2002 SUMMARY REPORT
of
EAGLE LAKE

Lake County, Illinois

Prepared by the

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EXECUTIVE SUMMARY

Eagle Lake is a 21.7 acre manmade lake located on Lake Forest Academy property in the Village of Lake Forest north of Route 60 in Libertyville Township. Access to Eagle Lake is private with bottom ownership belonging to the Lake Forest Academy, which has been on the lake since 1946. However, there are three private residences on the south side of the lake that have access and use the lake for boating (paddle, rowboat, canoe). Eagle Lake is made up of two lobes of water connected by a narrow channel and as a result are very different from one another.

Overall, Eagle Lake has *poor* water quality as compared to other County lakes. Dissolved oxygen concentrations are low in the east lobe and dangerously low in the west lobe. This is despite the fact that the Academy has installed an aeration system in both portions of the lake. In 2002, average total phosphorus concentrations in Eagle Lake was 0.095 mg/L in the east lobe and 0.074 mg/L in the west lobe, which is much higher than the Lake County median value of 0.056 mg/L. High concentrations are partially due to internal phosphorus loading from several sources. These high phosphorus concentrations are causing summer long algae blooms in the east lobe. The average total suspended solids concentration in the east lobe was 15.0 mg/L and was as high as 22.0 mg/L in September, which is over three and a half times the Lake County median concentration of 6.0 mg/L. These high concentrations of suspended sediment are significantly reducing clarity and contributing to the internal loading of nutrients in the east portion Eagle Lake. Total suspended solids concentrations were much lower in the west lobe and averaged 6.9 mg/L. This is mainly due to the over abundance of aquatic vegetation that are in the west portion of the lake, which keeps sediment resuspension and algae growth to a minimum. High phosphorus concentrations in the west lobe are largely from sediment release and plant /algae decomposition.

Aquatic plant assessments revealed average species diversity but problematic plant densities. The east lobe only had sporadic plant growth for much of the season and the west lobe had excessive growth the whole summer. Interestingly, most of the diversity occurred in the east lobe where plants could grow without interference from coontail, which there was very little of in the east lobe despite the overabundance in the west lobe. The Lakes Management Unit found no Eurasian water milfoil, which is a highly aggressive exotic aquatic weed. Every effort should be made by the Academy and residents to keep this nuisance plant out of Eagle Lake.

A majority of Eagle Lake's shoreline is developed (74%). The majority of this developed shoreline is made up of manicured lawn (67%) and buffered areas (19%). A majority of the undeveloped shoreline consisted of woodlands (97%). The high occurrence of buffer areas and woodlands provide good wildlife habitat. Eagle Lake provides ideal habitat for wildlife use. During the study, two black-crowned night herons along with a juvenile, a State of Illinois endangered bird species, were observed. This may indicate they are nesting on or near Eagle Lake. Additionally, there is a great blue heron and great egret rookery (nesting site) on an island in the west lobe. Several other species of migratory waterfowl were observed at Eagle Lake.

LAKE IDENTIFICATION AND LOCATION

Eagle Lake is located on the Lake Forest Academy property north of Route 60 in Libertyville Township in the Village of Lake Forest (T44N, R11E, Section 36). Eagle Lake is a 21.7 acre manmade lake consisting of two main lobes of water (east and west lobes) connected by a narrow channel (Figure 1). The current maximum water depth is 10 feet in the east lobe and 7.5 feet in the west lobe with an average depth of 5 feet (Lake County Health Department – Lakes Management Unit [LMU] estimate). The entire lake volume is estimated to be approximately 108.5 acre feet (LMU calculation). Eagle Lake is in the Middle Fork watershed of the Chicago River. There are several inlets to Eagle Lake with the major inlets consisting of two large stormwater inflows (one each on the east and west lobes) and a small creek on the north end of the west lobe. There is one outlet consisting of a small spillway located on the east side of the east lobe just off of Academy Drive.

BRIEF HISTORY OF EAGLE LAKE

Eagle Lake was created in 1906 by dredging and damming of a shallow wetland. Development around the lake also began in 1906 with the construction of the Armour mansion, which was completed in 1908. The old Armour mansion is still currently used by the Lake Forest Academy, which moved on to the lake in 1946. Eagle Lake is entirely owned by the Lake Forest Academy. The Academy used to utilize the lake for recreational boating and sailing classes until the late 1970's but now the Academy does not allow access to the lake. Three private residences do boarder Eagle Lake on the east portion but they do not own any of the lake bottom. However, all three property owners have piers and boats (canoes and rowboats) for use on the lake. In the past, the lake has had plant and algae problems that have been addressed using a variety of management techniques such as herbicides treatments and manual removal. The lake has also experienced fish kills due to low dissolve oxygen concentrations and as a result, two aeration systems (one in each lobe) have been in place since the late 1980's and are operated year round.

LIMNOLOGICAL DATA – WATER QUALITY

Water samples collected from Eagle Lake were analyzed for a variety of water quality parameters. Since Eagle Lake is so shallow, samples were collected from a depth of 3 feet below the surface from May through September at the deep hole locations in the east and west lobes (Figure 1). A narrow channel separates these two portions of the lake and therefore the water quality from these two sites is very different. The complete data set for both the east (Site 1) and west (Site 2) portions of Eagle Lake can be found in Table 1, Appendix A.

The east lobe is not thermally stratified, which means the lake does not divide into warm upper water (epilimnion) and cool lower water (hypolimnion) but instead stays well

mixed. This is due to the shallow lake morphology, long northeast fetches (the longest distance which wind blows across a lake uninhibited by land), aeration, and lack of aquatic plant growth. This mixing of water is reflected in the dissolved oxygen (DO) levels, which were fairly consistent from the surface to the bottom. The west lobe does thermally stratify during June and July. This is mainly due to the thick aquatic plant and filamentous algae growth that allows for greater water temperature differences and prevents mixing. Additionally, the aeration systems that are operating in both lakes appear to be having little to no effect on the DO concentrations. This may be due to their size as well as improper adjustment and as result DO concentrations are *poor* in both the east and west portions of Eagle Lake. In order to support aquatic life, DO concentrations should remain above 5.0 mg/L. If DO concentrations drop below this level for a prolonged period of time negative impacts such as fish kills can occur. In the east lobe, the average DO concentration was 6.66 mg/L, with concentrations fluctuating throughout the study from 9.61 mg/L (May) to 4.62 mg/L (June). The low DO concentrations in the east lobe are due to the widespread algae blooms that were present in the lake from June through September. Although algae produce oxygen during photosynthesis they also consume oxygen during respiration. This respiration, along with other factors such as decomposition of dying algae and plants (an oxygen consuming process) is creating a high biological oxygen demand (BOD) that is lowering the DO concentrations. In the west lobe, the average DO concentration was 2.42 mg/L, and ranged from 5.26 mg/L (May) to 0.99 mg/L (June). These *extremely* low DO concentrations in the west lobe may also due to a high BOD and stratification. However, the high BOD in the west lobe is being created by the over abundance of coontail as well as the occasional filamentous bloom.

Secchi disk depth is a direct indicator of water clarity as well as overall water quality. In general, the greater the Secchi depth, the clearer the water and better the water quality. Based on Secchi depth, the east lobe has *below average* water quality. The 2001 average Secchi disk depth in the east lobe was 2.1 feet, which is lower than the Lake County median Secchi disk depth of 3.81 feet. Monthly readings varied from 3.58 feet (May) to 1.38 feet (August). These variations were related to suspended organic (algae) and inorganic (sediment) particles in the water column. The average Secchi depth on the west lobe was 5.54 feet[1], which is over double that of the east lobe and is slightly higher than the County median Secchi depth. The above average Secchi depth on the west lobe is the result of the thick coontail growth as well as filamentous algae blooms, which keeps sediment resuspension as well as planktonic algae growth to a minimum.

Total suspended solids (TSS), which are a measurement of suspended particles in the water column such as silts, clays, algae and organic matter, differ greatly between the two portions of the lake. In the east lobe the average TSS was 15 mg/L, which is two and a half times higher than the Lake County median TSS (6.0 mg/L) and is negatively impacting water clarity (Secchi depth) (Figure 2). Average TSS on the west lobe was 5.5 mg/L, which is near the County median concentration. Calculated nonvolatile suspended

[1] This average uses only data from May, June, and September. July and August Secchi readings were inhibited by aquatic plant growth and therefore no Secchi depth was determined.

solids (NVSS), which is the part of TSS that is made up of inorganic particles (such as sediment) also differed greatly between the two portions of the lake. The east lobe had an average NVSS concentration of 12 mg/L while the west lobe's average NVSS was 4 mg/L. However, NVSS accounted for 80% of the TSS in both portions of the lake.

Average total dissolved solids (TDS), total solids (TS), total volatile solids (TVS) were slightly above their respective County medians in both lobes. These elevated TVS concentrations could be due in part to decomposition of aquatic plant and algae blooms, which can cause an increase in organic matter in the water column and directly impact clarity. Above average TDS concentrations are due to elevated levels of dissolved minerals (carbonates and chlorides). This is further reinforced by elevated conductivity levels, which is also a measure of dissolved minerals such as chlorides. In 2002, the east and west portions of Eagle Lake had an average conductivity of 1.187 milliSiemens/cm and 1.286 milliSiemens/cm, respectively, compared to the County average of 0.7389 milliSiemens/cm. Average chloride concentrations in the east lobe were 253 mg/L and 247 mg/L in the west lobe and are both above the threshold of 210 mg/L at which negative impacts occur for aquatic organisms. High conductivity and chloride concentrations may be due to stormwater runoff containing high amounts of road salts. These salts could have originated from nearby roads (Route 60) and detention ponds from nearby parking lots, which drain into Eagle Lake via the two large storm water pipes located on each lake. Additionally, road salt applied on the Academy's property also enters the lake through runoff.

High nutrient concentrations are usually indicative of water quality problems. Algae need light and nutrients, most importantly carbon, nitrogen (N) and phosphorus (P), to grow. Light and carbon are not normally in short supply (limiting). This means that the nutrients N&P are usually the limiting factors in algal growth. To compare the availability of these nutrients, a ratio of total nitrogen to total phosphorus is used (TN:TP). Ratios < 10:1 indicate nitrogen is limiting. Ratios of >15:1 indicate phosphorus is limiting. Ratios >10:1, <15:1 indicate that there is enough of both nutrients for excessive algal growth. As with other water quality parameters the TN:TP ratio was different between the east and west portions with the east having a ratio of 22:1, and the west having a ratio of 14:1. Also, the east lobe may have a higher ratio as some algae can utilize nitrogen from the air, which increases the amount of nitrogen in the water column.

The total phosphorus (TP) concentrations in both portions of the lake were well above the Lake County median TP concentration of 0.056 mg/L. The average concentration in the east lobe (0.095 mg/L) was almost 30% higher than the average concentration in the west lobe (0.074 mg/L). While TP concentrations remained fairly stable throughout the study in the east lobe, they were variable in the west lobe. The main source of this variability could be due to thermal stratification. Due to thermal stratification, the lower waters of the west lobe became hypoxic (DO concentrations of <1.0 mg/L) during most of the summer. During these hypoxic conditions phosphorus can be released from the nutrient rich sediment via biological and chemical processes. Since the stratification was weak in the west lobe, these nutrients can mix into the surface waters. Additionally, these fluctuations can also be related to the mats of filamentous algae that were present in May and June. As the filamentous algae mats die and decompose (due to increasing water temperature), phosphorus is released into the water. This is supported by detectable concentrations of soluble reactive phosphorus (SRP) in May and June, which is a form of phosphorus that is released upon decomposition of plant matter (i.e., the filamentous algae). After the filamentous algae had completely died off, the concentrations of SRP were below laboratory detection limits. Coontail die off was gradual and any SRP released during decomposition was probably taken up by the healthy coontail and algae. High phosphorus concentrations in the east lobe are more than likely due to the resuspension of nutrient rich sediment. This is supported by the well above average TSS concentrations, which correspond with TP and NVSS concentrations (Figure 3). This is a common source of phosphorus in shallow, nutrient rich lakes such as Eagle. These internal sources may not be the only explanation of elevated TP concentrations in both the east and west portions of the lake. Another input of phosphorus may be from sources outside of the lake (external). They can include fertilizer runoff, failing septic systems, geese feces, and erosion. TP concentrations did not correlate with rainfall data, which may indicate that a majority of Eagle Lake's TP may be from internal sources (Figure 4).

Nitrate (NO_3-N) and ammonia (NH_3-N) concentrations were below detectable concentrations for much of the study with May and June (east lobe) the only months with detectable NO_3-N concentrations. However, even though the nitrogen concentrations were below detectable limits for most of the study, the average nitrogen concentration in the east lobe were well above the County median for both nitrate and ammonia when detectable. This could be due to nutrient release from dying aquatic vegetation (curly leaf pondweed) in the east lobe during May and June. Additionally, the east lobe experienced season long blue-green algae blooms, which are able to fix atmospheric nitrogen into a biologically usable form. This is supported by the total Kjeldahl nitrogen concentrations (TKN)(a measure of the organic forms of nitrogen) in the east lobe in May and June, which were higher than other months of the study. Additionally, average TKN concentrations in the east lobe were 2.11 mg/L, which was almost double that of the County median concentration of 1.170 mg/L. The west lobe did not experience the massive die off of aquatic vegetation that occurred in the east lobe in May and June and as a result the average TKN concentrations in the west lobe were 1.022 mg/L, which is slightly below the County median.

Another way to look at phosphorus concentrations and how they affect the productivity of the lake is to use a Trophic State Index (TSI) based on phosphorus. TSI values are commonly used to classify and compare lake productivity (trophic state). The higher the phosphorus concentration, the greater amount of algal biomass, which then results in a higher TSI and corresponding trophic state. Based on TSI phosphorus values of 69.8 (east lobe) and 66.3 (west lobe), Eagle Lake is classified as eutrophic ($\geq$50, <70 TSI). A eutrophic lake is defined as a productive system that has above average nutrient concentrations and high algal biomass (growth). Eagle Lake is highly eutrophic, almost hypereutrophic (TSI$\geq$70), and did experience widespread planktonic algal blooms in the east lobe and filamentous algae blooms in the west lobe both triggered by high nutrient

concentrations. Without the competition from aquatic plants, algal blooms in the west lobe would be more widespread and of greater intensity. TSI can also be used to compare lakes within the County. Based on the average phosphorus TSI[2], Eagle Lake ranks 71 out of 103 lakes studied by the LMU between 1998-2002 (Table 2, Appendix A). TSI values along with other water quality parameters can be used to calculate impairment assessments and use indexes established by the Illinois Environmental Protection Agency (IEPA). Most impairment assessments (NO_3-N, NH_3-N, pH, NVSS) were listed as *None*. However, Eagle Lake was listed as having impairments based on high concentrations of TP and TDS, Low DO concentrations, and excessive aquatic plant growth (west lobe). For the Aquatic Life Use impairment index Eagle Lake is listed as providing *Full* support. However, this index does not take into consideration the low DO concentrations, which prohibit establishment of a quality fishery in Eagle Lake. For the Overall Use impairment index, Eagle Lake was listed as providing *Full* support.

LIMNOLOGICAL DATA – AQUATIC PLANT ASSESSMENT

A healthy aquatic plant population is critical to good lake health. Aquatic vegetation provides important food sources and wildlife habitat. Additionally, aquatic plants provided many water quality benefits such as sediment stabilization and competition with algae for available resources. Aquatic plant diversity on Eagle Lake is *average*. During the 2002 study of Eagle Lake, only seven species of aquatic plants were found (Table 3). The month with the highest plant diversity was July, in which all seven species were sampled (Table 4, *Appendix A*). The most frequent species during the study was coontail, which occurred at 47% of all sample sites from May-September (all in the west lobe) and is by far the dominant plant species in the west lobe covering 95-100% of the bottom area of that portion of the lake. Other plants that were commonly present included sago pondweed (17% of sites) and curly leaf pondweed (26% of sites). The curly leaf pondweed was only present in May and June in the east lobe (90-100% bottom coverage). Because curly leaf pondweed is an early season grower (when water temperature are cool) there was very few plants found after June. Diversity was uneven between the two lobes with east having much higher diversity than the west. This is due to the monoculture of coontail found in the west lobe, which is preventing other species from growing.

Floristic quality index (FQI) (Swink and Wilhelm 1994) is a rapid assessment metric designed to evaluate the closeness that the flora of an area is 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. Each submersed and floating aquatic plant species (emergent shoreline species were not counted) in the lake is assigned a number between 1 and 10 (10 indicating the plant species most sensitive to disturbance). Nonnative species were also counted in the FQI calculations for Lake County lakes. We then averaged these numbers and multiplied by the square root of the number of species present to

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[2] The TSI from Site 1 (east lobe) was used since this site was near the outlet and therefore is more representative of the overall water quality of Eagle Lake.

calculate an FQI. A high FQI number indicates that there are a large number of sensitive, high quality plant species present in the lake. In 2002, Eagle Lake has a FQI of 14.0.The average FQI of lakes studied by the LMU in 2000-2002 was 14.2. This FQI supports that Eagle Lake has *average* aquatic plant diversity compared to other lakes in Lake County.

While the *diversity* of Eagle Lake's aquatic plant population is average the *density* of these plants was below average in the east lobe and excessive in the west lobe. The east lobe was dominated by curly leaf pondweed in the spring. However, after the curly leaf pondweed die-off in late spring/early summer, which is a natural phenomenon, the east lobe was dominated by blue-green algae blooms and subsequently had little plant growth. As previously stated, the west lobe was dominated by coontail throughout the season. The Academy reports that copper sulfate is used in the west lobe to treat the excessive stands of coontail and curly leaf pondweed. Unfortunately, copper sulfate is an algaecide and has little to no effect on aquatic plants; these treatments are ineffective and should be discontinued. The treatments may have had an impact on the mats of filamentous algae that were in the west lobe. However, visual observations saw no noticeable change to the mats. If future treatments are to continue, Lake Forest Academy should select an *herbicide* that is labeled for control of coontail (i.e., 2,4-D). However, the continuation of herbicide treatments should be reevaluated based on the goals of the Academy and the usage of the lake. Since Eagle Lake is not used for recreational purposes, it may not be necessary to continue treating the lake.

Table 3. Aquatic and shoreline plants on Eagle Lake, May-September 2002.

<u>*Aquatic Plants*</u>	
Coontail	*Ceratophyllum demersum*
Common Duckweed	*Lemna minor*
Curlyleaf Pondweed	*Potamogeton crispus*
Leafy Pondweed	*Potamogeton foliosus*
Sago Pondweed	*Potamogeton pectinatus*
Flatstem Pondweed	*Potamogeton zosteriformis*
Small Pondweed	*Potamogeton pusillus*
<u>*Shoreline Plants*</u>	
Beggars Tick	*Bidens frondosa*
Common Buckthorn	*Rhamnus cathartica*
Elderberry	*Sambucus* sp.
European Black Alder	*Alnus glutinosa*
Ground Ivy	*Glechoma hederacea*
Honey Suckle	*Lonicera* sp.
Purple Loosestrife	*Lythrum salicaria*
Reed Canary Grass	*Phalaris arundinacea*
White Pine	*Pinus strobus*

LIMNOLOGICAL DATA – SHORELINE ASSESSMENT

Shoreline assessment was conducted at Eagle Lake on August 21, 2002. Shorelines were assessed for a variety of criteria (*Appendix B* for methodology). A large majority (74%) of Eagle Lake's shoreline is developed. A majority of the developed shoreline consisted of buffered areas (47%), lawn (34%), and woodlands (19%), (Figure 5). The high occurrence of buffered and woodland shoreline combined with the moderate extent of undeveloped shoreline is encouraging, as they contain plants with deep root systems that are less prone to erosion and provide good wildlife habitat. Also noted during the assessment were the absence of seawalls and rip rap. Seawalls (and rip rap to some extent) are undesirable because of their tendency to reflect wave action back into the lake. This can cause resuspension of near shore sediments, which can lead to a variety of water quality problems. Seawall and rip rap are often considered undesirable. However, manicured lawn, which accounted for 34 % of the shoreline, is a poor shoreline/water interface. This is due to the poor root structure of turf grasses, which provide poor soil stabilization in addition to providing poor wildlife habitat. The portion of the shoreline that was undeveloped (26%) was made up of woodland (93%) and shrub (7%).

The shoreline was also analyzed for the presence of erosion. The occurrence of erosion on Eagle Lake is *moderately high*. Overall, 60% of the shoreline on Eagle Lake had some type of erosion (Figure 6). A majority of the shoreline was *Slightly* eroded (46%) with some experiencing *Moderate* (12%) and *Severe* (2%). The most affected shoreline type regardless of development was woodland, which accounted for 22% of total shoreline erosion. Of the undeveloped shoreline, *Slightly* eroded woodland was the most common type (63%). This can be attributed to the unmanaged nature of these developed and undeveloped areas. These wooded areas have become over grown with dense tree growth (European black alder and common buckthorn). This dense growth shades out deep-rooted beneficial under story vegetation, which helps to stabilize the shoreline. Of the developed shorelines, manicured lawn was the most eroded type (29% of the total developed shoreline). Furthermore, manicured lawn was the only type that was assessed as having *Moderate* or *Severe* erosion. The lawn areas that have experienced erosion were found to be poorly maintained and as stated previously, are predisposed to erosion due to the lack of quality root structure. The Academy as well as individual homeowners around the lake could easily address these *Slightly* eroded areas by establishing well-maintained buffer strips consisting of prairie grasses and wildflowers. Additionally, it would be beneficial to extend these buffers into lake by planting native emergent vegetation. Improving the *Moderate* and *Severely* eroded areas would involve more labor-intensive measures.

LIMNOLOGICAL DATA – WILDLIFE ASSESSMENT

Wildlife observations were made on a monthly basis during water quality and plant sampling activities. All observations were visual. Several types of waterfowl were observed during the course of the study including three State of Illinois threatened and endangered species (Table 5). LMU staff observed black-crowned night herons, two adults and one juvenile, on several occasions, which may indicate that this endangered bird species is nesting on or near Eagle Lake. The endangered osprey and threatened pied-bill grebe, were probably passing through during migration as they were only seen on a few occasions and never accompanied by juveniles. Much to the surprise of LMU staff, there is a small great blue heron and great egret rookery located on the island in the middle of the west lobe. Additionally, there are healthy populations of mature trees that provide good habitat for a variety of bird species. There are also a few large dead trees that provide excellent habitat for double-crested cormorants, which were frequently observed on the lake. Furthermore, much of the west lobe and portions of the east lobe had shrub and woodland areas that provide habitat for a variety of bird and small mammals.

The diversity of the wildlife found at Eagle Lake can be directly related to the habitat that surrounds the lake. Overall, Eagle Lake provides good habitat for a variety of wildlife species and may be the best use of the Lake. Even though a large majority of Eagle Lake's shoreline is developed, this shoreline is dominated by vegetated buffers and woodland, which provided good habitat. However, much of the buffer and woodland areas are over run with nuisance exotic species such as European black alder and common buckthorn, which have shaded out the under story of these areas and has resulted in shoreline erosion due to poor root structure. Additionally, another very invasive species, purple loosestrife, has also become established along the shorelines of Eagle Lake. Purple loosestrife is extremely aggressive and can quickly dominate shorelines, forcing out desirable, native species. Every effort should be made to conserve and improve these habitat areas as well as the undeveloped shoreline around the lake by eliminating these nuisance species.

Due to low DO concentrations there have been several fish kills in the past with the most recent occurring in December of 2000. IDNR fishery surveys have reported fish kills in the past. Despite the continual operation of two aeration systems, which were installed in the late 1980's after a severe fish kill, Eagle Lake still has low DO concentrations. As a result, fish kills will continue to occur. Eagle Lake will not be able to support a health fish population until the low DO issues are rectified. This may not be critical, as Eagle Lake is not used for recreational fishing. However, it may have an impact on wildlife that use the lake as a source of food and habitat.

Table 5. Wildlife species observed on Eagle Lake, May – September 2002.

<u>Birds</u>	
Pied-billed Grebe+	*Podilymbus podiceps*
Double-crested Cormorant	*Phalacrocorax auritus*
Canada Goose	*Branta canadensis*
Mallard	*Anas platyrhnchos*
Wood Duck	*Aix sponsa*
Red-breasted Merganser	*Mergus serrator*
American Coot	*Fulica americana*
Ring-billed Gull	*Larus delawarensis*
Great Egret	*Casmerodius albus*
Great Blue Heron	*Ardea herodias*
Green Heron	*Butorides striatus*
Black-crowned Night Heron*	*Nycticorax nycticorax*
Killdeer	*Charadrius vociferus*
Solitary Sandpiper	*Tringa solitaria*
Cooper’s Hawk	*Accipiter cooperii*
Red-tailed Hawk	*Buteo jamaicensis*
Osprey*	*Pandion haliaetus*
Mourning Dove	*Zenaida macroura*
Common Flicker	*Colaptes auratus*
Downy Woodpecker	*Picoides pubescens*
Eastern Kingbird	*Tyrannus tyrannus*
Purple Martin	*Progne subis*
Barn Swallow	*Hirundo rustica*
Tree Swallow	*Iridoprocne bicolor*
Chimney Swift	*Chaetura pelagica*
American Crow	*Corvus brachyrhynchos*
Blue Jay	*Cyanocitta cristata*
Black-capped Chickadee	*Poecile atricapillus*
Ruby-crowned Kinglet	*Regulus calendula*
Catbird	*Dumetella carolinensis*
American Robin	*Turdus migratorius*
Cedar Waxwing	*Bombycilla cedrorum*
Red-eyed Vireo	*Vireo olivaceus*
Yellow-rumped Warbler	*Dendroica coronata*
Chestnut-sided Warbler	*Dendroica penEagleica*
Yellow Warbler	*Dendroica petechia*
Common Yellowthroat	*Geothlypis trichas*
Ovenbird	*Seiurus aurocapillus*
Red-winged Blackbird	*Agelaius phoeniceus*
Common Grackle	*Quiscalus quiscula*

Table 5. Wildlife species observed on Eagle Lake, May-September 2002.

Birds(cont.)	
Starling	*Sturnus vulgaris*
House Sparrow	*Passer domesticus*
Northern Cardinal	*Cardinalis cardinalis*
House Finch	*Carpodacus mexic*
American Goldfinch	*Carduelis tristis*
Chipping Sparrow	*Spizella passerina*
Song Sparrow	*Melospiza melodia*
Reptiles	
Painted Turtle	*Chrysemys picta*
Snapping Turtle	*Chelydra serpentina*
Amphibians	
Spring Peepers	*Pseudacris crucifer*
American Toad	*Bufo americanus*
Bull Frog	*Rana catesbeiana*
Western Chorus Frog	*Pseudacris triseriata triseriata*

+Threatened in Illinois
*Endangered in Illinois

EXISTING LAKE QUALITY PROBLEMS

Eagle Lake has *below average* water quality due to high nutrient and suspended sediment concentrations in addition to low DO levels. These are common problems throughout Lake County especially in shallow, manmade lakes. Despite the fact that Eagle Lake is a low use site, these lake quality problems should still be addressed before the lake degrades further. However, all aspects of Eagle Lake are not in poor condition. Eagle Lake provides good habitat for a variety of wildlife species including several State threatened and endangered species.

- *Shoreline Erosion*

  The overall occurrence of erosion on Eagle Lake was moderately high. As stated previously, Eagle Lake has some form of erosion on 60% of its shoreline. The main cause of this erosion is lack of suitable shoreline vegetation. The two most eroded shoreline types were found to be developed woodlands and manicured lawn. Both of these shoreline types contain shallow rooted vegetation, which are unable to stabilize the soil. Erosion is contributing to water quality problems such as sedimentation, nutrient enrichment and resulting nuisance algae blooms. If left unattended, the erosion problem will continue to worsen, further aggravating related water quality issues. For this reason, shoreline erosion on Eagle Lake should be addressed immediately. Depending on the severity of erosion these techniques on Eagle Lake include the use of regrading, rip rap, biologs, and buffer strips. Lake Forest Academy, as well as individual property owners should promote and implement the use of more naturalized shoreline types (buffer strips of native vegetation) when replacing existing structures and to extend these buffers into the lake by planting emergent vegetation, which will help to dissipate wave action. This will benefit not only the water quality of Eagle Lake, but also improve the wildlife habitat surrounding the lake.

- *Low Dissolved Oxygen*

  Despite the operation of an aeration system in both portions of the lake, Eagle Lake has low DO concentrations for much of the summer. The east lobe had DO concentrations that were below or just above 5.0 mg/L in July and August, which is the minimum concentration needed to sustain aquatic life. In the west portion of the lake, DO concentrations were well below 5.0 mg/L for June, July, August, and September. Furthermore, these DO measurements were taken during the day when concentrations are at their highest. Concentrations are probably dangerously below the threshold limit (5.0 mg/L) during the evening/early morning hours when oxygen is being consumed by biological respiration. Eagle Lake experiences periodic fish kills due to low DO conditions even with the aeration system operating. The main factor contributing to these low DO conditions is decomposing organic matter. Portions of Eagle Lake experience season long planktonic algae blooms as well as periodic filamentous algae blooms. Bacterial decomposition consumes oxygen as these blooms decay. Additionally, the west portion of the lake is choked with dense growth of coontail, which also consumes oxygen as it decomposes as well as in day-to-day metabolic processes. To rectify this problem, the Lake Forest Academy needs to reevaluate the size of the compressors that run the aeration systems in Eagle Lake. Currently the compressors on Eagle Lake are 2.0 horsepower each and have an estimated output of 5 psi. Based on the surface area of Eagle Lake, each compressor unit should be at least 2.0 – 4.0 horsepower and operating at a minimum of 5 psi and 20 –28 CFM. However, just upgrading the compressor may not fix the problem since there may be high biological oxygen demand (especially the west lobe), which may still over come the effect of the aeration units. For these reasons the Academy may want to consider shutting off the aeration units during the summer months and only operate the units in the winter to prevent lake-wide ice formation. This would prevent winterkills while reducing the resuspension of sediment during the summer months. Since fishery health is not a concern at Eagle Lake, summer DO concentrations are inconsequential so operation of the aeration units for the purpose of improving DO conditions is not a priority. Additionally, it may be beneficial to remove the filamentous algae blooms by hand instead of treating them with algaecides. This would reduce the amount of decaying organic matter in the lake.

- *Invasive Species Management*

  Four exotic invasive species were found along Eagle Lake's shoreline: European black alder, purple loosestrife, reed canary grass, and common buckthorn. These nuisance species are extremely aggressive and have displaced desirable, native vegetation, which has lead to loss of food, habitat and increased erosion in several areas around the lake. The spread of these aggressive species must be stopped before they become further established. There are several different management techniques that can be used in control. Some species like the European black alder are already well established and control may involve more intensive management practices such as removal. Care should be taken when removing near shore growth to minimize disturbance in order to prevent further erosion.

- *Aquatic Plant Densities*

  One key to a healthy lake is a healthy aquatic plant population. Eagle Lake has average plant *diversity*. However, plant *densities* are of concern. The eastern portion of the lake has *poor* densities and the western portion of the lake has *excessive* plant densities. The negative impacts associated with an unbalanced aquatic plant community are wide spread and include water quality and fishery health problems. The lack of aquatic plant coverage in the east lobe, and subsequent loss of water clarity, is more than likely the result of excessive suspended solids. Curly leaf pondweed is the dominant plant in the spring, but after die-off, very little aquatic vegetation grows in the east lobe. This may be due the shading effect of the curly leaf in the spring, algae blooms, carp activity, or a combination of these factors. In contrast, the aquatic pant densities in the west lobe are *excessive*. This is due to the aggressive nature of coontail combined with the shallow morphometry of the west lobe. Establishing a balanced aquatic plant community is essential in improving the quality of Eagle Lake. Establishing aquatic vegetation in the east lobe will stabilize sediment and help to reduce algae blooms, which will improve water clarity/quality. Controlling the excessive growth of coontail in the west lobe will improve DO concentrations as well as improve plant diversity in that portion of the lake. Additionally, these vegetated areas will provide valuable fish and wildlife habitat. This is a long-term process and involves other management practices as well.

- *Lake Data*

  The lack of quality lake data is a common problem for many of the lakes in Lake County. This is either due to poor record keeping or lack of involvement on the part of the management entity/residents. The Lake Forest Academy has been managing the lake for decades but accurate records may not have always been kept. Additionally, data such as Secchi depth, water fluctuations, and DO profiles are not collected/monitored. Collection of this type of lake data can be very important in making decisions on the management of the lake. This data can be used to track changes (or lack of) in lake quality over many years. Additionally, this data is very important to agencies, such as the LMU, when conducting studies of the lake and allows for a more complete analysis. It is our recommendation that Eagle Lake (Lake Forest Academy) becomes involved in the IEPA's Volunteer Lake Monitoring Program (VLMP). This program uses volunteers to collect bimonthly lake data for the IEPA. This program is worth the time and effort and provides valuable information about the lake.

- *Lack of a Bathymetric Map*

  There has never been a bathymetric (contour) map made for Eagle Lake. These maps can be of great use to fishermen as well as lake managers. Bathymetric data can show where possible problematic areas may be located (i.e., shallow areas). Bathymetric maps can also provide volumetric data that can be utilized for management techniques such as aeration and volumetric applications of products such as herbicides and rotenone (a fish toxicant). These practices cannot be properly executed without a good bathymetric map and accompanying data. These maps can be easily made using different methods. All lakes in the County should have a current, good quality bathymetric map and Eagle Lake is no exception.

POTENTIAL OBJECTIVES FOR EAGLE LAKE MANAGEMENT PLAN

I. Shoreline Erosion Control
II. Dissolved Oxygen Improvement
III. Eliminate/Control Invasive Species
IV. Aquatic Plant Control/Revegetation
V. Volunteer Lake Monitoring Program
VI. Create a Bathymetric Map with Morphometric Data

OPTIONS FOR ACHIEVING THE LAKE MANAGEMENT PLAN OBJECTIVES

Objective I: Shoreline Improvement and Erosion Control

Erosion to shorelines on Eagle Lake is a problem. Shoreline erosion 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. During the 2002 survey of Eagle Lake a large majority of shoreline was found to be eroded. Approximately 60% (5,713 feet) of Eagle Lake's shoreline had some form of erosion. These areas should be addressed as soon as possible in order to avoid further deterioration.

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: Install Rock Rip Rap

Rip rap is the term for using rocks to stabilize shorelines. Size of the rock depends on the severity of the erosion, distance to rock source, and aesthetic preferences. Generally, four to eight inch diameter rocks are used. *The use of rip rap should be viewed as a last resort* after other alternatives such as biologs have been tried or are inappropriate. Rip rap can be incorporated with other erosion control techniques such as plant buffer strips. If any plants will be growing on top of the rip rap fill will probably be needed to cover the rocks and provide an acceptable medium for plants to grow on. *It is imperative that filter fabric be used under the rip rap to provide quality, long lasting results.* Prior to the initiation of work, permits and/or surveys from the appropriate government agencies need to be obtained (see costs below). Rip rap is best used for areas of **moderate erosion** and gentle to moderately sloped shores (<2:1). If rip rap is to be used on shorelines steeper than 2:1, then grading must be done in order to reduce grade to ≤ 2:1, preferably 3:1. *Every effort should be made to use more natural, less intrusive methods of shoreline stabilization (buffer strips and biologs).* However, the site must be prepared (grading, etc.) accordingly.

Pros

Rip rap can provide good shoreline erosion control. Rocks can absorb some of the wave energy while providing a more aesthetically pleasing appearance than seawalls. If installed properly, rip rap will last for many years. Maintenance is relatively low; however, undercutting of the bank can cause sloughing of the rip rap and subsequent shoreline. Areas with slight to moderate erosion problems may benefit from using rip rap. In all cases, a filter fabric should be installed under the rocks to maximize its effectiveness.

Fish and wildlife habitat can be provided if large boulders are used. Crevices and spaces between the rocks can be used by a variety of animals and their prey. Small mammals, like shrews can inhabit these spaces and prey upon many invertebrate species, including many harmful garden and lawn pests. Also, small fish may utilize the structure created by large boulders for foraging and hiding from predators.

Cons

A major disadvantage of rip rap is the initial expense of installation and associated permits. Installation is expensive since a licensed contractor and heavy equipment are generally needed to conduct the work. Permits are required if replacing existing or installing new rip rap and must be acquired prior to work beginning. If any fill material is placed in the floodplain along the shoreline; compensatory storage may also be needed. Compensatory storage is the process of excavating in a portion of a property or floodplain to compensate for the filling in of another portion of the floodplain. While rip rap absorb wave energy more effectively than seawalls, there is still some wave deflection that may cause resuspension of sediment and nutrients into the water column.

Small rock rip rap is poor habitat for many fish and wildlife species, since it provides limited structure for fish and cover for wildlife. As noted earlier, some small fish and other animals will inhabit the rocks if boulders are used. Smaller rip rap is more likely to wash way due to rising water levels or wave action. On the other hand, larger boulders are more expensive to haul in and install.

Rip rap may be a concern in areas of high public usage since it is difficult and possibly dangerous to walk on due to the jagged and uneven rock edges. This may be a liability concern to property owners.

Costs
Cost and type of rip rap used depend on several factors, but average cost for installation (rocks and filter fabric) is approximately $30-45 per linear foot. Based on assessed *moderately* eroded shoreline, Eagle Lake would need approximately 1134 linear feet of rip rap. This would come to a cost of approximately $34,020 – $51,030. The steeper the slope and severity of erosion, the larger the boulders that will need to be used and thus, higher installation costs. In addition, costs will increase with poor shoreline accessibility and increased distance to rock source. Costs for permits and surveys can be $1,000-2,000 for installation of rip rap, depending on the circumstances. Additional costs will be incurred if compensatory storage is needed. Contact the Army Corps of Engineers, local municipalities, and the Lake County Planning and Development Department.

<u>Option 3: Buffer Strips</u>
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 shorelines with **slight erosion** and 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 more 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 or rip rap. Furthermore, it is our recommendation that buffer strips be established along all applicable shorelines of Eagle Lake regardless of shoreline type.

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 6 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., muskrats) by placing a wire cage over the plants for at least one year.

A technique that is sometimes implemented along shorelines is the use of willow posts, or live stakes, which are harvested cuttings from live willows (*Salix* spp.). They can be planted along the shoreline along with a cover crop or native seed mix. The willows will resprout and begin establishing a deep root structure that secures the soil. If the shoreline is more highly eroded, willow posts may have to be used in conjunction with another erosion control technique such as biologs or rip rap. The use of buffer strips in conjunction with other methods such as rip rap and seawalls is highly recommended.

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 6 should be considered for native plantings.

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 and "weedy" aquatic plants. 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. Two invertebrates of particular importance for lake management, the water-milfoil weevils (*Euhrychiopsis lecontei* and *Phytobius leucogaster*), which have been shown to naturally reduce stands of exotic Eurasian water-milfoil. Weevils need proper over wintering habitat such as leaf litter and mud which are typically found on naturalized shorelines or shores with good buffer strips. Many species of amphibians, birds, fish, mammals, reptiles, and invertebrates have suffered precipitous declines in recent years primarily due to habitat loss. Buffer strips may help many of these species and preserve the important diversity of life in and around lakes.

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. Based on the 2002 assessment, *slightly* eroded shoreline, Eagle Lake would need approximately 4362 linear feet of buffer strip. This would come to a cost of approximately $76,335. It is advisable that buffer strips be planted on all appropriate shoreline areas on Eagle Lake. However, some of this shoreline would be better suited for use of biologs incorporated with buffer vegetation (see *Option 4* below), which includes the use of buffer strips. 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.

Option 4: Install Biolog, Fiber Roll, or Straw Blanket with Plantings

These products are long cylinders of compacted synthetic or natural fibers wrapped in mesh. The rolls are staked into shallow water. Once established, a buffer strip of native plants can be planted along side or on top of the roll (depending if rolls are made of synthetic or natural fibers). They are most effective in areas where plantings alone are not effective due to already severe erosion. These products are best used in areas on more **moderately** eroded shorelines or areas with highly erodable soil types. Many times biologs are used in conjunction with vegetated buffer strips as an alternative to rip rap.

Pros
Biologs, fiber rolls, and straw blankets provide erosion control that secure the shoreline in the short-term and allow native plants to establish which will eventually provide long-term shoreline stabilization. They are most often made of bio-degradable materials, which break down by the time the natural vegetation becomes established (generally within 3 years). They provide additional strength to the shoreline, absorb wave energy, and effectively filter run-off from terrestrial sources. These factors help improve water quality in the lake by reducing the amount of nutrients available for algae growth and by reducing the sediment that flows into a lake.

Cons
These products may not be as effective on highly erodible shorelines or in areas with steep slopes, as wave action may be severe enough to displace or undercut these products. On steep shorelines grading may be necessary to obtain a 2:1 or 3:1 slope or additional erosion control products may be needed. If grading or filling is needed, the appropriate permits and surveys will have to be obtained.

Costs

Costs range from $25 to $35 per linear foot of shoreline, including plantings. Based on *moderately* eroded shorelines, Eagle Lake would need 1134 linear feet of one of the above products on the moderate eroded areas of shoreline. This would cost approximately $28,350 – 39,690. This does not include the necessary permits and surveys, which may cost $1,000 – 2,000 depending on the type of earthmoving that is being done. Additional costs may be incurred if compensatory storage is needed.

Objective II: Dissolved Oxygen Improvement

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

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

Ice-covered (nutrient-enriched) lakes may also develop variations of DO dependent on depth. If there is little or no snow cover to block sunlight, algae and some plants may continue to photosynthesize, resulting in a small increase in DO just below the ice. But as microorganisms continue to decompose material in the lower water column and in the sediment, they consume oxygen, and the DO is depleted. No oxygen input from the air occurs because of the ice cover, and, if snow covers the ice, it becomes too dark for photosynthesis. This condition can cause high fish mortality during the winter, known as "winter kill." Lakes in this area that do not have at least 25% of their surface area with a depth of at least 10 feet are prone to winter kill. Since no bathymetric map exists for Eagle Lake it is impossible to calculate if Eagle Lake meets this requirement. However, based on field observations almost all of Eagle Lake is shallower than 10 feet and therefore is at a high risk for winter fish kills without aeration.

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

Option 1. No Action

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

Pros

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

Cons

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

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

Option 2: Aeration via Artificial Circulation

Artificial circulation of lakes has been employed as a management technique since at least the early 1950s. Initially it was used to prevent fish kills during winter in shallow, ice-covered lakes. Since the 1960s it has also been used as a technique to obtain additional water quality improvements and control nutrient enrichment. Artificial circulation is probably the most widely used lake management technique for lake rehabilitation. Eagle Lake installed an aeration system in the late 1980's. This unit is operated year round to avoid fish kills.

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

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

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

Pros

When properly sized for the lake, these systems can improve DO concentrations in the water column to help prevent fish kills and increase habitat for aquatic life.

Zooplankton and warmwater fish such as bass and bluegill can inhabit a larger volume of the lake, due to higher DO concentrations throughout the lake.

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

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

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

Cons

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

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

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

Costs

In the late 1980's, the Academy installed two aeration systems in Eagle Lake (one in each lobe). These systems each consist of a 2 horsepower compressor, two diffuser heads (box bubblers), and tubing placed at the deep locations in each lobe. However, these compressors may not be functioning at optimum efficiency and may not be producing enough circulation to sufficiently oxygenate the water column. To properly aerate Eagle Lake and provide adequate oxygen concentrations, the compressor unit(s) should have a combined horsepower rating of 4.0-7.7 (2.0-3.8 horsepower each). The cost for these sized units would be approximately $2,200 -$4,500. The electricity for this size of a unit should be between $1,000 and $2,000 per year. Additionally, a manifold ($100) should be used in order to control the flow of air to the diffusers. While the compressors at Eagle Lake meet the minimum power requirements the output of these units are questionable. The Academy needs to verify the operating efficiency of these units before adjusting or upgrading the compressors. /

Objective III: 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 European black alder (*Alnus glutinosa*) are three examples. These exotic and invasive plants have made their way onto the shores of Eagle Lake. 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 per plant), and high seed germination rate, purple loosestrife spreads quickly. Buckthorn is an aggressive shrub species that grows along lake shorelines as well as most upland habitats. It shades out other plants and is quick to become established on disturbed soils. Reed canary grass is an aggressive plant that if left unchecked will dominate an area, particularly a wetland or shoreline, in a short period of time. Since it begins growing early in the spring, it quickly out-competes native vegetation that begins growth later in the year. Control of purple loosestrife, buckthorn, and reed canary grass are discussed below. However, these control measures can be similarly applied to other exotic species such as garlic mustard (*Allilaria officianalis*) or honeysuckle (*Lonicera* spp.) as well as some aggressive native species, such as box elder (*Acer negundo*).

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

<u>Option 1: No Action</u>

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 monoculture. Access to lake shorelines may be impaired due to dense stands of non-native plants. Other recreational activities, such as swimming and boating, may not be effected.

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

Option 2: Hand Removal

Controlling exotic plants by hand removal is most effective on small areas (< 1 acre) and if done prior to heavy infestation. This is probably the best method (combined with herbicides) for removal of some of the invasive species on Eagle Lake. 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 excavated. This is probably the most effective method of removal on Eagle Lake for purple loosestrife on individual homeowner's lots. Spring or summer is the best time to cut or mow, since late summer and fall is when many of the plant seeds disperse. Additionally, hand removal (cutting) may be one of the most effective ways to remove mature stands of buckthorn and European black alder. 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

Treatment with herbicides is one of the best options for controlling **mature stands** of some invasive species, such reed canary grass and purple loosestrife, on Eagle Lake. 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. In the case of mature tree species, special application methods may be needed in order to be effective and reduce damage to off target vegetation.

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. The label is the law. Table 7 (Appendix A) contains herbicides that are approved for use near water for control of nuisance vegetation. Included in this table are rates, costs, and restrictions on use.

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

See Table 7 (Appendix A) for herbicide rates and prices. Total cost to treat the limited amount of purple loosestrife and other invasive species on Eagle Lake would be minimal and could be done by individual homeowners or the Lake Forest Academy. Hand-held and backpack sprayers costs from $25-$45 and $80-150, respectively. Wicking devices are $30-40. For other species, such as the buckthorn and European black alder, a device such as a Hydrohatchet®, a hatchet that injects herbicide through the bark (about $300) may be needed. Another injecting devise, E-Z Ject® is $450. Hand-held and backpack sprayers costs from $25-$45 and $80-150, respectively. Wicking devices are $30-40. A low cost alternative to specialized spray equipment is the use of household spray bottles (commonly used for window and bathroom cleaners). These bottles can be purchased at department stores for minimal costs. However, after there use for herbicide application they should not be used for anything else. Similarly, spray canisters like those used to apply lawn chemicals also provide lower costs alternatives to commercial spray equipment. The Academy may already own much of the necessary equipment, which would dramatically reduce costs.

Objective IV: Aquatic Plant Control/Revegetation

All aquatic plant management techniques have both positive and negative characteristics. If used properly, they can all be beneficial to a lake's well being. If misused or abused, they all share similar outcomes - negative impacts to the lake. Putting together a good aquatic plant management plan should not be rushed. Plans should consist of a realistic set of goals well thought out before implementation. The plan should be based on the management goals of the lake and involve usage issues, habitat maintenance/restoration, and limitations of the lake. For an aquatic plant management plan to achieve long term success, follow up is critical. A good aquatic plant management plan considers both the short and long-term needs of the lake. The management of the lake's vegetation does not end once the nuisance vegetation has been reduced/eliminated. It is critical to continually monitor problematic areas for regrowth and remove as necessary. An association or property owner should not always expect immediate results. A quick fix of the vegetation problems may not always be in the best interest of the lake. Sometimes the best solutions take several seasons to properly solve the problem. The management options covered below are commonly used techniques that are coming into wider acceptance and have been used in Lake County. There are other plant management options that are not covered below as they not are very effective, unreliable, or are too experimental to be widely used.

Option 1: No Action

If the lake is dominated by *native*, *non-invasive* species, the no action option could be ideal. Under these circumstances native plant populations could flourish and keep nuisance plants from becoming problematic. However, if a no action aquatic plant management plan in a lake with non-native, invasive species, nothing would be done to control the aquatic plant population of the lake regardless of the type and extent of the vegetation. Nuisance vegetation could continue to grow until epidemic proportions are reached. Growth limitations of the plant and the characteristics of the lake itself (light penetration, lake morphology, substrate type, etc.) will dictate the extent of infestation. Rooted plants, such as curly leaf pondweed (*Potamogeton crispus*) and elodea (*Elodea canadensis*), will be bound by physical factors such as substrate type and light availability. Plants such as Eurasian watermilfoil and coontail, which can grow unrooted at the surface regardless of water depth, could grow to cover 100% of the water's surface. This could cause major inhibition of the lakes recreational uses and impact fish and other aquatic organisms adversely.

Pros

There are positive aspects associated with the no action option for plant management. The first, and most obvious, is that there is no cost. However, if an active management plan for vegetation control were eventually needed, the cost would be substantially higher than if the no action plan had not been followed in the first place. Another benefit of this option would be the lack of environmental manipulation. Under the no action option, no chemicals, mechanical alteration, or introduction of any organisms would take place. This is important since studies have shown that nuisance plants are more likely to invade disrupted areas. If the lake contains native, non-invasive plant species, expansion of the native plant population would increase the overall biodiversity and health of the lake. Habitat, breeding areas, and food source availability would greatly improve. Use of the lake would continue as normal and in some cases might improve (fishing) if native plants keep "weedy" plants under control.

An additional benefit of the no action option is the possible improvement in water quality. Turbidity could decrease and clarity should increase due to sediment stabilization by the plant's roots. Algal blooms could be reduced due to decreased resource availability and sediment stabilization. However, the occurrence of filamentous algae may increase/remain stable due to their surface growth habitat. The lake's fishery could improve due to habitat availability, which in turn would have numerous positive effects on the rest of the lake's ecosystem.

Cons

Under the no action option, if nuisance vegetation is dominant in the lake and were uninhibited and able to reach epidemic proportions, there will be many negative impacts on the lake. By their weedy nature, the nuisance plants would out-compete the more desirable native plants. This could eventually, drastically reduce or even eliminate the native plant population of the lake and reduce the lake's biodiversity. The fishery of the lake may become stunted due the to lack of quality forage fish habitat and reduced predation. Predation will decrease due to the difficulty of finding prey in the dense stands of vegetation. This will cause an explosion in the small fish population and with food resources not increasing, growth of fish will be reduced. Decreased dissolved oxygen levels, due to high biological oxygen demand from the excessive vegetation, will also have negative impacts on the aquatic life. Wildlife populations will also be negatively impacted by these dense stands of vegetation. Birds and waterfowl will have difficulty finding quality plants for food or in locating prey within the dense plant stands.

Water quality could also be negatively impacted with the implementation of the no action option. Deposition of large amounts of organic matter and release of nutrients upon the death of the massive stands of vegetation is a probable outcome of the no action option. These dead plants will contribute to the sediment load of the lake and could accelerate its filling in. The large nutrient release when the plants die back in the fall could lead to lake-wide algae blooms and an overall increase of the internal nutrient load. In addition, the decomposition of the massive amounts of vegetation will lead to a depletion of the lakes dissolved oxygen. This can cause fish stress, and eventually, if the stress is frequent or severe enough, fish kills. All of the impacts above could in turn have negative impacts on numerous aspects of the lake's ecosystem.

In addition to the ecological impacts, many physical uses of the lake will be negatively impacted. Boating could be nearly impossible without becoming entangled in thick stands of plants. Swimming could also become increasingly difficult due to thick vegetation that would develop at beaches. Fishing could become more and more exasperating due in part to the thick vegetation and also because of the stunted fish population. In addition, the aesthetics of the lake will also decline due to large areas of the lake covered by tangled mats of vegetation and the odors that will develop when they decay. The combination of the above events could cause property values on the lake to suffer. Property values on lakes with weedy plant/algae problems have been shown to decrease by as much as 15-20%.

Costs
No cost will be incurred by implementing the no action management option. However, if in the future a management plan was initiated, costs might be significantly higher since a no action plan was originally followed.

Option 2: Aquatic Herbicides

Aquatic herbicides are the most common method to control nuisance vegetation/algae. When used properly, they can provide selective and reliable control. Products can not be licensed for use in aquatic situations unless there is less than a 1 in 1,000,000 chance of any negative effects on human health, wildlife, and the environment. Aquatic herbicides are not allowed to be environmentally persistent, bioaccumulate, or have any bioavailability. Prior to herbicide application, licensed applicators should evaluate the lake's vegetation and, along with the lake's management plan, choose the appropriate herbicide and treatment areas, and apply the herbicides during appropriate conditions (i.e., low wind speed, DO concentration, temperature).

There are two groups of herbicides: contact and systemic. Contact herbicides, like their name indicates, kill on contact. These herbicides affect only the above ground portion of the plant that they come into contact with and therefore do not kill the root system. An example of a contact herbicide is diquat. Systemic herbicides are taken up by the plant and disrupt cellular processes, which in turn cause plant death. These herbicides kill both the above ground portions of the plant as well as the root system. An example of a systemic herbicide is fluridone. Both types of herbicides are available in liquid or granular forms. Liquid forms are concentrated and need to be mixed into water to obtain the desired concentration. The solution is then sprayed on the water's surface or injected into the water in the treatment areas. Granular herbicides are broadcast in a known rate over the treatment area where they sink to the bottom. Some granular products slowly release the herbicide, which is then taken up by the plant. These are referred to as SRP formulations (Slow Release Pellet). Other granular herbicides come in crystal form and dissolve as they come in contact with water. This is typical of herbicides such as copper sulfate. Many herbicides come in both liquid and granular forms to fit the management needs of the lake. Herbicide applications can either be done as whole lake treatments or as more selective spot treatments. Multiple herbicides are often mixed and applied together. This is called a tank mix. This is done to save time, energy, and cost.

Aquatic herbicides are best used on actively growing plants to ensure optimal herbicide uptake. For this reason, herbicides are normally applied mid to late spring when water temperatures are above 60^0F. This is the time of year when the plants are most actively growing and before seed/vegetative propagule formation. Follow up applications should be done as needed. When choosing an aquatic herbicide it is important to know what plants are present, which ones are problematic, which plants are beneficial, and how a particular herbicide will act upon these plants. The herbicide label is very important and should always be read before use. There may be more than one herbicide for a given plant. As with other management options, proper usage is the key to their effectiveness, benefits, and disadvantages.

The main use of herbicides in Eagle Lake would be to control the excessive growth of coontail in the west lobe. Additionally, algaecides could be used to control the filamentous algae blooms in the west lobe during the spring. Currently, the Lake Forest Academy is using an algicide (copper sulfate) to try to control both the coontail and the filamentous algae. While the algicide is effective on the filamentous algae blooms it is ineffective on the coontail since it is a vascular plant not a algae. Use of the algicide for control of coontail should stop immediately. Should they continue to treat the coontail, Lake Forest Academy should select an herbicide that is labeled for control of coontail (i.e., 2,4-D, fluridone, or diquat).

Pros

When used properly, aquatic herbicides can be a powerful tool in management of excessive vegetation. Often, aquatic herbicide treatments can be more cost effective in the long run compared to other management techniques. A properly implemented plan can often provide season long control with minimal applications. Ecologically, herbicides can be a better management option than using mechanical harvesting or grass carp. When properly applied, aquatic herbicides may be selective for nuisance plants such as Eurasian water milfoil but allow desirable plants such as American pondweed (*Potamogeton nodosus*) to remain. This removes the problematic vegetation and allows native and more desirable plants to remain and flourish with minimal manipulation.

The fisheries and waterfowl populations of the lake would benefit greatly due to an increase in quality habitat and food supply. Dense stands of plants would be thinned out and improve spawning habitat and food source availability for fish. Waterfowl population would greatly benefit from increases in quality food sources, such as large-leaf pondweed (*Potamogeton amplifolius*). Another environmental benefit of using aquatic herbicides over other management options is that they are organism specific. The metabolic pathways by which herbicides kill plants are plant specific which humans and other organisms do not carry out. Organisms such as fish, birds, mussels, and zooplankton are generally unaffected.

By implementing a good management plan with aquatic herbicides, usage opportunities of the lake would increase. Activities such as boating and swimming would improve due to the removal of dense stands of vegetation. The quality of fishing may improve because of improved habitat. In addition to increased usage opportunities, the overall aesthetics of the lake would improve, potentially increasing property values on the lake.

Cons

The most obvious drawback of using aquatic herbicides is the input of chemicals into the lake. Even though the United States Environmental Protection Agency (USEPA) approved these chemicals for use, human error can make them unsafe and bring about undesired outcomes. If not properly used, aquatic herbicides can remove too much vegetation from the lake. This could drastically alter biodiversity and ecological. Total or over-removal of plants can cause a variety of problems lake-wide. The fishery of the lake may decline and/or become stunted due to predation issues related to decreased water clarity. Other wildlife, such as waterfowl, which commonly forage on aquatic plants, would also be negatively impacted by the decrease in food supply.

Another problem associated with removing too much vegetation is the loss of sediment stabilization by plants, which can lead to increased turbidity and resuspension of nutrients. The increase in turbidity can cause a decrease in light penetration, which can further aggravate the aquatic plant community. The resuspension of nutrients will contribute to the overall nutrient load of the lake, which can lead to an increased frequency of noxious algal blooms. Furthermore, the removal of aquatic vegetation, which competes with algae for resources, can directly contribute to an increase in blooms.

After the initial removal, there is a possibility for regrowth of vegetation. Upon regrowth, weedy plants such as Eurasian watermilfoil and coontail quickly reestablish, form dense stands, and prevent the growth of desirable species. This causes a decrease in plant biodiveristy. Additionally, these dense stands of nuisance vegetation can lead to an overpopulation of stunted fish due to a decrease in predation of forage species by predatory fish. This disruption in the fisheries can have negative impacts throughout the ecosystem from zooplankton to higher organisms such as waterfowl and other wildlife. Additionally, some herbicides have use restrictions regarding their use in relation to fish, swimming, irrigation, etc.

Over-removal, and possible regrowth of nuisance vegetation that may follow will drastically impair recreational use of the lake. Swimming could be adversely affected due to the likelihood of increased algal blooms. Swimmers may become entangled in large mats of filamentous algae. Blooms of planktonic species, such as blue-green algae, can produce harmful toxins as well produce noxious odors. If regrowth of nuisance vegetation were to occur, motors could become entangled making boating difficult. Fishing would also be negatively impacted due to the decreased health of the lake’s fishery. The overall appearance of the lake would also suffer due to an increase in unsightly algal blooms and massive stands of vegetation. This in turn could have an unwanted effect on property values.

Studies have shown that problematic algal blooms can decrease property values by 15-20%.

Costs

Cost would be dependent on the area to be treated and the type of herbicide that were to be used. For the use of 2,4-D, which is commonly used to treat coontail, the cost would be approximately $350 –450 per acre (including labor). Diquat would cost approximately $425 per acre with follow up treatments as necessary. Fluridone treatments are based on whole lake volume (not area) with costs of approximately $10-12 per acre-foot depending on desired concentration. Based on preliminary estimates, lake volume is an approximately 108 acre feet, which would cost $1100-1300 to treat with fluridone. However, this would be a whoel lake treatment and could remove more desirable vegetation such as sago pondweed and flatstem pondweed.

Option 3: Hand Removal

Hand removal of excessive aquatic vegetation is a commonly used management technique. Hand removal is normally used in small ponds/lakes and limited areas for selective vegetation removal. Areas surrounding piers and beaches are commonly targeted areas. Typically tools such as rakes and cutting bars are used to remove vegetation. These are easily obtainable through many outdoor supply catalogs or over the internet. Some rakes are equipped with tines as well as cutting edges. Tools can also be hand made by drilling a hole in the handle of a heavy-duty garden rake and tying it to a length of rope. Weights may be needed in order to provide forceful contact with the plants. In many instances, homeowners on lakes with near shore vegetation problems simply cut swaths through the weeds to create pathways to open water. Due to the limited amount of biomass removed, harvested plant material is often used as fertilizer and compost in gardens.

Pros

Hand removal is a quick, inexpensive, and selective way to remove nuisance vegetation. Hand removal is an activity in which all lake residents could participate. The work involved in removing plants can provide a rewarding sense of accomplishment. By removing excess vegetation, use of beaches and piers would be improved. Many of the improved water quality benefits of a well-executed herbicide program or harvesting program are also shared by hand removal. Wildlife habitat, such as fish spawning beds, could be greatly improved. This in turn would benefit other portions of the lake's ecosystem.

Cons

There are few negative attributes to hand removal. One negative implication is labor. Depending on the extent of infestation, removal of large amount, of vegetation can be quite tiresome. Another drawback can be disposal. Finding a site for numerous residents to dispose of large quantities of harvested vegetation can sometimes be problematic. However, individual homeowners would be removing limited quantities of plant material so there would not be much to dispose of. Another drawback is possible nonselective removal by hand harvesting. By throwing a rake blindly into the depths, it is impossible to determine what plants are removed and which ones are not until the rake is pulled up. Even in shallow depths, untrained persons might mistakenly remove desirable vegetation and/or disrupt valuable habitat (fish spawning beds). Over removal could also be a problem but is not normally a concern with hand removal.

Costs

Plant removal rakes can range in price from $50-150 and cutting tools commonly range in price from $50-200. Both are available from numerous catalogs and from the internet. A homemade rake would cost about $20-40.

Option 4: Reestablishing Native Aquatic Vegetation

Revegetation should only be done when existing nuisance vegetation, such as Eurasian water milfoil or coontail, are under control using one of the above management options. If the lake has poor clarity due to excessive algal growth or turbidity, these problems must be addressed before a revegetation plan is undertaken. Without adequate light penetration, revegetation will not work. At maximum, planting depth light levels must be greater than 1-5% of the surface light levels for plant growth and photosynthesis.

There are two methods by which reestablishment can be accomplished. The first is use of existing plant populations to revegetate other areas within the lake. Plants from one part of the lake are allowed to naturally expand into adjacent areas thereby filling the niche left by the nuisance plants. Another technique utilizing existing plants is to transplant vegetation from one area to another. The second method of reestablishment is to import native plants from an outside source. A variety of plants can be ordered from nurseries that specialize in native aquatic plants. These plants are available in several forms such as seeds, roots, and small plants. These two methods can be used in conjunction with one another in order to increase both quantity and biodiversity of plant populations. Additionally, plantings must be protected from herbivory by waterfowl and other wildlife. Simple cages made out of wooden or metal stakes and chicken wire are erected around planted areas for at least one season. The cages are removed once the plants are established and less vulnerable. If large-scale revegetation is needed it would be best to use a consultant to plan and conduct the restoration. Table 6 lists common, native plants that should be considered when developing a revegetation plan. Included in this list are emergent shoreline vegetation (rushes, cattails, etc) and submersed aquatic plants (pondweeds, *Vallisneria*, etc). Prices, planting depths, and planting densities are included and vary depending on plant species.

Pros

By revegetating newly opened areas that were once infested with nuisance species, the lake will benefit in several ways. Once established, expanded native plant populations will help to control growth of nuisance vegetation. This provides a more natural approach as compared to other management options. In addition, using established native plants to control excessive invasive plant growth can be less expensive in the long run than other options. Expanded native plant populations will also help with sediment stabilization. This in turn will have a positive effect on water clarity by reducing suspended solids and nutrients that decrease clarity and cause excessive algal growth. Properly revegetating shallow water areas with plants such as cattails, bulrushes, and water lilies can help reduce wave action that can lead to shoreline erosion. Increases in desirable vegetation will increase the plant biodiversity and also provide better quality habitat and food sources for fish and other wildlife. Recreational uses of the lake such as fishing and boating will also increase due to the improvement in water quality and the suppression of weedy species.

Cons

There are few negative impacts to revegetating a lake. One possible drawback is the possibility of new vegetation expanding to nuisance levels and needing control. However, this is an unlikely outcome. Another drawback could be high costs if extensive revegetation is needed using imported plants. If a consultant is used costs would be substantially higher. Additional costs could be associated with constructing proper herbivory protection measures.

Costs

See Table 6 for plant pricing. Additional costs will be incurred if a consultant/nursery is contracted for design and labor.

Objective V: 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.

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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Objective VI: Create a Bathymetric Map and Morphometric Data

A bathymetric (depth contour) map is an essential tool for effective lake management since it provides critical information on the morphometric features of the lake (i.e., acreage, depth, volume, etc.). This information is particularly important when intensive management techniques (i.e., chemical treatments for plant or algae control, dredging, fish stocking, etc.) are part of the lake's overall management plan. Some lakes in Lake County do have a bathymetric map, but they are frequently old, outdated and do not accurately represent the current features of the lake. Eagle Lake does not have a bathymetric map. Eagle Lake should have a detailed bathymetric map made. Maps can be created by agencies like the Lake County Health Department - Lakes Management Unit or other companies. Costs vary, but can range from $3,000-10,000 depending on lake size.