-2 times per year) for specific plants or physically removing other weedy species may be needed.

The buffer strip will stabilize the soil with its deep root structure and help filter run-off from lawns and agricultural fields by trapping nutrients, pollutants, and sediment that would otherwise drain into the lake. This may have a positive impact on the lake's water quality since there will be less "food" for nuisance algae. Buffer strips can filter as much as 70-95% of sediment and 25-60% of nutrients and other pollutants from runoff.

Another benefit of a buffer strip is potential flood control protection. Buffer strips may slow the velocity of flood waters, thus preventing shoreline erosion. Native plants also can withstand fluctuating water levels more effectively than commercial turfgrass. Many plants can survive after being under water for several days, even weeks, while turfgrass is intolerant of wet conditions and usually dies after several days under water. This contributes to increased maintenance costs, since the turfgrass has to be either replanted or replaced with sod. Emergent vegetation can provide additional help in preserving shorelines and improving water quality by absorbing wave energy that might otherwise batter the shoreline. Calmer wave action will result in less shoreline erosion and resuspension of bottom sediment, which may result in potential improvements in water quality.

Many fish and wildlife species prefer the native shoreline vegetation habitat. This habitat is an asset to the lake's fishery since the emergent vegetation cover may be used for spawning, foraging, and hiding. Various wildlife species are even dependent upon shoreline vegetation for their existence. Certain birds, such as marsh wrens (*Cistothorus palustris*) and endangered yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) nest exclusively in emergent vegetation like cattails and bulrushes. Hosts of other wildlife like waterfowl, rails, herons, mink, and frogs to mention just a few, benefit from healthy stands of shoreline vegetation. Dragonflies, damselflies, and other beneficial invertebrates can be found thriving in vegetation along the shoreline as well.

In addition to the benefits of increased fish and wildlife use, a buffer strip planted with a variety of native plants may provide a season long show of various colors from flowers, leaves, seeds, and stems. This is not only aesthetically pleasing to people, but also benefits wildlife and the overall health of the lake's ecosystem.

Cons
There are few disadvantages to native shoreline vegetation. Certain species (i.e., cattails) can be aggressive and may need to be controlled occasionally. If stands of shoreline vegetation become dense enough, access and visibility to the lake

may be compromised to some degree. However, small paths could be cleared to provide lake access or smaller plants could be planted in these areas.

Costs

If minimal amount of site preparation is needed, costs can be approximately $10 per linear foot, plus labor. Cost of installing willow posts is approximately $15-20 per linear foot. The labor that is needed can be completed by the property owner in most cases, although consultants can be used to provide technical advice where needed. This cost will be higher if the area needs to be graded. If grading is necessary, appropriate permits and surveys are needed. If filling is required, additional costs will be incurred if compensatory storage is needed. The permitting process is costly, running as high as $1,000-2,000 depending on the types of permits needed.

Objective V: Conduct a Fisheries Assessment

Many lakes in Lake County have a fish stocking program in which fish are stocked every year or two to supplement fish species already occurring in the lake or to introduce additional fish species into the system. However, very few lakes that participate in stocking check the progress or success of these programs with regular fish surveys. Lake managers should have information about whether or not funds delegated to fish stocking are being well spent, and it is very difficult to determine how well stocked fish species are surviving and reproducing or how they are affecting the rest of the fish community without a comprehensive fish assessment. Lake Linden has been stocked with several different fish species since 1992 and supplemental stocking of musky, bluegill and catfish was performed in 2002. However, a fish assessment has not been conducted since a rotenone treatment in 1991.

A simple, inexpensive way to derive direct information on the status of a fishery is to sample anglers and evaluate the types, numbers and sizes of fish caught by anglers actively involved in recreational fishing on the lake. Such information provides insight on the status of fish populations in the lake, as well as a direct measure of the quality of fishing and the fishing experience. However, the numbers and types of fish sampled by anglers are limited, focusing on game and large, catchable-sized fish. Thus, in order to obtain a comprehensive assessment of the fish community status, including non-game fish species, more quantitative methods must be employed. These include gill netting, trap netting, seining, trawling, angling (hook and line fishing) and electroshocking. Each method has its advantages and limitations, and frequently multiple gear and approaches are employed. The best gear and sampling methods depend on the target fish species and life stage, the types of information desired and the environment to be sampled. The table below lists examples of suitable sampling gear for collecting adults and young of the year (YOY) of selected fish species in lakes.

Typically, fish populations are monitored at least annually. The best time of year depends on the sampling method, the target fish species and the types of data to be collected. In many lakes and regions, the best time to sample fish is during the fall turnover period after thermal stratification breaks down and the lake is completely mixed because (1) YOY and age 1+ (one year or older) fish of most target species should be present and vulnerable to most standard collection gear, including seines, trap nets and electroshockers; (2) species that dwell in the hypolimnion during the summer may be more vulnerable to capture during fall overturn; and (3) lower water temperatures in the fall can help reduce sampling-related mortality. Sampling locations are also species-, life stage-, and gear-dependent. As with sampling methods and time, locations should be selected to maximize capture efficiency for the target species of interest and provide the greatest gain in information for the least amount of sampling effort.

The Illinois Department of Natural Resources (IDNR) will perform a fish survey at no charge on most public and some private water bodies. In order to determine if your lake is eligible for a survey by the IDNR, contact Frank Jakubecik, Fisheries Biologist at (815) 675-2319. If a lake is not eligible for an IDNR fish survey, or if a more comprehensive survey is desired, two known consulting firms have previously conducted fish surveys in Lake County: EA Engineering, Deerfield, IL, (847) 945-8010 and Richmond Fisheries, Richmond, IL, (815) 675-6545.

		GEAR[a]	
TAXON	**FISH LIFE STAGE**	**STANDARD**	**SUPPLEMENTAL**
Trout, salmon, whitefish, char (except lake trout)	YOY Adult	Electrofishing Trap nets	Gill nets, trawls, seine Gill nets, electrofishing (F)
Lake trout	YOY Adult	Electrofishing (F) Trap nets (F)	Seine (F), trawls
Pike, pickerel, muskellange	YOY Adult	Seine (Su) Trap nets (S), gill nets (S,F)	
Catfish, bullheads	YOY Adult	Seine Gill nets, trap nets[b]	Baited traps Slat nets, angling
Bass, sunfish, crappie	YOY Adult	Seine, electrofishing Electrofishing	Trap nets, angling
Minnows, carp, dace, chub, shiners	YOY Adult	Electrofishing Electrofishing	Seine Seine
Yellow perch	YOY Adult	Seine (Su), electrofishing Gill net, trap net	Trawls (S)
Walleye	YOY Adult	Seine (S), electrofishing Trap nets (S), gill nets (S, F), electrofishing (S, F)	Trawls (S)

[a]Letter codes indicate seasonal restrictions on gear use to the spring (S), summer (Su), or fall (F).
[b]Bullheads only.