2000 SUMMARY REPORT
of
SALEM LAKE

Lake County, Illinois

Prepared by the

LAKE COUNTY HEALTH DEPARTMENT
ENVIRONMENTAL HEALTH SERVICES
LAKES MANAGEMENT UNIT
3010 Grand Avenue
Waukegan, Illinois 60085

Christina L. Brant
Michael Adam
Mary Colwell
Joseph Marencik
Mark Pfister

July 2001

Table of Contents

LAKE IDENTIFICATION AND LOCATION

Salem Lake is located in Ela Township within the village of Long Grove between Cuba Road and Old McHenry Road (T 43N, R 10E, S 24SW ¼). The lake is a shallow man-made impoundment with a surface area of 38.0 acres and a mean depth of 4.5 feet. The southwestern larger portion of the lake has a maximum depth of 8 feet, while the smaller northeastern part of the lake has a maximum depth of 9 feet. However, most of the lake falls between the 5 and 7 foot depth contours. Lake volume is approximately 184.1 acre-feet (Lake Management Unit surface area * average depth). The shoreline of Salem Lake is approximately 2.0 miles long and the fetch (longest distance wind blows unobstructed across a water body) is 0.5 miles. Salem Lake is in the Indian Creek Watershed, a sub-basin of the Des Plaines River Watershed. The lake receives its water through rainfall and stormwater inflows, and water level fluctuates very little. The outflow of the lake is a weir-like dam on the northwest shore that allows water to drain into Kildeer Creek to the north, and eventually connects with Indian Creek and the Des Plaines River. Water flow out of the lake was minimal during the 2000 study. Two areas of the shoreline on the northwest and northeast ends of the lake are built up with earth and rock. These are believed to be the original dams that were constructed to create the lake.

BRIEF HISTORY OF SALEM LAKE

The lake was created in 1942 by flooding a wetland area through the construction of two dams. Bottom ownership of Salem Lake belongs primarily to CF Industries, located on the southwest shore of the lake, but several parcels on the eastern end of the lake and along the east tributary area are privately owned. The Long Grove Park District owns one large parcel along the northeast shoreline of Salem Lake.

SUMMARY OF CURRENT AND HISTORICAL LAKE USES

Access to Salem Lake is public, to CF Industries' employees, and to visitors of Long Grove Park. Homeowners along the eastern shoreline have private access through their properties. Neither CF Industries nor private homeowners have formed an association to address lake management issues, but CF Industries does provide limited funds for fishery and plant management. The lake's main use is fishing, as swimming is prohibited. Rowboats and small boats with electric motors are the most common watercraft on the lake, as CF Industries does not allow gas-powered motors. The immediate watershed of Salem Lake is small and made up of a light industrial green parkway, a nature preserve and 11 homes. The rest of the watershed is a mixture of agricultural fields, residential areas, and the land surrounding Central Slough and Kemper Lakes.

LIMNOLOGICAL DATA – WATER QUALITY

Water samples collected from Salem Lake were analyzed for a variety of water quality parameters (See *Appendix A* for methodology). Samples were collected at 3 foot and 5-6 foot depths (depending on water level) from the deep hole location in the lake (Figure 1). Salem Lake did not thermally stratify in 2000. Thermal stratification occurs when a lake divides into an upper, warm water layer (epilimnion) and a lower, cold water layer (hypolimnion). When stratified, the epilimnetic and hypolimnetic waters do not mix, and the hypolimnion typically becomes anoxic by mid-summer. Salem Lake currently has five aerators, each with two diffusers. The diffusers are concentrated in the small bay east of CF Industries and throughout a small area northeast of their private pier. All 10 diffusers run from April through November, while only four diffusers in the small bay run year-round. By employing equations that incorporate lake acreage and the size of the aerators, it was determined that the aerators are properly sized to keep the water column completely mixed and oxygenated throughout the summer. Without these aerators, Salem Lake would probably stratify, and deeper areas of the lake would become anoxic. This would lead to increased nutrient loading from the sediment under anoxic conditions and further amplify the algae problem in the lake.

The absence of stratification in Salem Lake was discovered by assessing the water quality data, which showed that concentrations of most parameters collected from shallow water samples were similar to those same parameters collected from deep water samples. As a result, only data from the epilimnetic samples will be discussed. These parameters are explained in detail in a document accompanying this report*: Interpreting Your Water Quality Data*. The complete data set for Salem Lake is located in Table 1. Below is a brief discussion of the analysis of the water quality data collected over the five-month study of Salem Lake.

Phosphorus is a nutrient that can enter lakes through runoff or be released from lake sediment, and high levels of phosphorus typically trigger algal blooms. The average total phosphorus (TP) concentration in Salem Lake (0.165 mg/l) was 2.5 times higher than the Lake County average (0.066 mg/l), and reached a maximum concentration of 0.323 mg/l in July. Additionally, soluble reactive phosphorus (SRP) concentrations were above average from June through September. SRP is a readily available form of phosphorus and is easily utilized by algae and aquatic plants. As a result of these extremely high TP and SRP concentrations, some of the worst lake-wide blue-green algal blooms in Lake County during the summer of 2000 were observed on Salem Lake from July through September. Subsequently, low Secchi depths were recorded during each of these months. Secchi depth is a direct indicator of water clarity and overall water quality, and can be reduced by either algae or sediment in the water column. Secchi depth readings in Salem Lake declined from the lake bottom (6 feet) in May and June to approximately 1.5 feet from July through September. This corresponded with a dramatic increase of phosphorus and algae in the lake from July through September (Figure 2).

Besides causing decreased Secchi depth, lake-wide algal blooms negatively impacted other water quality parameters. Total suspended solids (TSS) increased from 3.4 mg/l in

May, to as high as 28.0 mg/l in August. Average TSS in 2000 was 16.5 mg/l, almost double the Lake County average of 8.6 mg/l (1995-2000 samples). Average total volatile solids (TVS) (134 mg/l), which represent the amount of organic material in the water (algae, plant matter, etc.), was also above the county average (129 mg/l). In addition, the maximum TVS concentration of 156 mg/l coincided with the maximum TSS value measured in August, indicating that increasing algae biomass in the water column was the cause of increased TSS values.

As stated above, excess nutrients were the cause of these dense algal blooms in Salem Lake. Typically, lakes are either phosphorus or nitrogen limited. This means that these nutrients are in short supply and that any addition of phosphorus or nitrogen to the lake will result in an increase of plant or algal growth. Other resources necessary for plant and algae growth, such as light or carbon, can be limiting, but this is rarely observed. Most lakes in Lake County are phosphorus limited, but to compare the availability of nitrogen and phosphorus, a ratio of total nitrogen to total phosphorus (TN:TP) is used. Ratios less than or equal to 10:1 indicate nitrogen is limiting. Ratios greater than or equal to 15:1 indicate that phosphorus is limiting. Ratios greater than 10:1, but less than 15:1 indicate that there are enough of both nutrients to facilitate excess algal or plant growth. Salem Lake had an average overall TN:TP ratio of 10:1. This indicates that the lake is borderline nitrogen limited, and that algal growth could be hindered by a lack of nitrogen. It also indicates that the addition of nitrogen to the lake would lead to an increase in algae growth.

Nitrogen can come from a variety of external sources, but can also be taken from the atmosphere and "fixed", (transformed from an atmospheric form to an organic form) by blue-green algae. This makes nitrogen input virtually impossible to control. Phosphorus input is typically easier to control, but the level of control largely depends on the phosphorus source. The source of phosphorus in a lake can be either external or internal. External sources originate outside of the lake and can include fertilizer runoff, erosion, or failing septic systems. Internal sources originate from plants and algae cells or lake sediment, a common source of phosphorus in man-made lakes, which typically contain rich, organic sediment. Phosphorus can be released from oxic sediment through biological or mechanical processes, or from plant or algae cells as they die. This typically occurs in lakes like Salem Lake that do not stratify, and the phosphorus released from bottom sediment or algal/plant cells can be easily distributed throughout the water column. Increases in P and nitrogen (N) in Salem Lake did not coincide with similar increases in rainfall from month to month, as would be expected if the sources were external. The source of phosphorus in Salem Lake appeared to be algal cells, and the concentration of phosphorus in the water column was largely dependent on the concentration of nitrogen available to the algae. As mentioned above, Salem Lake is nitrogen limited, meaning that, at times, there was not enough N in the water column to sustain algal growth. If algae is not growing, it will not take up and utilize either N or P from the water. However, as the algae in the water die, SRP will be released from those cells, resulting in a build-up of unused P in the water. This appears to be what was happening in Salem Lake during the summer of 2000. Although P levels were high in June, the N:P ratio was 11:1 due to a large pulse of NH_3 released from the decomposition of curly leaf pondweed plants treated in May (Table 1). This source of N was gone by early July and the NH_3 concentration dropped. The phosphorus concentration, however, remained high due to continued release from plant and algae decomposition. Subsequently, the N:P ratio in July was 4:1, indicating extreme N-limitation. Without a source of N, the algae were not able to use any P for growth. This resulted in the dramatic increase in the P concentration as the unused P built up in the water column in July. By August, the N-starved blue-green algae began to fix atmospheric nitrogen, driving up the N:P ratio to 12:1 and enabling the algae to utilize P in the water column. As a result, TP and SRP levels decreased in August and September (Table 1, Figure 3).

Phosphorus levels can be used to indicate the trophic state (productivity level) of a lake. The Trophic State Index (TSI) uses phosphorus levels, chlorophyll *a* levels and Secchi depth to classify and compare lake trophic states using just one value. The TSI is set up so that an increase in phosphorus concentration is related to an increase in algal biomass and a corresponding decrease in Secchi depth. A high TSI value indicates eutrophic (TSI=50-69) to hypereutrophic (TSI ≥70) lake conditions. Salem Lake has a phosphorus TSI value of 78 indicating hypereutrophic conditions. This means that the lake is a highly productive system and has excessive nutrient concentrations and algae growth. Dissolved oxygen concentrations would, likely, fall at certain times during the summer if the aerators were not present, and lake clarity is poor. Although the TSI of Salem Lake is not unusual for Lake County (most man-made lakes in the County fall into the eutrophic and hypereutrophic categories), it has the 63rd highest TSI value of 86 lakes studied in Lake County from 1988-2000. The ranking would be much lower (83rd out of 86) if only 2000 data was used. (Table 2).

Most of the water quality parameters discussed can be used to analyze the water quality of Salem Lake based on use impairment indices established by the Illinois Environmental Protection Agency (IEPA). According to this index, Salem Lake has *Partial* overall use impairment due to low water clarity and elevated phosphorus levels. The lake provides *Full* aquatic life support, but *Nonsupport* for swimming and recreational uses due to poor Secchi depth readings, which prevent adequate swimming conditions, high TSS values, and macrophyte growth. Additionally, the Illinois Department of Public Health recommends at least 48” Secchi disk depth for safe swimming (Salem Lake’s average was 19”).

LIMNOLOGICAL DATA – AQUATIC PLANT ASSESSMENT

Aquatic plant surveys were conducted every month for the duration of the study (See *Appendix A* for methodology). Shoreline plants of interest were also observed and recorded. However, no quantitative surveys were made of these shoreline species and all data are purely observational (Table 3). Based on 1% light level, the depth at which plant growth could occur in Salem Lake differed on a monthly basis, but decreased throughout the summer as algae blooms increased from 6 feet in May and June to 5 feet in July and 4 feet in August and September. CFI Industries has used Reward in Salem Lake in recent years to treat about 5 acres of curly leaf pondweed in front of their building and pier. Due to chemical drift, approximately half of the lake is actually treated by this application. In 1998, Reward® was applied in both May and July. In 1999 and 2000, only May treatments were applied. Despite the herbicide treatment in 2000, curly leaf pondweed dominated the plant community in May (present in 91% of the plant survey sites), while coontail, Eurasian watermilfoil and duckweed dominated from July through September. A higher diversity of plants was present in May, including *Elodea*, *Chara*, small pondweed and wild celery. However, once Eurasian watermilfoil and coontail began to dominate, they shaded out these other, more slowly growing plants for the remainder of the summer. (Table 3 & Table 4). Typically, high plant density equals high water clarity in a lake. Plants compete with algae for light and resources, and will stabilize bottom sediments to prevent resuspension. However, the extremely high phosphorus concentrations in Salem Lake resulted in dense algae blooms despite high plant coverage early in the year, and may have contributed to the relatively low plant diversity later in the summer. Unlike coontail and Eurasian watermilfoil, most native plants do not typically grow to the water surface, and dense algae blooms may have shaded these plants out by mid summer. Buckthorn, an invasive, exotic tree species, was observed on the shoreline of several properties during the summer.

Table 3: Aquatic and Shoreline Plants on Salem Lake, May-September 2000

Aquatic Plants	
Coontail	*Ceratophyllum demersum*
Chara	*Chara* sp.
Elodea	*Elodea canadensis*
Duckweed	*Lemna minor*
Water stargrass	*Heteranthera dubia*
Eurasian watermilfoil	*Myriophyllum spicatum*
Curlyleaf pondweed	*Potamogeton crispus*
Leafy pondweed	*Potamogeton foliosus*
Sago pondweed	*Potamogeton pectinatus*
Small pondweed	*Potamogeton pusillus*
Flatstem pondweed	*Potamogeton zosterifomis*
Wild celery/Eelgrass	*Vallisneria americana*
Watermeal	*Wolffia columbiana*
Shoreline Plants	
Buckthorn	*Rhamnus cathartica*

LIMNOLOGICAL DATA – SHORELINE ASSESSMENT

A shoreline assessment was conducted at Salem Lake on May 24, 2000. The shoreline was assessed for a variety of criteria (See *Appendix A* for methods). Based on these assessments, several important generalizations could be made. Approximately half of Salem Lake's shoreline (53.2%) is developed, and the majority of this developed shoreline (61.8%) is comprised of manicured lawn. This shoreline type is considered undesirable because it provides a poor shoreline-water interface due to the poor root structure of turf grasses. These grasses are incapable of stabilizing the shoreline and typically lead to erosion. The other half of the shoreline of Salem Lake was dominated by woodland (oak savannas) (58.9%), a more desirable shoreline type. Other shoreline types present in small quantities included buffer strips (4.5%), rip rap (3.3%) and beach (0.5%) (Figure 4). Despite the large amount of desirable woodland shoreline present on Salem Lake, 80.6% of the shoreline had slight to severe erosion. Most of the erosion (60.4%) was occurring on shorelines consisting of woodland vegetation, while 34.1% of the erosion was occurring along areas dominated by manicured lawn (Figure 5). As mentioned above, manicured lawns provide poor soil stabilization because the root structure of grass is ill- equipped to prevent erosion. Although woodland-dominated lots may seem to provide the ideal shoreline, if the slope is steep or if these lots are not maintained, severe erosion can occur. Deciduous trees present along these shorelines have very large roots that are also unable to stabilize soil as well as native grasses and plants. If these trees become so large that they shade out all understory plants (whose roots provide the best stabilization) beneath them, the shoreline will become eroded. Suggestions on how to improve the shoreline around Salem Lake can be found in *Objective IV: Shoreline Erosion Control* (p. 24).

LIMNOLOGICAL DATA – WILDLIFE ASSESSMENT

Fish kills have historically occurred on Salem Lake as a result of dense aquatic vegetation and algae blooms. When the lake was created in 1942, largemouth bass and bluegill were stocked at an unknown rate. A lake survey was performed by the Illinois Department of Natural Resources (IDNR-formerly the IDOC-Illinois Department of Conservation) in 1951 after fish kills of bullheads, bass, bluegill and crappie were reported in 1950 and 1951. Recommendations were to observe the composition of future fishing and, if only bullheads remained, to restock with bass and bluegill. In 1971, another lake survey was performed by the IDNR. Recommendations at that time were to apply the herbicide Aquathol K® for treatment of dense aquatic vegetation, to perform a complete fish rehabilitation by applying Rotenone and to restock with largemouth bass and bluegill fingerlings. In 1980, a complete fish removal program was initiated to remove carp, bullheads and crappie from the lake. This removal program was successful and the lake was restocked (year and fish species stocked is unknown). In 1991, another summer fish kill occurred during a period of hot weather and low lake level. It is believed that several different parties on the lake had applied herbicides simultaneously and that the decomposition of nearly all plant life in the lake at the same time had caused the oxygen crash. Only bluegill were thought to have survived. In 1993, 12 tiger muskie were stocked to prey upon the bluegill left after the fish kill. An unknown number of largemouth bass were also stocked. Bluegill appear to be back to good levels and sizes, but largemouth bass have decreased in size. No fish kills have occurred in recent years. CF Industries has not stocked any grass carp (*Ctenopharyngodon idella* Val.), but the fish are believed to be present in the lake and to have been stocked by homeowners on the east side of the lake. Common carp (*Cyprinus carpio*) were observed by Lake County Health Department-Lakes Management Unit staff during the 2000 survey.

Wildlife observations were made on a monthly basis during water quality and plant sampling activities (See *Appendix A* for methodology). All observations were visual and several types of waterfowl were observed over the course of the study (Table 5). Wildlife habitat was quite good around Salem Lake. Oak stands along much of the north shore of the lake provide good habitat for many species of wildlife. Dead trees were also found along much of the shoreline. These trees can serve as excellent habitat for birds like herons and cormorants. In addition, once a tree falls into the water, it provides excellent habitat for many wildlife species (i.e., turtles, fish, birds). There are many areas around Salem Lake (such as the large percentage of manicured lawn) on which habitat can be improved to facilitate more bird and waterfowl nesting. Also, buckthorn, an invasive shrub/tree species, was observed along several shoreline parcels. This shrub becomes very dense very quickly and is seldom used by wildlife for food or shelter. It will displace native, more desirable plant and tree species with root toxins, and will eventually become the only species in an area. Most of the buckthorn that had been present along the lake in recent years was removed in 1999-2000. A small amount of this exotic shrub still remains and actions should be taken to eliminate the remaining buckthorn around Salem Lake. See *Objective V: Eliminate or Control Exotic Plant Species* (p. 28). Additionally, shoreline habitat could be improved and should include buffer strips to prevent erosion and encourage wildlife nesting and habitation.

Table 5: Observed Wildlife Species on Salem Lake, May-September 2000

<u>*Birds*</u>	
Double Crested Cormorant	*Phalacrocorax auritus*
Mute Swan	*Cygnus olor*
Canada Goose	*Branta canadensis*
Mallard	*Anas platyrhnchos*
Great Blue Heron	*Ardea herodias*
Green Heron	*Butorides striatus*
Belted Kingfisher	*Megaceryle alcyon*
<u>*Reptiles*</u>	
Painted turtle	*Chrysemys picta*

EXISTING WATER QUALITY PROBLEMS

- *Lack of a Quality Bathymetric Map*

A bathymetric (depth contour) map is an essential tool in effective lake management, especially if the long term lake management plan includes intensive treatments, such as fish stocking, dredging, chemical application or alum application. Morphometric data obtained in the creation of a bathymetric map is necessary for calculation of equations for correct application of these types of treatments.

- *Nuisance Plant Growth*

One key to a healthy lake is a healthy aquatic plant community. Salem Lake has a diverse plant community, but is plagued by nuisance densities of several undesirable, exotic plant species. Curly leaf pondweed dominated during May and early June, and was replaced by Eurasian water milfoil and coontail (a native) by July. The density of these plants is, most likely, negatively impacting the plant and fish communities, and severely hampering any recreational activities on the lake.

- *High Nutrient Levels and Algae Blooms*

Blue-green algae blooms were wide-spread and continuous in Salem Lake from June through September. The blooms largely consisted of colonial blue-green algae and were caused by high phosphorus levels. It was determined that phosphorus was probably originating from algae cells in the lake and that phosphorus concentrations were dependent upon nitrogen concentrations in the water column. Increases in alga blooms over the course of the summer lead to a dramatic decrease in water clarity, a decrease in light penetration, and increases in TSS and TVS.

- *Poor Water Clarity*

As a result of the dense algae blooms, water clarity is low and may be preventing native aquatic plants from growing. As mentioned before, high algae densities are the result of high nutrient levels. Poor water clarity reduces the aesthetics of recreational activities such as swimming and fishing. Swimming becomes unsafe and fish species decrease in size and number as it becomes more difficult to find prey in murky waters.

- *Erosion Along Shoreline*

Approximately half of the shoreline along Salem Lake is developed and 60% of this developed shoreline consists of manicured lawn, which does not provide soil stabilization. The undeveloped shoreline along the lake is dominated by woodlands, which are typically more desirable for erosion prevention. However, despite this large concentration of woodlands around the lake, 81% of the shoreline is slightly to severely eroded because the large root systems of woodland trees do not provide good soil stabilization if the woodland areas are not maintained or if the slope of the shoreline if very steep. Additionally, the presence of buckthorn along much of the shoreline does little to stabilize soils and shades out many of the understory plants that would provide good shoreline stabilization.

POTENTIAL OBJECTIVES FOR THE SALEM LAKE MANAGEMENT PLAN

I. Create a bathymetric map, including a morphometric table
II. Establish better aquatic plant management techniques
III. Establish an algae management plan
IV. Shoreline erosion control
V. Eliminate or control exotic plant species

OPTIONS FOR ACHIEIVING THE LAKE MANAGEMENT PLAN OBJECTIVES

Objective I: Create a Bathymetric Map, Including a Morphometric Table

A bathymetric (depth contour) map is an essential tool in effective lake management since it provides information on the morphometric features of the lake, such as depth, surface area, volume, etc. The knowledge of this morphometric information would be necessary if lake management treatments such as fish stocking, dredging, an alum treatment or aeration were part of the overall lake management plan. Salem Lake does have a bathymetric map. However, it is outdated (1971), may not accurately represent the lake features, and does not include morphometric data (which are pertinent for certain calculation). Maps can be created by the Lake County Health Department – Lake Management Unit or other agencies for costs that vary from $3,000-$10,000, depending on lake size.

Objective II: Establish Better Aquatic Plant Management Techniques

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, and 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, or their implementation would be impractical in Salem Lake.

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

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. With a no action aquatic plant management plan in a lake with non-native nuisance 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 lake's 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 altercation, 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. 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 kept "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 on the surface of new plants, and the high concentration of P would continue to fuel planktonic algal growth. The lake's fishery could improve as a result of increased 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, as it is in Salem 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. This will also impact fish populations. The fishery of the lake may become stunted due the to lack of quality forage fish habitat and reduced predation resulting from increased difficulty in 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 to the lake. 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 mats of plants. Swimming could also become increasingly difficult due to thick vegetation that would develop at beaches. Fishing could become more and more exasperating in thick vegetation with a 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.

Costs

No cost will be incurred by implementing the no action management option.

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 cannot 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).

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 Reward®. Systemic herbicides are taken up by the plant and disrupt cellular processes, which in turn cause plant death. These herbicides kill both the upper 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 and 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 (tank mix), which saves 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 in mid to late spring when water temperatures are above 60^{0}F. 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. As with other management options, proper usage is the key to herbicide effectiveness, benefits, and disadvantages. Curly leaf pondweed in Salem Lake is currently being treated with Reward®, which is a primary herbicide for curly leaf, but affects coontail and Eurasian watermilfoil to a lesser extent.

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 watermilfoil but allow desirable plants such as native pondweeds to remain. This removes the problematic vegetation and allows native and more desirable plants to remain and flourish with minimal manipulation.

Fisheries and waterfowl populations of the lake would greatly benefit 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 and are not carried out by humans and other organisms. Therefore, 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 recover 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. Although the United States Environmental Protection Agency (USEPA) has 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 the biodiversity and ecological balance of the lake. Total removal 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 vegetation.

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 compete 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 consumption, swimming, irrigation, etc.

Overremoval, 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 as 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 with 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

CF Industries is currently treating with Diquat (Reward®), a contact herbicide that affects curly leaf pondweed and, to a lesser extent, Eurasian watermilfoil and coontail. At an application rate of 1-2 gallons/surface acre or $425/surface acre, the treatment of 5 acres is costing a little over $2,000. Drawbacks to using Diquat are that it also effectively treats native pondweeds, plants that would be desirable to have in the lake, and that it requires the addition of a surfactant to be effective on hard-to-control plants. If Reward® continues to be used, it is suggested that the application be conducted earlier in the season so that the density of curly leaf pondweed is less at the time of the application. This may result in less phosphorus release into the water column via plant decomposition after the herbicide treatment.

An alternative to Reward® is 2,4-D, another contact herbicide, that is effective on Eurasian watermilfoil and coontail (but not curly leaf pondweed). This could be used in mid June on Eurasian watermilfoil and coontail, once the curly leaf pondweed has subsided. At an application rate of 100 lbs/surface area or $350-$425/surface area, treating 5 acres would cost approximately $1,750-$2,125.

Additionally, Sonar™ is a systemic herbicide that is applied as a whole-lake treatment. It is most effective in lakes like Lake Salem, with few inflows and outflows. Sonar™, at low concentrations, targets Eurasian watermilfoil, leaving curlyleaf pondweed, as well as most native plants, unharmed. At an application rate of 8 ppb, Sonar™ costs $9.75/acre-foot. One early-season application would cost approximately $1,800. At a higher concentration (10 ppb), more plant material would be removed, but the chemical becomes less selective. At $11.75/acre-foot, an application at 10 ppb would cost approximately $2,200. Sonar™ would be the most effective on Eurasian watermilfoil, but could not be incorporated with any other treatment method, such as the milfoil weevil (See Option 4 below).

Option 3: Mechanical Harvesting

Mechanical harvesting involves the cutting and removal of nuisance aquatic vegetation by large specialized boats with underwater cutting bars. Plants are cut below the water at a level that will restore use of the lake. Typically, problematic areas are harvested and other areas are left alone. However, some management plans call for more widespread harvesting, especially when nuisance plants such as Eurasian watermilfoil become dominant.

Pros

Mechanical harvesting can be a selective means to reduce nuisance vegetation stands in a lake. Typically, plants are cut low enough to restore recreational use and limit or prevent regrowth. This practice normally improves habitat for fish and other aquatic organisms. Some plant species such as curlyleaf pondweed, if harvested at the right time, do not grow back to nuisance proportions after harvesting. Plant clippings are high in nutrients and can be used as fertilizer or compost. Additionally, use of the lake is uninterrupted while harvesting is occurring.

By removing large quantities of plant biomass the overall quality of the lake may improve in many ways. The decrease in vegetative biomass will reduce the dissolved oxygen (DO) demand on the lake. This will cause increased dissolved oxygen levels. Some nuisance vegetation such as coontail have extremely high oxygen demands. Dense stands of these plants can quickly deplete a lake of DO Additionally, a decrease in plant density will improve the lake's fishery by creating better opportunities for predation, which is essential in creating a balanced fish population. By removing nuisance vegetation from the lake, release of P from dead or dying plants will be reduced. Since this is the primary source of P to the lake, reduction could decrease the occurrence and density of algal blooms.

Cons

Once widespread, mechanical harvesting is becoming a less attractive management technique for a variety of reasons. Many applicators that regularly employed mechanical harvesting no longer use or even offer this service due to low public demand. In addition, high initial investment, extensive maintenance, and high operational costs have also led to decreased use. Since many applicators no longer offer harvesting services, a lake association would have to purchase and maintain their own harvester. Many associations do not have the financial resources to cover the maintenance and operational cost involved with owning a harvester. Harvester costs can range from $50,000-$150,000. Beside the financial limitations there are also physical limitations. Mechanical harvesters cannot be used in less than 2-4 ft of water (depending on draft of the harvester) and can not maneuver well in tight places. The harvested plant material must be disposed of properly to a place that can accommodate large quantities of plants and prevent any from washing back into the lake. Fish, mussels, turtles and other aquatic organisms are commonly caught in the harvester and injured or even removed from the lake in the harvesting process.

After the initial removal, there is a possibility for vegetation regrowth. 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 may lead to an overpopulation of stunted fish due to a decrease in predation of forage species by predatory fish. This disruption in the fishery will have negative impacts throughout the ecosystem from zooplankton to higher organisms such as waterfowl.

The total removal or over removal (neither of which should ever be the plan of any management entity) of plants by mechanical harvesting should never be attempted. To avoid complete or over removal, the management entity should have a harvesting plan that determines where and how much vegetation is to be removed. However, if complete/over removal does occur several problems can result. One problem 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 also contribute to overall nutrient load of the lake, which can lead to increased frequency of algal blooms. Furthermore, the removal of aquatic vegetation, which competes for resources with algae, can directly contribute to an increase in algal blooms. Removal of plants may lead to increased turbidity and decreased clarity. The fishery of the lake may decline and/or become stunted due to changes in predation related to decreased water clarity. Other organisms, such as waterfowl, which commonly forage on native aquatic plants, would also be negatively impacted by the removal of these plants.

Another problem with mechanical harvesting, if not properly done, is that it can be a nonselective process. In the areas where harvesting is being conducted, one plant cannot be removed and another left. All the plants are removed from that area. After the initial removal, regrowth of desirable plants does not typically occur in these harvested areas. Due to their weedy nature, plants such as Eurasian water milfoil are able to grow more quickly than native plants, have a tolerance to being cut, and become more established in harvested areas. This will create a monoculture of nuisance vegetation. This causes an overall decrease in plant biodiversity, which can have detrimental effects to the entire ecosystem. Depending on the plant species, frequent harvesting might be required (typically 2-4 times per season). Along with this increased harvesting frequency come increased operational costs (labor, gas, maintenance, etc.). Nuisance plants such as coontail and Eurasian watermilfoil can spread by vegetative fragments that may escape collection during the harvesting process and spread to uninfested parts of the lake. In addition to the release of plant fragments, as the plants are cut, there is a possibility of plant associated nutrients being released into the lake. This could cause an increase is algal blooms whenever harvesting in conducted. Short-term turbidity may also be created by the harvester paddle wheels stirring up sediment in harvested area.

Cost

Depending on the type of the harvester (cutting width, payload capacity, hull material, HP of the motor, trailer options, etc) prices range from $50,000 to $150,000. Operational and maintenance cost typically range from $161.00-$445.00/acre.

<u>Option 4: Water Milfoil Weevil</u>

Euhrychiopsis lecontei (*E. lecontei*) is a biological control organism used to treat Eurasian watermilfoil (EWM). *E. lecontei* is a native weevil, which feeds exclusively on milfoil species. It was originally discovered while investigating declines of EWM in a Vermont lake in the early 1990's, and was spotted in northeastern Illinois lakes by 1995. Another weevil, *Phytobius leucogaster*, also feeds on EWM but does not cause as much damage as *E. lecontei*. Therefore, *E. lecontei* is stocked as a biocontrol and is commonly referred to as the Eurasian watermilfoil weevil. Currently, the LCHD-Lakes Management Unit has documented weevils (*E. lecontei* and/or *P. leucogaster*) in 16 Lake County lakes. Many of these lakes have seen declines in EWM density in recent years. It is highly likely that *E. lecontei* and/or *P. leucogaster* occurs in all lakes in Lake County that have excessive EWM growth.

Weevils are stocked in known quantities to achieve a density of 1-4 weevils per stem. As weevil populations expand, EWM populations may decline. After EWM declines, weevil populations also decline and do not feed on any other aquatic plants. When EWM starts to grow again in the spring, the weevil populations respond by increasing in density, keeping the milfoil under control before it becomes a problem. Once the weevil is established in a lake, EWM should no longer reach nuisance proportions and becomes more sparse. Best results are achieved in lakes that have shallow EWM infestations in areas where the plant is undisturbed by recreational and management activities. Weevils need proper overwintering habitat such as leaf litter and mud, which are typically found on naturalized shorelines or shores with good buffer strips. Additionally, water temperatures need to be 68-70^{o}F for maximum weevil activity. For this reason, weevils are typically stocked in late spring/early summer. Currently only one company, EnviroScience Inc., has a stocking program (called the MiddFoil® process). The program includes evaluation of EWM densities and current weevil populations (if any), stocking, monitoring, and restocking as needed.

Pros

The milfoil weevil can provide long-term control of EWM. Typically, by the end of June, EWM stands are starting to decline due to weevil damage. In many situations, EWM beds might not reach the surface before weevil damage causes declines. *E. lecontei* is also a selective means to control EWM. Studies have shown that *E. lecontei* has a strong preference for EWM and the only other plant it will potentially feed on is northern watermilfoil.

If control with milfoil weevils was successful, the quality of the lake would be improved. Native plants could then start to recolonize. The fish community in the lake would improve due to more balanced predation and higher quality habitat. Waterfowl would benefit from increased food sources and availability of prey. Recreational activities such as fishing, swimming, and boating would be easier and more enjoyable with the removal of inhibiting mats of EWM. Additionally, this is a low maintenance treatment option. Once the weevils are stocked in the lake, no additional action is necessary.

Cons

Use of milfoil weevils does have some drawbacks. Control using the weevil has been inconsistent in many cases. EWM has been substantially reduced one year, only to be unaffected the next. Reasons for these inconsistencies are under investigation. One possible explanation is lack of suitable overwintering habitat. The highly developed, manicured shorelines of many lakes in the County are not suitable habitat for weevil overwintering. Another possible explanation is cooler than normal summer water temperatures. Studies have shown that cooler water temperatures reduce weevil feeding and egg production.

Milfoil control using weevils may not work well on plants in deep water. Plants are able to compensate for weevil damage on upper portions of the plant by increasing growth on lower portions where the weevil does not feed. Furthermore, weevils do not work well in areas where plants are continuously disturbed by activities such as powerboating, swimming, harvesting or herbicide use. In areas where weevils are to be stocked, activity should be reduced as much as possible. This may either limit the extent to which the weevils can be used or limit recreational use of the lake.

One of the most prohibitive aspects to weevil use is its short-term price. Typically weevils are stocked to achieve a density of 1-4 weevils per stem. This translates to 500-3000 weevils per acre of plant bed. At a cost of $1 per weevil plus labor, a EWM management program using weevils can be expensive. Additionally, there is no guarantee that weevils will provide long term control or even produce any results at all. However, if long-term control is achieved, the long-term cost is equal to or less than many other plant treatment methods.

Costs
EnviroScience, Inc.
3781 Darrow Road
Stow, Ohio 44224
1(800) 940-4025

Weevils are sold in units of 1000 bugs at a cost of $1,000 per unit, and stocking rates must be at least 1 unit/area stocked. Normally there is a minimum purchase of 5-10 units. The cost of the weevils does not include the labor involved in initial surveys, stocking and monitoring, which typically run an additional $3,500-$4,500.

Objective III: Establish a Better Algae Management Plan

The growth of nuisance or excessive algae can cause a number of problems. Excessive algal growth can cause decreases in water clarity and light penetration. This can lead to several major problems such as loss of aquatic plants, decline in fishery health, and interference with recreational activities. Health hazards, such as swimmer's itch and other skin irritations have been linked to excessive algal growth. Normally, excessive algae growth is a sign of larger problems such excessive nutrients and/or lack of aquatic plants. Some treatment methods, such as copper sulfate, are only quick remedies to the problem. Solving the problem of excessive algal growth involves treating the factors that cause the excessive growth, not the algae itself. Long term solutions to excessive algae typically include an integrated approach such as alum treatments, revegetation with aquatic plants, and limiting external sources of nutrients. Interestingly enough, these long-term management strategies are seldom used, typically because of their high initial costs. Instead, the cheap, quick fix of using copper sulfate, though temporary, is much more widely used. However, the costs of continually applying copper sulfate over years, even decades, can eventually far exceed the costs of a slower acting, more effective, integrated approach.

As with aquatic plant management techniques, algae management practices have both positive and negative characteristics. If used properly, they can be beneficial to a lake's well being. If misused or abused, they all share similar outcomes - negative impacts to the lake. The plan should be based on the management goals of the lake and involve usage issues (beaches, boat ramps, etc.), habitat maintenance/restoration issues, and nutrient levels. As with a plant revegetation plan, for an algal management plan to achieve long-term success, follow up is critical. The management of the lake's algae problem does not end once the blooms and/or mats have been reduced/eliminated. It is critical to continually monitor problematic areas for regrowth and treat as necessary. Sometimes the best solutions take several seasons to properly address the problem. The management options covered below are coming into wider acceptance, and have been used in Lake County. There are other algae management options that are not covered below as they not are very effective or are too experimental to be widely used.

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

With a no action management plan, nothing would be done to control the nuisance algae regardless of type and extent. Nuisance algae, planktonic and/or filamentous, could continue to grow until epidemic proportions are reached. Growth limitations of the algae and the characteristics of the lake itself (light penetration, nutrient levels) will dictate the extent of infestation. Unlike aquatic plants, algae are not normally bound by physical factors such as substrate type. The areas in which filamentous and thick surface planktonic blooms (scum) occur can be affected by wind and wave action if strong enough. However, under normal conditions, with no action, both filamentous and planktonic algal blooms can spread to cover 100% of the lake 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 nuisance algae management. The first, and most obvious, is that there is no cost. However, if an active management plan for algae control were eventually needed, the cost would be substantially higher than if the no action plan had been followed in the first place. Another benefit of this option would be the lack of environmental manipulation. Under the no action option, no introduction of any chemical or organisms would take place. Use of the lake would continue as normal unless blooms worsened.

Cons

Under the no action option, if nuisance algae becomes wide spread and able to reach epidemic proportions, there will be many negative impacts on the lake. The fishery of the lake may become stunted due the to lack of quality forage fish habitat and reduced predation. This will cause an explosion in the small fish population and, with food resources not increasing, growth of fish will be reduced. Fish kills can result from toxins released by some species of blue-green algae. Blue-green algae can also produced toxins that are harmful to other algae. This allows blue-green algae to quickly dominate a body of water. Decreased dissolved oxygen levels, due to high biological oxygen demand from the excessive algae growth, will also have negative impacts on the aquatic life. Wildlife populations will also be negatively impacted by dense growths of algae. Birds and waterfowl will have difficulty in finding quality plants for food or in locating prey within the turbid green waters. Additionally, some algae species are poor sources of food for zooplankton and fish.

Water quality could also be negatively impacted with the implementation of a no action option. Decomposition of organic matter and release of nutrients upon algal death is a probable outcome. Large nutrient release with algae die back could lead to lake-wide increases of internal nutrient load. This could, in turn, increase the frequency or severity of other blooms. In addition, decomposition of massive amounts of algae will lead to a depletion of dissolved oxygen in the lake. This can cause fish stress, and eventually, if stress is frequent or severe enough, fish kills.

In addition to ecological impacts, many physical lake uses will be negatively impacted. Boating could be nearly impossible without becoming entangled in thick mats of filamentous algae. Swimming could also become increasingly difficult and unsafe due to thick mats and reduction in visibility by planktonic blooms. Fishing could become more and more exasperating due in part to the thick mats and stunted fish populations. In addition, the aesthetics of the lake will decline due to large areas of the lake covered by large green mats and the odors that may develop as a result. The combination of above events could cause property values on the lake to suffer. Property values on lakes with 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.

Option 2: Algicides

Algicides are a quick and inexpensive way to temporarily treat nuisance algae. Copper sulfate ($CuSO_4$) and chelated copper products are the two main algicides in use. These two compounds are sold by a variety of brand names by a number of different companies. They all work the same and act as contact killers. This means that the product has to come into contact with the algae to be affective. Algicides come in granular and liquid forms. Granular herbicides are spread by hand or machine over an affected area. They can also be placed in a porous bag (such as a burlap sack) and dragged though the water in order to dissolve and disperse the product. Granular algicides are mainly used on filamentous algae where they are spread over the mats. As the granules dissolve, they kill the algae. Liquid algicides, which are much more widely used, are mixed with a known amount of water to achieve a known concentration. The mixture is then sprayed onto/into the water. Liquid algicides are used on both filamentous and planktonic algae. Liquid algaecides are often mixed with herbicides and applied together to save on time and money, and the effectiveness of some herbicides are enhanced when mixed with an algicide. When applying an algicide, it is imperative that the label is completely read and followed. If too much of the lake is treated at any one time an oxygen crash may occur and decomposition of the treated algae may cause fish kills. Additionally, treatments should never be made when blooms/mats are at their fullest extent. It is best to divide the lake into at least two sections, depending on the size of the lake, and treat one section at a time, allowing at least two weeks between treatments. Furthermore, application of algicides should never be done in extremely hot weather (>90^{o}F). This will help lessen the likelihood of an oxygen crash and resulting fish kills. When possible, treatments should be made as early in the season as possible. It is best to treat in spring or when the blooms/mats start to appear so that the algae are killed before it becomes a problem. Cutrine Plus® is currently being applied to Salem Lake in May, but only seems to be effective until June.

Pros
When used properly, algicides can be a powerful tool in management of nuisance algae growth. A properly implemented plan can often provide season-long control with minimal applications. Another benefit of using algicides is the low costs. The fisheries and waterfowl populations of the lake would greatly benefit by a decrease in nuisance algal blooms. By reducing the algae, clarity would increase. This, in turn, would allow the native aquatic plants to return to the lake, improving spawning habitat and food source availability for fish. Waterfowl population would also greatly benefit from increases in quality food sources, such as large-leaf pondweed (*Potamogeton amplifolius*) and sago pondweed (*Potamogeton pectinatus*). Additionally, copper products, at proper dosages, do not affect aquatic vascular plants or wildlife.

By implementing a good management plan, usage opportunities for the lake would increase. Activities such as boating and swimming would improve due to the removal of thick blooms and/or mats of algae, and health risks associated with excessive algae growth (toxins, reduced visibility, etc.) would be reduced. The quality of fishing may recover due to improved habitat and feeding opportunities. In addition to increased usage opportunities, overall aesthetics of the lake would improve, potentially increasing property values.

Cons
The most obvious drawback of using algicides is the input of chemicals into the lake. Even though the United States Environmental Protection Agency (USEPA) approved these chemicals for use, human error and overuse can make them unsafe and bring about undesired outcomes. By continually killing particular algal species, lake managers may unknowingly be creating a larger problem. In many instances, over use of copper is leading to selection of species tolerant to copper. As the algae are continuously exposed to copper, some species are becoming more and more tolerant. This results in the use of higher concentrations in order to achieve adequate control, which can be unhealthy for the lake. In other instances, by eliminating one type of algae, lake managers are finding that other, more problematic species are filling the empty gaps. Additionally, excessive use of copper products can lead to a build up of copper in lake sediments. This can cause problems for activities such as dredging which would require special permits and disposal methods for dredged sediment with high copper concentrations.

Costs
Chelated copper (Cutrine Plus®), a copper-based product for treatment of microscopic and filamentous algae is currently being used in Salem Lake. It differs from copper sulfate in that it is coated with an organic molecule that prevents the copper from binding with other ions in the water. This makes the product more effective, but also more expensive. The lake is being treated with 4 gallons of Cutrine Plus®, at a cost of $35/gal, for a total of approximately $140/year plus application fees. These approximate costs cover one application

only. The copper treatments are only lasting until June and are only treating a very small part of the lake. Additionally, algae from untreated areas moved into the treated areas within a few days of application and made it appear as if the treatment had not been performed at all. In order to really rehabilitate Salem Lake, the entire lake would need to be treated with chelated copper at least once a month. At a cost of approximately $10,000 per month, this is financially impractical for any of the lake owners. Therefore, it is recommended that the chelated copper treatments be stopped and that the money being spent on these treatments would be better utilized elsewhere.

<u>Option 3: Alum Treatment</u>

A possible remedy to excessive algal growth is to eliminate or greatly reduce the amount of phosphorus in the water column. This can be accomplished by using aluminum sulfate (alum). Alum does not directly kill algae as copper sulfate does. Instead, alum binds phosphorus, making it unavailable to algae, thus reducing algal growth. Alum is sprayed as a liquid onto the water surface. It then binds phosphorus in the water column as it forms a solid flocculent layer that settles on the bottom. This layer can then also prevent sediment bound phosphorus from being released from the sediment and entering the water column. Phosphorus inactivation using alum has been in use for 25 years. However, cost and unreliable results deterred its wide spread use. Currently, alum is commonly being used in ponds, and its use in larger lakes is increasing. Alum treatment typically lasts 1 to 20 years depending on various parameters. Lakes with low mean depth to surface area are good candidates, and lakes that are thermally stratified experience longer inactivation than non-stratified lakes due to isolation of the flocculent layer. Lakes with small watersheds are also better candidates because external phosphorus sources can be limited. Alum treatments must be carefully planned and carried out by an experienced professional. If not properly performed, there may be many detrimental side effects. Regardless, a good bathymetric map is essential before any alum treatment can be carried out.

Pros

Phosphorus inactivation is a possible long-term solution for controlling nuisance algae and increasing water clarity. Alum treatments can last as long as 20 years. This makes alum more cost effective in the long-term as compared to continual treatment with algaecides. Studies have shown reductions in phosphorus concentrations by 66% in spring and 68% in summer. Chlorophyll *a*, a measure of algal biomass, was reduced by 61%. Reduction in algal biomass caused an increase in dissolved oxygen and a 79% increase in Secchi disk readings. Effects of alum treatments can be seen in as little as a few days. The increase in water clarity can have many positive effects on the lake’s ecosystem. With increased clarity, plant populations could expand or become reestablished. This, in turn, would improve fish habitat and provide improved food sources for other organisms. Recreational activities such as swimming and fishing would be improved due to increased water clarity and healthy plant populations. Typically, there is a slight invertebrate decline immediately following treatment but populations recover fully by the following year.

Cons
There are several drawbacks to alum. External nutrient inputs must also be reduced or eliminated for alum to provide long-term effectiveness. With larger watersheds this could prove to be physically and financially impossible. Phosphorus inactivation may be shortened by excessive plant growth or motorboat traffic, which can disturb the flocculent layer and allow phosphorus to be released. Also, lakes that are shallow, non-stratified, and wind-blown typically do not achieve long term control due to disruption of the flocculent layer. If alum is not properly applied, toxicity problems may occur. Typically aluminum toxicity occurs if the pH of the water is below 6 or above 9. Salem Lake is in this range, but special precautions must still be taken when applying alum. By adding the incorrect amounts of alum, pH of the lake could drastically and quickly change. Due to these dangers, it is highly recommended that a lake management professional plans and administers the alum treatment.

Costs
Cost for an alum treatment based on volume and phosphorus concentrations in Salem Lake would be approximately $20,000. This is based on full lake volume. A water draw down would decrease the costs proportionally. Draw down could be easily carried out on Salem via the spillway. These costs are approximate and include labor. When doing an alum treatment it is best to hire an *experienced* applicator. If alum treatments are not properly done, the alum may be ineffective and/or bring about several unwanted effects.

Objective IV: Shoreline Erosion Control

Erosion is a potentially serious problem to lake shorelines and occurs as a result of wind, wave, or ice action or from overland rainwater runoff. While some erosion to shorelines is natural, human alteration of the environment can accelerate and exasperate 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 begin to fill in the lake, decreasing overall lake depth and volume, and potentially impairing various recreational uses.

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

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, utilized by various wildlife species, are exposed during the erosion process.

Cons

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

Costs

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

Option 2: Create a Buffer Strip

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

Stabilizing the shoreline with vegetation is most effective on slopes no less than 2:1 to 3:1, horizontal to vertical, or flatter. Usually a buffer strip of at least 25 feet is recommended, however, wider strips (50 or even 100 feet) are recommended on steeper slopes or areas with severe erosion problems. In 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. Most of Salem Lake's shoreline has a slope of 2:1 and would greatly benefit from establishment of ground vegetation, especially along woodland areas.

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 highly erodible, willow posts may have to be used in conjunction with another erosion control technique such as biologs.

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. Buffer strips would be the most cost effective and lake-friendly treatment for shoreline erosion among Salem Lake and is highly recommended by the LCHD-Lake Management Unit. Along woodland lots, some of the larger trees that are shading out the ground vegetation could be trimmed and species such as box elder and buckthorn should be completely removed. This would allow a natural buffer strip to revegetate the area without any additional planting or costs.

Pros

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

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

Another benefit of a buffer strip is potential flood control protection. Buffer strips may slow the velocity of flood waters, thus preventing shoreline erosion. Native plants also can withstand fluctuating water levels more effectively than commercial turfgrass. Many plants can survive after being under water for several days, even weeks, while turfgrass is intolerant of wet conditions and usually dies after several days under water. This contributes to increased maintenance costs, since the turfgrass has to be either replanted or replaced with sod. Emergent vegetation can provide additional help in preserving shorelines and improving water quality by absorbing wave energy that might otherwise batter the shoreline. Calmer wave action will result in less shoreline erosion and resuspension of bottom sediment, which results 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 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 (*Myriophyllum spicatum*), 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. 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 3: 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.

Pros
Biologs, fiber rolls, and straw blankets provide erosion control that secures the shoreline in the short-term and allows native plants to establish to 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. 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 V: Eliminate or Control Exotic Plant Species

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

Purple loosestrife is responsible for the “sea of purple” seen along roadsides and in wetlands during summer. It can quickly dominate a wetland or shoreline. Due in part to an extensive root system, large seed production (estimates range from 100,000 to 2.7 million 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*).

The 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, some 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 5 lists several native plants that can be planted along shorelines.

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

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

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

<u>Option 2: Control by Hand</u>
Controlling exotic plants by hand removal is most effective on small areas (< 1 acre) and if done prior to heavy infestation. Some exotics, such as purple loosestrife and reed canary grass, can be controlled to some degree by digging, cutting, or mowing if done early and often during the year. Digging may be required to ensure the entire root mass is excavated. Spring or summer is the best time to cut or mow, since late summer and fall is when many of the plant seeds disperse. Proper disposal of excavated plants is important since seeds may persist and germinate even after several years. Once exotic plants are removed, the disturbed ground should be planted with native vegetation and closely monitored. Many exotic species, such as purple loosestrife, buckthorn, and garlic mustard are proficient at colonizing disturbed sites.

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

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

established stand of an exotic like purple loosestrife or reed canary grass may require several years of intense removal to control or eliminate.

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

<u>Option 3: Herbicide Treatment</u>
Chemical treatments can be effective at controlling exotic plant species. However, chemical treatment works best on individual plants or small areas already infested with the plant. In some areas where individual spot treatments are prohibitive or unpractical (i.e., large expanses of a wetland or woodland), chemical treatments may not be an option because a broadcast application would be needed. Since many of the herbicides that are used are not selective, meaning they kill all plants they contact, this may be unacceptable if native plants are found in the proposed treatment area.

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

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

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

public perception of them. Costs may also be prohibitive if plant stands are large. Depending on the device, cost of the application equipment can also be high.

Costs

Glyphosate (Round-up™, Rodeo®) is commonly used to treat buckthorn at an application rate of 5-8% Rodeo® per spray solution, 25-30% Rodeo® per wicking solution or 50-100% Rodeo® on cut stumps at a cost of $65/gallon plus applicator costs. Buckthorn was observed on several properties around Salem Lake, and one to two gallons, shared among property owners, would be sufficient to treat around the lake. Cidekick, a surfactant, can be used to obtain better results. A Hydrohatchet®, a hatchet that injects herbicide through the bark, is about $300.00. Another injecting devise, E-Z Ject® is $450.00. Hand-held and backpack sprayers costs from $25-$45 and $80-150, respectively. Wicking devices are $30-40.