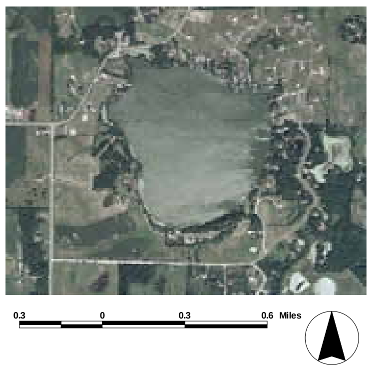
Fish Lake Aquatic Vegetation Management Plan

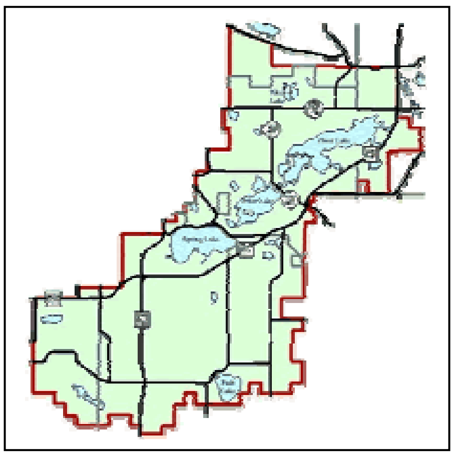
January 2005

Prepared for: Prior Lake-Spring Lake Watershed District

Prepared by: The Kestrel Design Group, Inc.

Fish Lake aerial view





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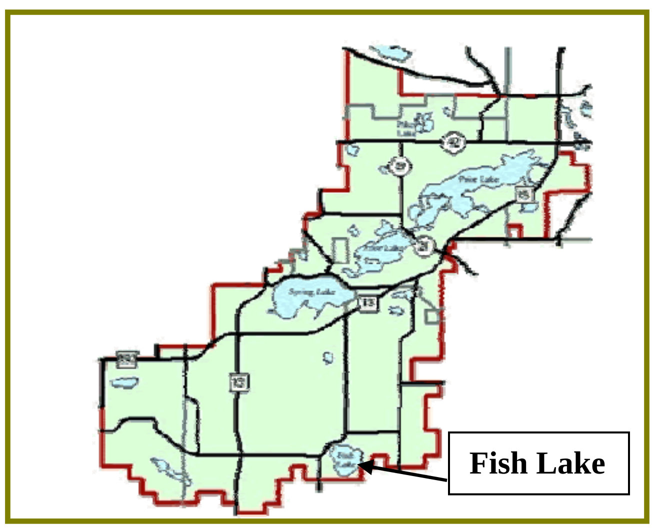
Introduction

The Prior-Lake Spring Lake Watershed (PLSLWD) initiated development of an aquatic vegetation management plan in response to developing water quality and aquatic vegetation concerns. The Kestrel Design Group, Inc. was retained to develop the plan in cooperation with the watershed district and stakeholders. The plan focuses on control of harmful exotic plant species (primarily curlyleaf pondweed) and nuisance algae blooms to improve water quality and recreational use of the lake in a sustainable manner.

In assessing existing conditions and management options, an ecological approach was taken, utilizing the alternative stable states model. This model explains that a shallow, productive lake such as Fish Lake can exist in two opposing conditions: 1) a healthy clear-water state with a diversity of native aquatic plants and fishes, or 2) a degraded state with turbid water, poor fisheries and abundant algae levels. In order to achieve long-term sustainable control of harmful aquatic plants it is necessary to address all the factors causing the excessive growth of unwanted plant species. These factors include watershed inputs, lake shape and depth, internal recycling of nutrients and the interactions between fish, aquatic plants, zooplankton, and algae within the lake.

Fish Lake sits near the edge of the Minneapolis/St. Paul metro area just beyond the suburbs. Fish Lake is in the headwaters of Prior Lake-Spring Lake Watershed (Figure 1). Currently Fish Lake supports both a productive walleye fishery and recreational boating. While the watershed is increasingly developing with new lakeside homes, its headwaters location, and relatively small watershed to lake area ratio make it feasible to control nutrient loading to the lake. With control over watershed loading in-lake management activities can be done to further reduce eutrophication, improve water clarity and reduce excessive growth of unwanted plants and algae blooms. A multi-faceted approach incorporating "top-down" (manipulation of plant and animal communities) and "bottom-up" (watershed controls) strategies is the most likely strategy to succeed and minimize costs over the long-term (decades).

Figure 1: Location of Fish Lake within Prior Lake-Spring Lake Watershed



Executive Summary

Excessive growth of curly-leaf pondweed, an invasive exotic plant, and water quality concerns prompted the PLSLWD to develop an aquatic vegetation management plan for Fish Lake. Despite the detrimental growth of exotic aquatic plants, the lake supports a healthy diversity of aquatic plants that are beneficial to fisheries and water quality. Curly-leaf pondweed growth is concentrated in a few locations around the lake, making it possible to control this harmful species without causing excessive damage to the native plant and fish communities of Fish Lake.

Despite its metro area location, the lake still supports a productive walleye fishery and good water clarity. However phosphorous, and chlorphyll-*a* levels are high, indicating the lake is moving towards a more eutrophic, algal-dominated condition. This would be very damaging ecologically, recreationally, and aesthetically but may be prevented by active management.

Several management options exist for controlling the exotic plants, (curlyleaf pondweed). Alternatives include herbicide application, manual plant harvesting, and reduction of nutrient loading, and increasing native plant coverage to compete with curlyleaf. A multi-faceted approach was recommended including a combination of the above strategies.

Goals for vegetation in the lake were identified during stakeholder meetings held in the fall of 2004. Major goals included: reduction in nuisance curlyleaf pondweed coverage to less than 4 acres; increasing the native plant diversity and coverage particularly in spring and increasing stands of native emergent vegetation while maintaining floating-leaf vegetation. Reduction in frequency of nuisance algae blooms in summer was also established as a related goal.

Maintaining game fish populations and aquatic vegetation that provides habitat was determined to be a major priority. In relation to both fish and plant populations it was found to be necessary to survey and evaluate carp populations to prevent further degradation of the lake ecosystem.

Specific management actions were selected by PLSLWD staff with feedback from the Fish Lake stakeholder group. A variety of short–term and long-term actions were selected, including, treatment of 16 acres of nuisance curlyleaf via application of endothall, continued vegetation monitoring and inventory of aquatic plants and, if necessary, explore the feasibility of active littoral area plant restoration.

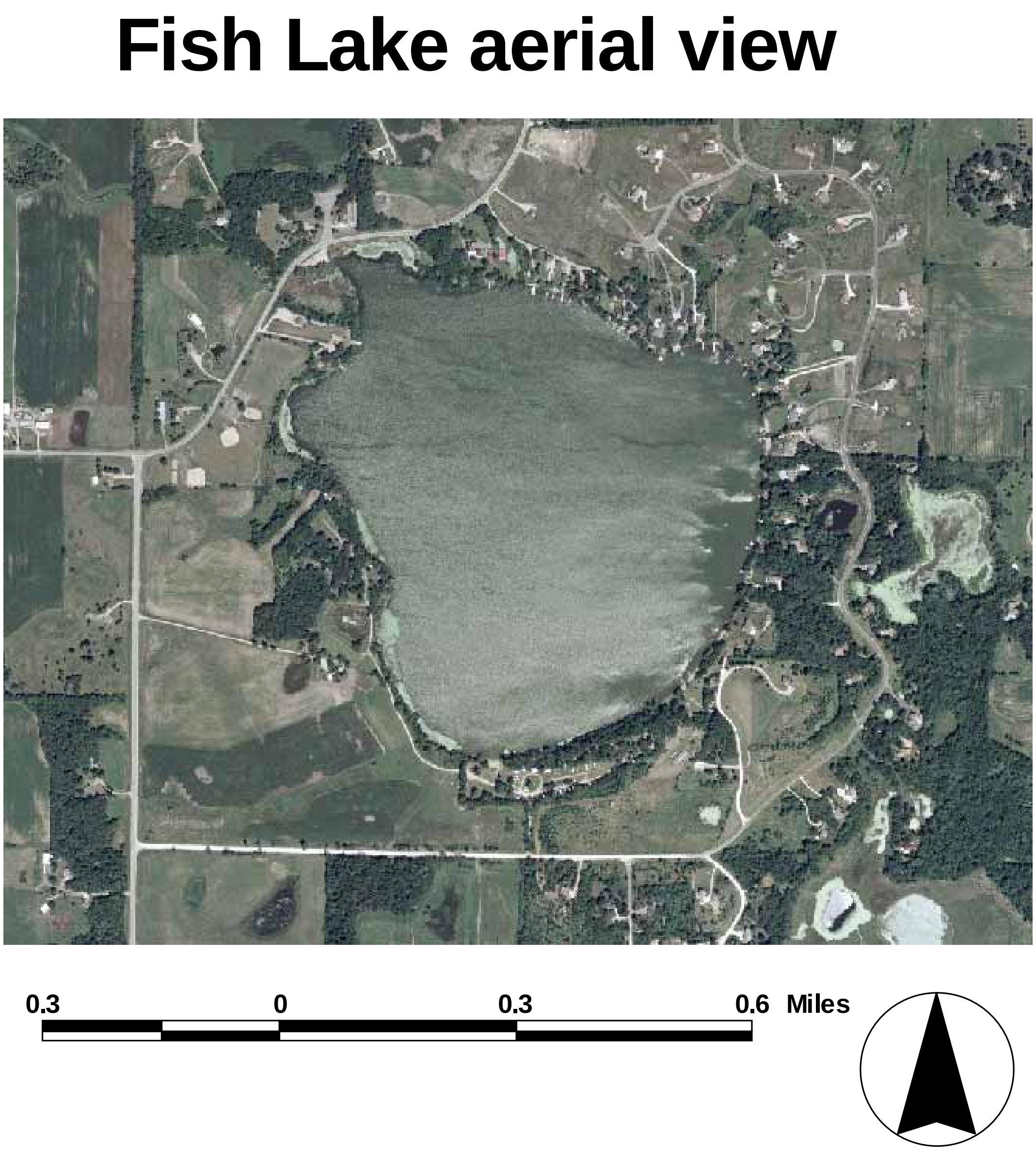
To achieve above goals, management zones were identified within the lake based on recreational usage and plant community data. Wake limitations will be explored as a means of protecting native aquatic plants. Efforts to promote shoreline restoration and protection of existing undisturbed shoreline will be made. Finally lakeshore residents will be educated on aquatic herbicide treatments and benefits of native aquatic plants.

In addition to these actions, a comprehensive lake management plan will aid in the achievement of the

vegetation management goals, by

reducing nutrient supply to the lake.

Figure 2: Aerial view of Fish Lake (2002 photo)



BACKGROUND & EXISTING CONDITIONS: PLANT COMMUNITIES

Methods

Data on plant communities was obtained from the aquatic plant survey done in 2003 by Steve McComas. No aerial infrared photography was taken by the DNR at Fish Lake. A field visit in June 2004 was used to augment information on existing plant communities, particularly emergent zones which were not thoroughly analyzed in the 2003 survey. Color aerial photos from 2002 were reviewed to locate zones of emergent and floating vegetation.

Plant community summary

The aquatic plant communities of Fish Lake consist of a large zone of Submerged and floating vegetation with a 0-10 m zone of emergent vegetation along much of the shoreline. The aquatic plant community is characterized by a large spring bloom of curlyleaf pondweed followed by growth of native species later in the summer (**Figures 2a and 2b**). The spring vegetation survey for 2003 revealed only six plant species, while the summer survey revealed 15 plant species, including two species of filamentous algae (Table 1). Eleven of the 13 non-algal species were submerged or floating aquatic plants, and two were emergent aquatics. Twelve of the 13 were native species; there was one exotic species (Curlyleaf pondweed).

Although the abundance of curlyleaf pondweed is a management problem, overall aquatic plant diversity is average to good compared to other lakes in the Upper Midwest. For comparison, Curtis (1959) found that aquatic plant communities have the lowest species diversity of any plant community type in Wisconsin, with species richness averaging seven species. Therefore, Fish Lake, with ten native species has good plant diversity for the region.

The most abundant species in terms of frequency of occurrence in early spring was curlyleaf pondweed with a frequency of 94%. Only five other species were found in the May survey. Fish Lake supports large areas of native aquatic plant coverage which increase in mid-late summer. Plant diversity increased in later summer with 15 total species (13 excluding green algae). Coontail (47% frequency) and water celery (31% frequency) were the most abundant late summer species (Table 1).

Emergent and floating vegetation

Fish Lake supports numerous zones of emergent wetland vegetation with cattail marsh, bulrushes and sedges in shoreline areas < 6 ft. deep (Figure 3). While much of the wetland area is covered by cattail (*Typha spp*.) and bulrush (*Scirpus spp*.), there is also a patch of sedge (*Carex spp.)* meadow at an inlet near the northwestern corner of the lake. Patches of irises (*Iris spp*.) are also common along the shoreline. Large patches of floating aquatics, such as duckweed (*Lemna spp*.) and larger lily pads (*Nuphar spp.)* (Figure 3) exist in and amongst the emergent plants.

Most of these small wetlands are on the north and western sides of the lake. The emergent wetland areas appear as the bright green areas close to the shore in Figure 2. These wetlands support a variety of wildlife species. Abundant turtles and wading birds, (such as herons) were observed on the site visit. They also provide nursery and spawning areas for some fish species, such as northern pike.

Figure 2a: Aquatic plant coverage in May 2003 (bright red area is curlyleaf pondweed coverage) (McComas 2003)

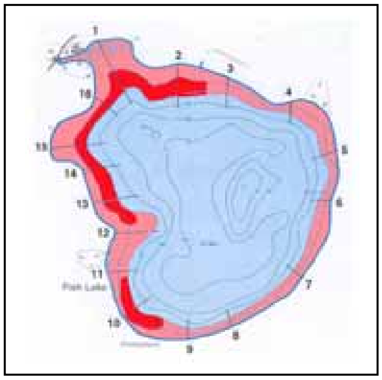
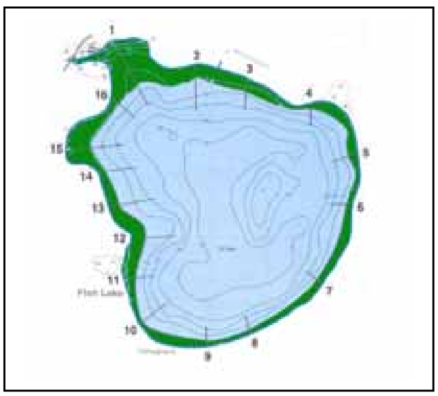


Figure 2b: Aquatic plant coverage in August 2003 (primarily) native plants (McComas 2003)



Summary and Significance for Management

Aquatic plant coverage is dense out to the 10 foot depth level of Fish Lake. Beyond that the lake is open water (Figures 2a and 2b). Fifty-five of 171 acres (or 32% of the lake) were covered by aquatic vegetation in May 2003, dropping to 20% in August. The vegetation is thickest on the north and west sides of the lake, the least developed parts of the lake. Vegetation is also abundant in sheltered bays or coves, particularly emergent and floating vegetation.

Excessive aquatic plant growth poses a problem for boat traffic and fisherman. Additionally the early growth and dieback of curlyleaf pondweed provides an input of phosphorous during the summer, promoting algae and plant growth. However, native aquatic plants provide many ecological benefits ranging from enhanced water clarity to fish habitat. Excessive removal of aquatic vegetation may promote degradation of the lake ecosystem by favoring growth of algae. Therefore, it is important to consider the costs and benefits of aquatic plant removal when selecting management options (see Lake Management section).

Figure 3: Floating aquatic community with lily pads (*Nuphar spp.*)

Figure 4: Emergent plant community with floating aquatics in foreground.

Table 1. Percent occurrence of aquatic plant species for the two 2003 surveys, based on 32 sampling stations (McComas, 2003).

Plant Common name (Scientific name)	**Plant category**	**May 15, 2003**	**August 18, 2003**
Bulrush (*Scirpus spp*)	Emergent	---	3
Cattails (*Typha spp*)	Emergent	6	3
Spatterdock (*Nuphar variegatum*)	Floating	6	16
White waterlily (*Nymphaea tuberosa*)	Floating	--	13
Coontail (*Ceratophyllum demersum*)	Submersed	13	47
Chara (*Chara spp*)	Submersed	--	9
Northern watermilfoil (*Myriophyllum sibiricum*)	Submersed	--	9
Naiads (*Najas spp*)	Submersed	--	6
Curlyleaf pondweed (*Potamogeton crispus*)	Submersed	94	6
Floatingleaf pondweed (*Potamogeton natans*)	Submersed	--	3
Sago pondweed (*Stuckenia pectinata*)	Submersed	--	9
Water celery (*Vallisneria americana*)	Submersed	--	31
Water stargrass (*Zosterella dubia*)	Submersed	6	13
Filamentous algae - floating	Floating	6	16
Filamentous algae - benthic	Submersed (bottom)	--	13

EXISTING CONDITIONS: WATER QUALITY

Methods: Monitoring data was obtained from The Lake Water Quality Project at the Minnesota Pollution Control Agency's (MPCA) website.

Water quality status
The available data (see summary in Appendix 1) indicates Fish Lake is at the lower boundary of eutrophy (based on secchi disk readings) but approaching hypereutrophism, based on Chlorophyll-*a* and phosphorous measurements. Compared to other lakes in the North Central Hardwood Forests EcoRegion, the lake is approximately average in transparency (Secchi depth) but is high for Chlorophyll-a and total phosphorous (Tables 2 and 3, Figure 5 and 6).

The meaning of the trophic state index (TSI) scores is described in Figure 5. Generally the TSI scores for Fish Lake indicate that blue-green algae is likely dominant or abundant at times with excessive macrophyte growth. The lower range of TSI scores for Fish Lake is indicative of some decreased water clarity with anoxic conditions in the hypolimnion during summer

Summary and Significance for Management:
Water quality data gives an indication that the lake has some algae problems and excessive macrophytic vegetation growth. Aquatic vegetation can have a strong influence on water quality and vice versa. Water quality data places the lake in the eutrophic category (with some parameters approaching hypertrophism). This means that plant and algae growth is excessive at times and steps should be taken to control nutrient inputs and prevent further eutrophication. While some native aquatic plant coverage is ecologically beneficial, an overgrowth of invasive exotic plants such as curlyleaf pondweed is indicative of increased nutrient levels from human activities.

The relative proportion of phosphorous sources could not be determined accurately with the information available here. Therefore in targeting phosphorous reduction strategies, to control plant growth it would be beneficial to have a better understanding of the relative loading rates (external, pond sediment, and vegetation growth cycles).

Table 2: Summary of water quality in Fish Lake (from MPCA)*			
Water parameter	**Reading**	**Units**	Maximum and minimum (number of measurements)
Alkalinity	126	ppm	Not reported (7)
Total Phosphorous	60	ppb	30/113 (51)
Mean Chlorophyll-*a*	33	ppb	1/81 (66)
Mean Secchi disk depth	1.6	meters	0/6 (51)
*Data obtained from The Lake Water Quality Project at the Minnesota Pollution Control Agency (MPCA). DNR Lake ID number: 70-0069 http://www.pca.state.mn.us/water/clmp/lkwqReadFull.cfm?lakeID=70-0069)			

Table 3: TROPHIC STATUS OF FISH LAKE Indices of trophic state for Fish Lake. Data from MPCA* The trophic state index (TSI) is also known as Carlson's TSI**			
TSI based on:	**Index score**	**Classification**	**TSI explanation**
Total phosphorous	63	Eutrophic (approaching hypereutrophic)	Dominance of blue-green algae, algal scums probable, extensive macrophyte problems. (see TSI chart below)
Mean Chlorophyll-*a*	65	Eutrophic (approaching hypereutrophic)	Dominance of blue-green algae, algal scums probable, extensive macrophyte problems. (see TSI chart below)
Mean Secchi disk depth	54	Eutrophic (lower level of eutrophism	Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnion during the summer, macrophyte problems evident, warm-water fisheries only. (see TSI chart below)
*Data obtained from The Lake Water Quality Project at the Minnesota Pollution Control Agency (MPCA). DNR Lake ID number: 70-0069			
**Equations used to calculate TSI scores: Total phosphorus TSI (TSIP) = 14.42*[ln(TP average)]+ 4.15 Chlorophyll-*a* TSI (TSIC) = 9.81*[ln(Chlorophyll-*a* average)] + 30.6 Secchi disk TSI (TSIS) = 60 - (14.41*[ln(Secchi average)])			

Figure 5: Clear water state

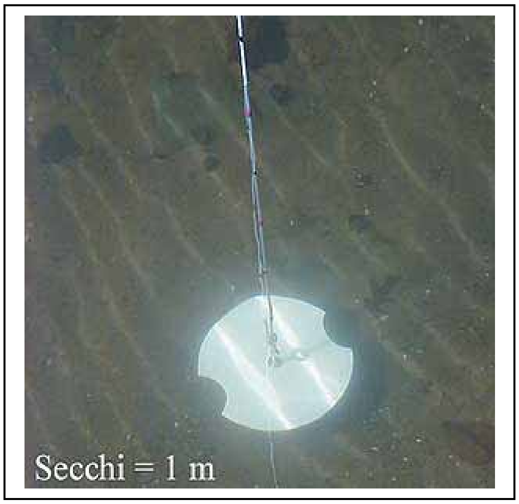


Figure 6: Turbid water state

TSI <30	Classic Oligotrophy; Clear water, oxygen through the year in the hypolimnion, salmonid fisheries in deep lakes.
TSI 30-40	Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.
TS 40-50	Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.
TS 50-60	Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnion during the summer, macrophyte problems evident, warm-water fisheries only.
TSI 60-70	Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.
TSI 70-80	Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.
TSI > 80	Algal scums, summer fish kills, few macrophytes, dominance of rough fish.

Carlson's Trophic State Index (TSI) explanation

Taken from the Lake Water Quality Project at the Minnesota Pollution Control Agency (MPCA).

EXISTING CONDITIONS: FISHERIES

Methods: The DNR Fisheries division has collected data for Fish Lake, which is available on the DNR lakefinder web site at (http://www.dnr.state.mn.us/lakefind/index.html). The data has been grouped into larger taxonomic groups (families) for interpretation purposes.

Status of the Fishery
The lake is described as a quality walleye fishery, particularly for a metro-region lake (*see Appendix 2 for detailed assessment*). In general bluegill is very abundant, as are several other panfish species. Northern pike numbers (a primary predatory in northern lakes) were low in 1997 data (Table 4). Fish groups are discussed below with relevance to lake ecology and vegetation management. Fish species composition and abundance can have a strong influence on plant populations and vice versa.

Family *Centrarchidae* - Sunfish
This panfish or sunfish group is the most abundant in Fish Lake, with Bluegill (*Lepomis macrochirus*) (Figure 7) the most frequent species found in samples (306 fish at 0.19 lbs/fish average in 06/23/1997 survey). Of the remaining fish in the lake, the vast majority were also members of the sunfish family (*Centrarchidae*), with bluegill, white crappie, black crappie, pumpkinseed, and hybrid sunfish the most abundant.
Summary: Sunfish are over-represented having a negative impact on water clarity, favoring algal growth.

Largemouth and smallmouth bass are also centrarchids found in the lake although they play a different role in the foodchain, as they are predatory and help to control "panfish population".
Summary: Bass are important sport fish and may help control panfish populations.

Family *Cyprinidae* -minnows, dace and carp
Carp has been mostly eliminated from the lake by a control structure at the lake outlet. Minnows and dace are present, but they tend to be underrepresented in sampling because of their small size they pass through the nets.
Summary: low carp population is good for lake health.

Family *Ictaluridae* - bullheads -
Bullheads were more abundant than average for similar lakes with primarily yellow bullhead with some black bulhead.
Summary: abundance of bullheads can lead to sediment re-suspension, negatively impacting the lake.

Family *Esocidae*– pike and musky
The lake contains low numbers of northern pike, mostly in older age classes (Figure 8). Musky were not found in the lake.
Summary: low numbers exist now, but increasing numbers to reduce panfish would benefit water quality and recreational fishing.

Family *Percidae* – darters and perches
Yellow perch are fairly abundant in the lake. Walleye are common and have been stocked heavily in Fish Lake in recent years. Walleye are the primary game fish in the lake and the target fish for many anglers.

Summary: Walleye and yellow perch are abundant, having a positive impact on lake ecology.

2003 Survey Data

Although not available in electronic format, a copy of the 2003 survey was obtained for review. The 2003 survey had similar results to past surveys in fish species composition. Walleye, the primary management species for the lake were less abundant, larger and older than 1997. Bluegills were at their highest level since 1949 with 115 per trap net. In gillnet sampling, bluegill, yellow perch, yellow bullhead, black crappie and northern pike were the next most abundant species, in descending order.

Summary and Significance for Management

Currently Fish Lake supports a healthy walleye fishery but the lake does have an overabundance of panfish. The lake has self-sustaining fish populations, except for walleye, which have been stocked by DNR Fisheries.

High levels of small panfish promote algae blooms as young panfish consume the algae-grazing *Daphnia*. In contrast to algae, native aquatic plant beds provide habitat for fish (Figure 7) and shelter for algae-grazing *Daphnia spp.* Thus, maintenance of native aquatic plants promotes clear water conditions and healthy fish populations.

Figure 7: Bluegill. Young bluegill and other panfish consume *Daphnia spp*. which control algae levels. Overabundance of panfish has been found to favor algae blooms, lowering water quality. Bluegill are the most abundant fish in the Lake

*Photo by William D. Shmid in **Fishes of Minnesota**, Bell Museum of Natural History web page, www.gen.umn.edu/research/fish/fishes/*

Figure 8: Northern Pike in Submersed plant bed. Predatory Fish such as pike, may control panfish levels if stocked in sufficient abundance.

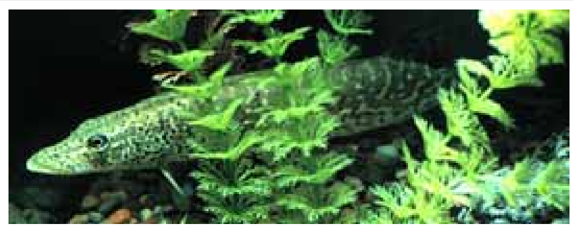


*Photo by Konrad Schmidt in **Fishes of Minnesota**, Bell Museum of Natural History web page at www.gen.umn.edu/research/fish/fishes/*

Table 4: DNR Fishery Sampling data from 1997 for Fish Lake *(trap net and gillnet data combined)										
	Number of fish caught in each category (inches)									
Species	***0-5***	***6-8***	***9-11***	***12-14***	***15-19***	***20-24***	***25-29***	***>29***	***Total***	% total
Black Bullhead	0	0	0	1	0	0	0	0	1	0.1%
Black Crappie	1	148	4	1	0	0	0	0	154	19.2%
Bluegill	101	205	0	0	0	0	0	0	306	38.1%
Brown Bullhead	0	0	0	3	1	0	0	0	4	0.5%
Green Sunfish	3	0	0	0	0	0	0	0	3	0.4%
Hybrid Sunfish	21	13	0	0	0	0	0	0	34	4.2%
Largemouth Bass	0	0	1	0	0	0	0	0	1	0.1%
Northern Pike	0	0	0	0	0	1	5	3	9	1.1%
Pumpkinseed Sunfish	29	7	0	0	0	0	0	0	36	4.5%
Walleye	0	0	16	0	19	9	1	0	45	5.6%
White Crappie	0	58	1	0	0	0	0	0	59	7.3%
Yellow Bullhead	0	0	21	10	0	0	0	0	31	3.9%
Yellow Perch	18	99	3	0	0	0	0	0	120	14.9%
* Data from DNR lakefinder web page at (http://www.dnr.state.mn.us/lakefind/index.html).										

Watershed setting and lake morphology

Methods
Watershed was delineated using USGS maps (Figure 9). Phosphorous loading modeling results were obtained from the watershed district. Lake morphology and temperature data was obtained from DNR fisheries division.

External nutrient loading
Runoff carried into a lake from its watershed generally constitutes the largest source of nutrients and sediment entering shallow eutrophic lakes. Lakes that have a very large watershed area in proportion to lake volume are more likely to suffer eutrophication problems. The Fish Lake Watershed is a headwaters watershed at the upstream end of Prior Lake-Spring Lake watershed. The relatively small watershed to lake area ratio makes watershed management a feasible option for controlling nutrients (Figure 9). The western side of the watershed contains the largest amount of agricultural land and should be targeted for runoff reduction/erosion control.

Modeling of phosphorous loading into Fish Lake
Runoff into Fish Lake was modeled during construction of a nearby highway producing phosphorous loading estimates from the watershed that were 37 lbs per year, based on a year of average rainfall and runoff quantities (Wenck & Associates). Using the year 1981, an average rainfall year, 57 acre-feet of runoff was produced carrying 37 lbs of total phosphorous into the lake (averaging 0.24 ppm phosphorous). This is a low-moderate rate of phosphorous loading for southern Minnesota lakes (about 0.05 lbs of P per acre). Still, key source areas should be targeted for phosphorous load reduction.

Lake morphology
Lake morphology (volume, depth, shape, substratum type and configuration) has a very strong influence on a lake's trophic status and water quality. Lake and watershed parameters determine water residence time, buffering capacity, vegetation zones, and stratification, for example. Much of Fish Lake is shallow, (less than 15 feet), with 43% of 171 acres classified as littoral zone (74 acres) by the MN DNR. Plants do not generally grow outside of the littoral zone. The maximum depth of Fish Lake is 28 feet.

Bedrock geology
The watershed lies on the Des Moines Lobe glacial till plain, which is characterized by deep layers of calcareous material that provides excellent buffering capacity. Alkalinity measurements of $CaCO_3$ averaged 126 ppm, (Table 2) which is classified as "moderately hard" water, suitable for alum treatment. (Lakes with low alkalinity may suffer from acidification problems.)

Thermal Stratification
Data collected by DNR Fisheries shows that Fish Lake does stratify in the summer. It develops a thermocline that seasonaly separates the lower lake from the upper lake until turning over again in the fall. Stratification reduces nutrient availability from pond sediments during the summer, but may cause large nutrient fluxes at the time of turnover.

Summary and significance for management
The Fish Lake watershed is relatively small, so control of external nutrient loading has a good chance of success.

Internal nutrient cycling:
Once external nutrients inputs are controlled, reducing availability of nutrients via internal recycling is the next important step in controlling eutrophication. Other potential sources of nutrients include groundwater inputs and internal recycling within the lake. Internal recycling within the lake from pond sediment to the water column may occur through diffusion, resuspension, and plant growth & death.

Figure 9: Fish Lake Watershed (approximate boundary)

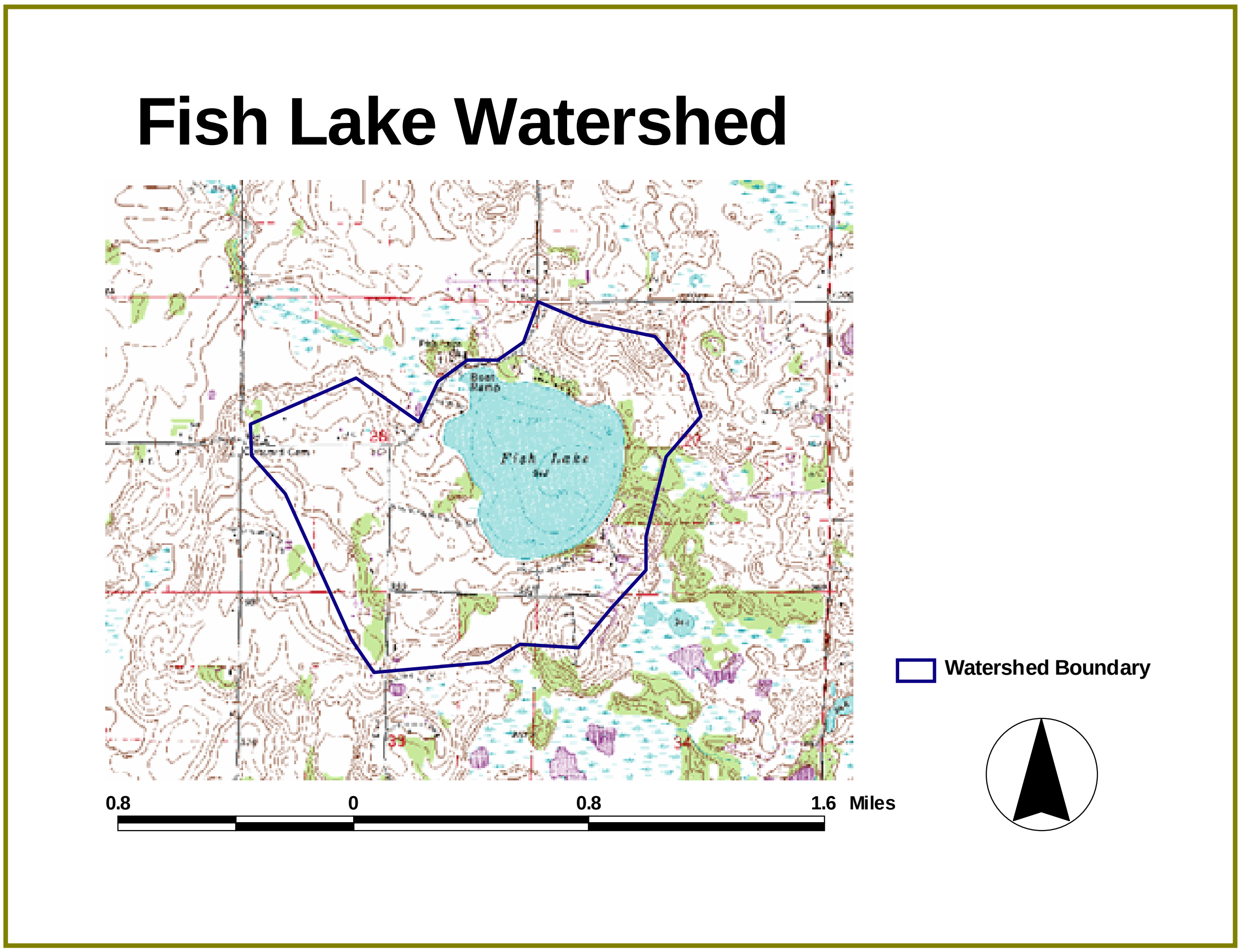


Table 5: Summary of existing conditions and implications for management			
	Existing condition	Possible goals	Management issues
Water Quality	Average, for water clarity (Secchi depth) but high for phosphorous and Chlorophyll-a	Reduce phosphorous and Chlorophyll-a levels	It is difficult to reduce phosphorous inputs and internal recycling
Vegetation	Dominance of curlyleaf pondweed. There is good native aquatic plant diversity in emergent, floating and Submersed plant zones.	Reduce curlyleaf pondweed and algae blooms in summer	*Expense of control options *Short - term effectiveness *May damage native aquatic plants.
Fish	Good walleye fishery, very abundant bluegill and other panfish	Reduce panfish population. Stock more predatory fish (e.g. Northern pike)	Biomanipulation may be difficult in lakes with heavy fishing pressure.
Trophic state	Eutrophic, bordering on hypereutrophic	Prevent switch to hypereutrophism (see Table 2)	Multifaceted approach with watershed and in-lake management needed.

MANAGEMENT of FISH LAKE

The primary management issue at Fish Lake at the present time is excessive growth of aquatic plants and algae, affecting both water clarity, nutrient availability and recreation (fishing, boating and swimming). Most lake management issues revolve around controlling nutrient sources to the lake because that is what causes excess plant growth. The goals of recreational use often correspond with water quality and ecological goals, but at times they may conflict. For example, some boaters may want to remove all aquatic vegetation, but this would be disastrous for lake health. The major management issues are discussed below, with an outline of techniques and suggested goals in the sections that follow.

MANAGEMENT ISSUES

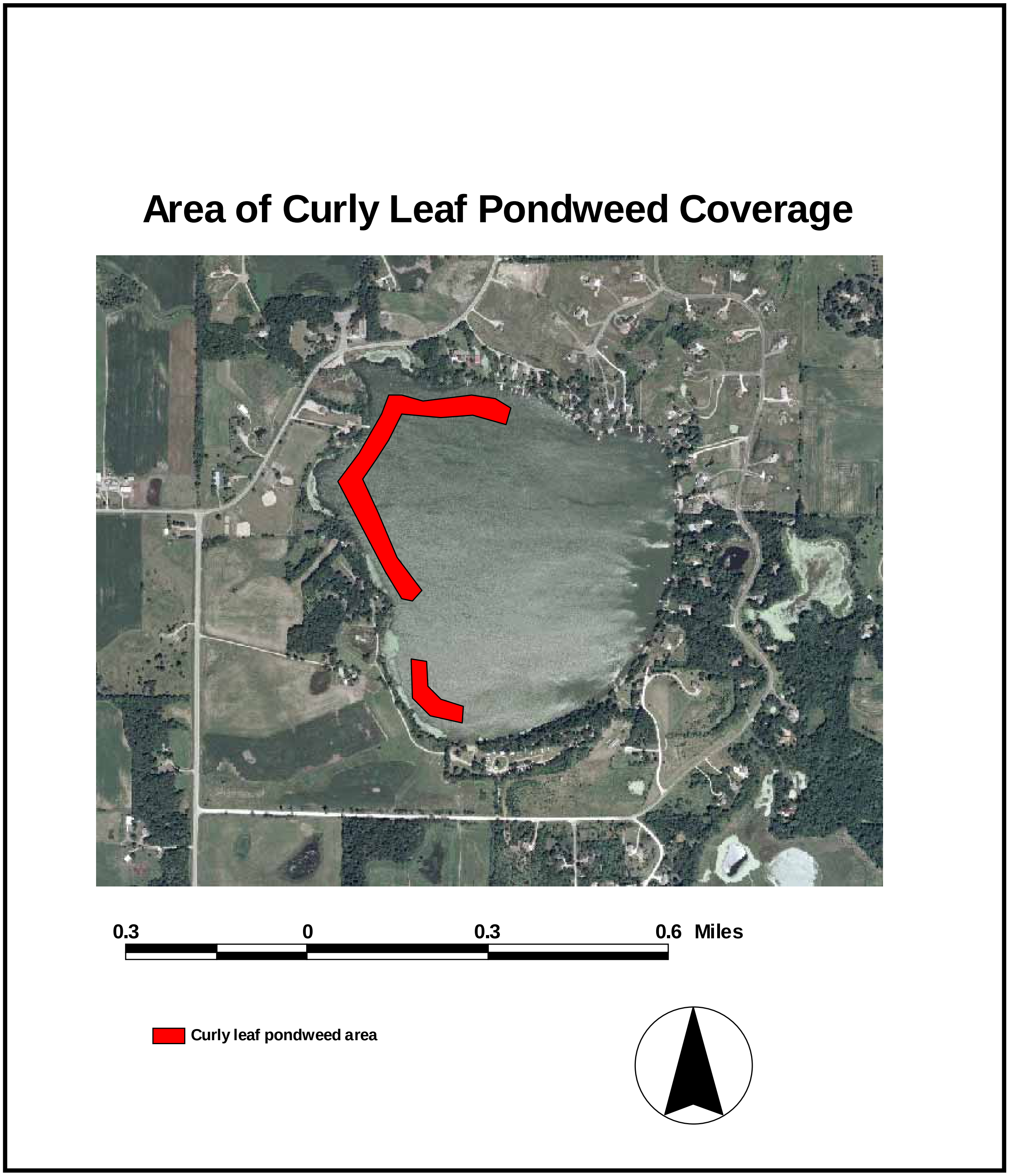
- **Excess aquatic vegetation**
  Growth of aquatic vegetation in some areas hinders boat access and hinders other recreational uses, such as swimming. Given that most aquatic vegetation is in the shallow littoral zone <100 ft from shore, this creates a problem for some boaters as they enter and exit their docks. Curlyleaf pondweed is also a major source of plant nutrients as they dieback in mid-summer promoting algae blooms (Figures 10-12).

- **Algae blooms**
  Algae blooms are an aesthetic as well as ecological problem. While some level of algae is healthy, excessive algae growth is unattractive and may lower water clarity pushing the lake ecosystem towards the turbid-algal dominated state.

Figure 10: Curlyleaf pondweed – before flowering

Figure 11: Curlyleaf pondweed develops "turions", which drop off and reproduce new plants the next year. They actually extend above water level, creating a boating nuisance.

Figure 12: Curlyleaf Pondweed Area (boundaries based on McComas 2003 survey)



- **Water clarity**

Water clarity is roughly average for the region of Minnesota, with a mean Secchi depth of 1.6 meters. The Secchi transparency depth was found to range from 0 to 6 m, however, so at times it is quite turbid.

- **Swimming**

The lake does not technically support swimming use according to MPCA water quality guidelines. However people still swim in the lake. Therefore improving water quality to support swimming use should be a priority management goal. Using MPCA guidelines, the Trophic State Index (TSI) must be < 60 to support swimming. For Fish Lake both phosphorous and chlorophyll-*a* just exceed this level, (65 and 63), but getting these values below 60 is an achievable goal.

- **Fisheries**

The lake supports a productive walleye fishery. There is also an abundance of panfish that may serve as game fish, such as black crappie and bluegill. Maintaining and or improving the quality of the fishery is a priority management goal. Biomanipulation to increase the predator to prey ratio may be beneficial to water quality. Reduction in panfish should increase *Daphnia* levels, which control algae levels, thereby reducing chlorophyll-*a* levels and improving water clarity.

- **Fish and wildlife habitat**

Currently the lake supports a diversity of emergent, submersed, and floating aquatic plant communities which provide fish habitat and shelter for a variety of birds, turtles as well as invertebrates. Many of the best fishing sites overlap with the zones of aquatic vegetation around the shoreline. Native aquatic plants beds provide habitat for numerous fish and support lower levels of the food chain. When removing the curlyleaf pondweed, excessive damage to native plant beds should be avoided when possible.

MANAGEMENT GOALS

Management goals were developed by the following process:

1. Following analysis of existing conditions, management recommendations were made by Kestrel Design Group, Inc.
2. PLSLWD staff reviewed and suggested revisions
3. Public meetings were held with stakeholder groups to obtain comments on desired goals for the aquatic plant community of Fish Lake.
4. Goals were revised based on stakeholder feedback and incorporated into final management plan.

Goals were set concerning exotic and native plant species diversity and abundance, frequency of algae blooms, fish community composition and fish habitat, and related water quality issues. The rationale for the goals is summarized in Table 6 with explanatory notes added below.

Exotic Species control is the major vegetation management concern. Curlyleaf pondweed is a major source of nutrients in the summer and competes with beneficial native plants. Reduction to < 4 acres coverage was selected as an achievable goal, since it is generally not possible to eradicate an entire population of invasive species.

Increasing the **native plant species diversity** in early spring (when curlyleaf is dominant), and expanding the coverage out into more of the potential littoral zone were seen as high priorities. Expanded littoral zone vegetation will add additional fish habitat and promote water clarity.

Maintenance of emergent and floating vegetation is important for fish habitat, water clarity and shoreline stabilization. Littoral wetlands also provide habitat for wildlife including wading birds and ducks, turtles and amphibians. Wetlands are at risk from future development as they tend to be eliminated by shoreline "improvement" when new lake houses are built.

Reduction in algae blooms was also a major priority for stakeholders, because of its negative impact on swimming and aesthetic appearance. Large, frequent blooms also deter growth of native aquatic plants by reducing water clarity.

Maintaining and improving fisheries habitat, in the form of native aquatic plant beds was determined to be a high priority, since game fishing is one of the major activities on the lake. In contrast, **carp control** was though to be necessary to prevent destruction of aquatic plant communities by uprooting vegetation and increasing turbidity. Therefore, stakeholders felt it was important to monitor for carp presence, although the current population is thought to be negligible.

Finally **water quality goals** were decided upon, primarily to reduce nutrient supply to the lake. Plant and algae productivity are directly related to nutrient levels, particularly phosphorous, and tend to favor aggressive invasive species and algae over native submersed plants. Nutrient control will be more thoroughly addressed in the comprehensive Fish Lake management plan, which will be developed in 2005.

Table 6: Overall Aquatic Plant and Fisheries Management Goals for Fish Lake

(Developed by PLSLWD in cooperation with stakeholders)

Category	Goal	Rationale
Exotic plant species	Primary Goal: Reduce **nuisance** curlyleaf pondweed coverage to <4 acres (from 16).	Curlyleaf pondweed is a major source of phosphorous in mid summer causing algae blooms. While it may not be possible to eradicate curlyleaf pondweed from Fish Lake, it is feasible to reduce nuisance levels
	Measure of Success/Secondary Goal: Increase native plant diversity in spring/early summer by 50%, from 6 species to a minimum of 9 species. Maintain late-summer species diversity at 10 species or more.	An increase in the diversity of native plants will enhance the stability of the plant community. Increased diversity will increase competition for curlyleaf pondweed.
Native aquatic plant distribution	Increase late summer native aquatic plant coverage to 32% of the lake area.	According to DNR map, potential littoral area is 73 acres, or 43% of the lake area. Greater native plant coverage of the littoral area will both enhance fisheries habitat and encourage greater water clarity.
Emergent and floating vegetation	Increase stands of bulrush and other desirable emergent vegetation and maintain current stands of floating-leaf vegetation.	Emergent and floating-leaf plants provide fish and wildlife habitat, protect the shoreline from erosion and help maintain clear water in the lake. Bulrush is particularly important for habitat and shoreline stability.
Algae Blooms	Reduce frequency of nuisance algae blooms in summer	Algae blooms deter swimming and are aesthetically negative. Reduced water clarity also deters native aquatic plant growth in a negative feedback loop.
Fisheries	Maintain game fish populations and habitat (walleye, pike, bass).	Sport fishing is one of main recreational uses of lake.
	Survey and evaluate carp population and consider management options.	Carp can harm beds of native aquatic plants by uprooting plants and preventing their establishment, and can also contribute phosphorus to the lake by stirring up the lake bottom and recycling bottom nutrients.
Related Water Quality Goals		
Water quality	Reduce phosphorous level to 40 µg/L.	This will restore the lake to "swimmable use."
Internal nutrient sources	Control internal recycling of phosphorous. Curlyleaf pondweed control also reduces mid-summer nutrient availability.	Sediments are major source of nutrients to water column and may contribute to eutrophication even after other nutrient sources have been controlled. Activities that stir-up and re-suspend sediment should be avoided.
Watershed nutrient loading	Reduce watershed contributions of phosphorous (from current estimate of 0.05 lbs/acre).	External loading of nutrients must be controlled to reduce nuisance plant and algae growth.

MANAGEMENT Tools & Techniques

There are a variety of tools and techniques that may be used to achieve management goals. Some of these techniques are briefly outlined below in Table 7.

Selection of appropriate management techniques depends first on the goals and objectives for the lake. Once goals are established, then considerations such as effectiveness, cost, and negative side effects need to be weighed in developing a management strategy.

Watershed management approaches

Controlling external nutrient loading through runoff reduction, erosion control and use of best management practices (BMPs) are vital tools for reducing nutrient input to lakes.

Controlling sediment inputs on construction sites, farmland and disturbed sites is particularly important for controlling nutrient inputs as most phosphorous is transported attached to soil.

In-Lake Approaches

If external watershed inputs have been brought under reasonable control, than phosphorous availability can be further reduced through various in-lake strategies such as:

- Reduction in availability of phosphorous in sediment
- Precipitation of phosphorous in water column via alum
- Control of curlyleaf pondweed which provides mid-summer phosphorous input

The small watershed area of Fish Lake greatly increases the probability that in-lake management practices will be successful. Still, a multi-technique approach is needed, incorporating watershed management and in-lake controls.

Specific management practices

In-Lake methods of controlling vegetation include a wide range of strategies ranging from herbicide application to biomanipulation. Methods are differentiated as physical/chemical techniques and biological/ecological approaches. Physical and chemical methods include dredging, plant harvest, roto-tillage of the bottom, herbicide application, alum treatment and others.

Biological methods include grass carp, hay bales, and biomanipulation among others. Grass carp can be successful at controlling aquatic vegetation, particularly in warmer climates. They should not be overstocked to prevent total destruction of all aquatic vegetation. The most successful strategy for Fish Lake is likely to use a combination of physical and chemical methods for more immediate response while watershed and ecological methods may have more of a long-term effect generally.

Table 7: Potential Aquatic Plant Management Techniques for Fish Lake
(Developed by Kestrel Design and refined by PLSLWD)

Technique	Notes	Feasibility/ Success
In-lake methods – physical		
Mechanical harvest of plants by machinery, or cutting/raking by hand.	Has immediate effect, but is expensive if done mechanically and not long-lasting.	Medium-high
Chemical methods – herbicide treatment	Generally done in small or contained areas of nuisance-level growth. Pilot whole-lake curlyleaf treatments have shown promise in Minnesota. A DNR variance is required to treat more than 15% of littoral area.	Medium-high
Water level manipulation – draw down	Can be effective in controlling curlyleaf. Has potential to temporarily impact fishery due to potential for winter kill. Requires ability to manipulate outlet.	N/A – does not appear to be feasible for Fish Lake
Mechanical control of plants by dredging	Can be highly effective in limited areas of high nutrient concentration, e.g. Lake inlets. Expensive. Can release nutrients from bottom by stirring up sediments.	Low
Mechanical control of plants by Bottom tillage/rotovation	Removes entire plant rather than just mowing off the top. Stirs up sediments. Not permitted on a large scale	Low-N/A
Water column dyes (such as Aquashade)	Commonly used on small farm ponds, can inhibit recreation for short time.	N/A
Physical methods to reduce nutrient availability—Bottom barrier/ cover	Not feasible on large scale. Useful at swimming areas.	N/A – Not allowed in Minnesota
In-lake methods – biological/ecological		
Biomanipulation	High potential for ecologic sustainability and low cost. Not as thoroughly tested as other methods.	High
Insects	Only a few plants have known insect control agents such as the beetles used on purple loosestrife.	Low or N/A
Hay bales	Releases compounds that control algae bloom – must be put in shallow water <2-4 ft. Does not control aquatic plants.	Low
Nutrient reduction – watershed management and in-lake control*		
Erosion control in agricultural areas	There is not a lot of acreage in agricultural use within watershed; however, some of the agricultural areas have highly erodible soils.	High
Erosion control at construction sites and developed areas	New development in watershed is occurring. Existing developed areas may be contributing nutrients from shoreline or yard erosion.	High
Runoff reduction	Fish Lake has a small watershed, but runoff from farms, yards and construction sites likely to add supply nutrients.	High
Chemical methods – nutrient precipitation via alum	Effective means to reduce in-lake nutrients, but costly on large scale. Long-term effectiveness is uncertain and variable. Lakes with a small watershed area to lake volume ratios are good candidates. Also, Fish Lake has adequate alkalinity to support alum application. However, significant quantities of phosphorus may still be recycled through the lake sediments and plants.	Medium

*Long-term nutrient reduction in Fish Lake will reduce aquatic plant and algae growth.

Framework for assessing management options: Alternate Stable States

The alternate stable states model has developed into the predominant framework for managing shallow lakes in an ecologically sound manner. This theory, developed initially by Scheffer et al. (1993), is based on the idea that lakes may exist in a stable clear water state, dominated by aquatic vascular plants or they may exist in a turbid, algal-dominated condition with poor water quality and biodiversity. Currently Fish Lake would fit into the clear water category, but it is in danger of switching towards the degraded, algae-dominated condition.

This model has been tested in Wisconsin and Minnesota lakes, and has been shown to provide a useful framework for assessing aquatic plant management actions and their potential impacts on the lake ecosystem (Lathrop et al. 1996, Moss 1998). While nutrient control is still the foundation of eutrophication management, management of fish and plankton populations can help promote clear water conditions as well. To develop a sustainable plant management plan it is necessary to consider the whole lake ecosystem.

In productive lakes within southern Minnesota, there will always be some level of aquatic plants and algae present. The clear water state is characterized by coverage of flowering aquatic plants such as pondweeds (*Potamogeton spp*.), lily pads (*Nuphar spp*.) water celery (*Vallisneria spp*.) and others. In contrast the turbid-water state is dominated by blue-green algae with only a few flowering aquatic plants and overall lower biological diversity (Moss 1998).

The challenge for lake managers is to choose actions that promote beneficial native aquatic plants, rather than increasing blue-green algae blooms.

The algae dominated-state may be caused by excess nutrient loading and/or other switches that eliminate beneficial native aquatic plants and drive a stable ecosystem towards a degraded algal-dominated state (Table 8). Several factors or switches may contribute to the shift, altering the entire food chain and resulting in an alternative (and lower quality) state dominated by algae with a high turbidity.

One of the main drivers behind a switch towards the turbid, algae-dominated state is a decline of *Daphnia sp*., a zooplankton that is one of the primary algal grazers in northern temperate lakes. The decline in *Daphnia spp*., is often driven by an increase in zooplankton-grazing fishes, such as bluegill and other "panfish".

Summary and Relevance to Management

In addition to high levels of nutrient-loading, there are factors that can drive a lake towards the high turbidity, algal dominated condition (highly eutrophic). While control of nutrient inputs is the primary tool for controlling eutrophication, management of biotic communities can complement watershed management to help control nutrients.

When viewed from the alternate stable states framework, the plant community in Fish Lake reflects that of a productive eutrophic lake that is still in the clear water state as there are still many native macrophytes and average Secchi-depth readings. However, data on nutrient levels and plant productivity (high phosphorous and Chlorophyll-*a* levels) and fisheries data suggest the lake may be moving towards the turbid algal-dominance state. This would be very detrimental to lake aesthetics, fisheries and recreation. In order to prevent this, development of aquatic vegetation management plans should incorporate actions that promote maintenance of the clear water condition. Actions that would cause a transformation of the lake into a degraded, turbid-algal dominance state should be avoided (Table 8).

Biomanipulation as a management option: "Growing algae-grazers"

A relatively new management approach, referred to as biomanipulation, has been used successfully Wisconsin as well as Minnesota to improve water clarity and reduce algae blooms (Shapiro and Wright 1984). The strategy is to manipulate the food web to increase populations of algae-grazing Daphnia, which eat blue-green algae, thus reducing algae levels in the lake. This is generally accomplished by introducing predatory fish such as musky or pike that reduce populations of bluegill and other zooplankton-eating fish.

Table 8: Alternative Stable States: Clear vs. Turbid water Controls or switches that drive a lake ecosystem from a healthy clear water state with aquatic plants towards a turbid, algal-dominated condition (adopted from Moss, 1998).	
Actions that drive a lake toward turbid, algal dominated state (generally with a high trophic state index)	**Actions that promote water clarity, with native aquatic plant communities (lake restoration). (Low trophic state index)**
a. *Actions that cause direct destruction of beneficial native aquatic plants*	▪ Stopping actions or switches listed in left column
▪ Excessive mechanical cutting	▪ Reduction of nutrient loading
▪ Boat damage causing direct destruction of plants	▪ Promotion of native vascular plant growth or active plant restoration, if they are rare or absent
▪ Herbicide use or accidental runoff	▪ Re-establishment of appropriate fish community structure
▪ Heavy grazing of aquatic plants	▪ Biomanipulation
▪ Raising water level to decrease light available to plants.	
b. *Actions that damage the "plant buffer system", favoring algal growth*	
▪ Destruction of zooplankton activity by pesticide or other toxins	
▪ Raising salinity to more than 5 ppt	
▪ Reduction of predatory fish to panfish ratio by deoxygenation in summer or winter fish kill	
▪ Over-fishing of large fish so that small size classes are favored.	

Management Alternatives

General considerations
In developing a management plan, it is generally a good idea to consider several alternatives to facilitate comparison of costs, benefits and strengths and weaknesses of each plan. Alternatives should range from taking no-action to an intensive, multi-pronged effort. Plans may also be ranked by their sustainability based on costs and impacts over time.

Selection of specific management strategies is based on a number of factors. The U.S. EPA recognized 7 categories that influence technique selection (EPA 1988). These practical considerations are outlined below. Technique selection is based on the effectiveness of each approach for Fish Lake with consideration for the costs and benefits of each approach, as well as the negative impacts and long-term sustainability of each practice.

Practical Considerations

- *Effectiveness*

Some techniques are highly effective at removing vegetation but may be costly, damaging and not have long-lasting benefits. An example of this would be dredging the bottom of the entire shallow littoral zone to remove plants.

- *Longevity*

When considering long-term sustainability, longevity is an important consideration. Watershed management techniques that reduce runoff and soil loss are likely to have long-term effects. In contrast, practices such as water-column dyes or hay bale installation have short-term benefits.

- *Reliability and confidence*

This applies to the certainty that a given technique will have the desired effect. For example, plant harvesting has very clear and demonstrated effect. Hay bale use has not been practiced as long in the U.S.A so results are less certain here (though it has been used successful in Europe for 300 years).

- *Applicability*

Each lake has unique characteristics including watershed setting, lake morphology, recreational uses and other factors. For each lake the applicability of techniques must be carefully examined in light of the lakes' unique circumstances.

- *Potential negative impacts*

This factor is of critical importance, as negative consequences may outweigh benefits of some techniques or make it completely unacceptable. One example of this would be complete removal of all aquatic vegetation using herbicides and physical removal, leading to algal dominance and destruction of fish habitat.

- *Capital Cost*

Capital cost is the initial cost of implementing a practice. High cost practices include plant harvesting and alum application. Low costs include many of the ecological approaches such as biomanipulation and hay bales.

- *Operations & Maintenance Costs*

Some practices requiring ongoing maintenance, such as construction of storm-water ponds to reduce sediment and nutrient inputs into the lake or continual plant harvesting. Other techniques may have one-time costs such as dredging of lake inlets or biomanipulation.

Development of a Sustainable Management Plan

In selecting management strategies it is important to develop a plan that will achieve the desired objective, support the long-term health of the lake and keep the combined capital and O&M costs down over an extended time span.

For a lake management plan to be sustainable, external inputs of nutrients must be controlled before or concurrently with in-lake management techniques. By starting from the "bottom-up", limiting the source of excess nutrients, "top-down" approaches are enabled to work. Long-term sustainability also requires minimizing energy and chemical inputs over time, particularly persistent chemicals that can have negative impacts through bioaccumulation in animals. For this reason, ecological control methods are favored over the physical/chemical methods when effective and appropriate. Ecological methods such as biomanipulation tend to be inexpensive and have few negative side effects.

Preliminary recommendations

1. Take short-term actions that will immediately reduce curlyleaf pondweed coverage. Herbicide application and plant harvesting can both be used to immediately reduce the area of curlyleaf pondweed.
2. Develop nutrient budget to compare relative quantities of phosphorous inputs from watershed runoff, groundwater inputs, and internal recycling (curlyleaf, other plants, re-suspension). Much of the data is available to do this, but would require additional data on internal nutrient levels (from sediment and plants).
3. Continue long-term measures, such as watershed management to control erosion and nutrient transport into the lake. Agricultural fields in the western basin and construction sites should be targeted.
4. Existing wetlands should be preserved and managed. Emergent vegetation (shallow littoral wetlands) provides fish and wildlife habitat, nutrient uptake and water quality improvement.
5. Biomanipulation should be considered to control algae levels when the comprehensive lake management plan is developed. Reduction in algae levels would favor native aquatic plant growth as well. This approach is inexpensive, has almost no negative side effects, and improves game fishing opportunity.
6. For further control of nutrients within the pond, alum treatment may be considered to reduce available phosphorous in the lake.
7. Monitor progress of curlyleaf pondweed control in late 2005 or spring 2006. The presence of the invasive exotic, Eurasian milfoil should be monitored for also.

MANAGEMENT PLAN

Management actions were selected by PLSLWD staff and the stakeholder group, with consideration of the preliminary KDG recommendations. The selected management actions included a range of short-term and long-term actions involving in-lake management as well as education (Table 9).

Short-Term actions

Immediate actions to reduce curlyleaf pondweed coverage

- Watershed district treatment of 16 acres of nuisance curlyleaf via early-season application of endothall (spring 2005).

- Survey carp population to begin to evaluate potential common carp impact on plant community and water quality.

Long-term actions

Vegetation Monitoring and adaptive management

- Continued vegetation monitoring/aquatic plant surveys. If plant surveys show that curlyleaf reduction is not resulting in increased late-summer plant coverage and diversity, explore feasibility of and options for planting/re-vegetating low diversity littoral areas.
- Explore options for wake limitations to promote/protect native plants.
- Active native plant restoration Promote shoreline restoration and protect existing undisturbed shoreline
- Development of management zones for native plant protection and exotic species management.
- Complete an overall lake management plan for Fish Lake that establishes nutrient reduction goals for the lake and a plan for achieving those goals; include plant management plan as a component of the overall lake management plan.

Education

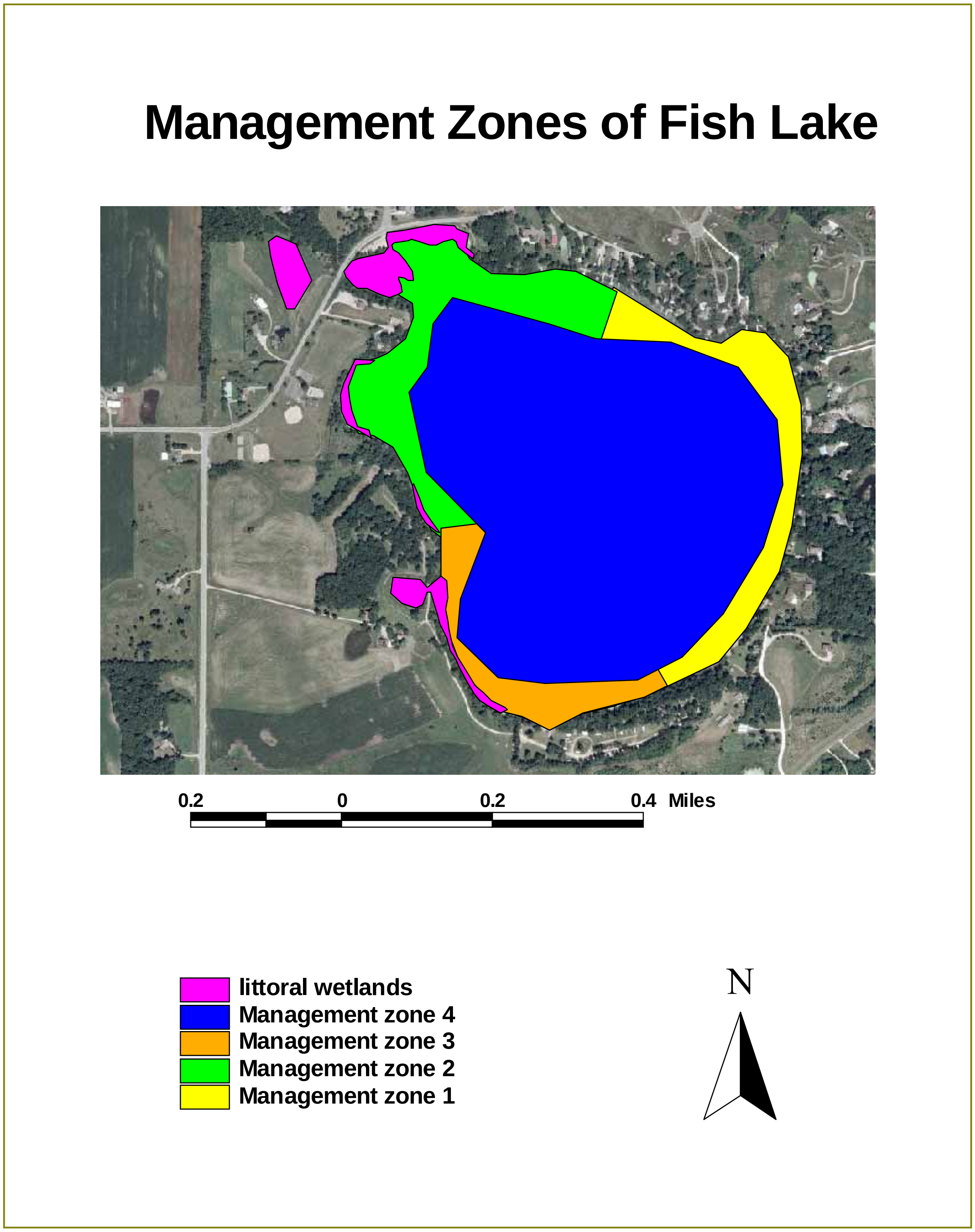
- Educate lakeshore residents on early-season treatment option for controlling curlyleaf while promoting native plants.
- Educate lakeshore residents on importance of native plants for a healthy lake, both for water quality and fisheries.

The management actions described above will be confined only to certain areas of the lake. For the purposes of this management plan, four lake management zones were proposed and the shallow littoral wetland zone that fringe parts of the lake.

Table 9: Fish Lake Aquatic Vegetation Management Plan Actions

Category	***Action***	***Contributing organizations***	***Time Scale: Short term/long term***	***Approximate cost***
Watershed	Complete overall lake management plan for Fish Lake establishing nutrient reduction goals for the lake and specific plans for accomplishing goals.	Watershed district, stakeholder groups, watershed landowners	Long-term (years)	$10,000's (depending on scope and type of plan)
In-lake	Treat of 16 acres of nuisance curlyleaf via early-season application of endothall.	Watershed district	Short-term (days)	$150-200/acre at 16 acres = $2400 to $3200^{+}
In-lake	Continue vegetation monitoring and inventory of aquatic plants.	Watershed district, volunteers	Long-term (years)	$2,000 to $8000
In-lake	If no increase in late-summer native plant coverage and diversity from management actions, then explore feasibility of active littoral area restoration/ revegetation.	Watershed district, stakeholder groups	Medium-term (Months)	$10,000's for littoral plant restoration.
In-lake	Survey carp population to evaluate potential carp impact on plant community and water quality.	Watershed district, MNDNR Fisheries	Short-term (days) (to do survey)	$1000's
In-lake	Explore options for wake limitations to promote/protect native plants.	Watershed district,	Long-term (years)	$100's to $1000's
In-lake	Promote shoreline restoration and protect existing undisturbed shoreline.	Watershed district, lakeshore residents	Long-term (years)	$100's to $1000's
Education/ outreach	Educate lakeshore residents on early-season treatment option for controlling curlyleaf while promoting native plants.	Watershed district, lakeshore residents	Short-term (months)	$100's to $1000's
Education/ outreach	Educate lakeshore residents on importance of native plants for a healthy lake, both for water quality and fisheries.	Watershed district, lakeshore residents	Long-term (months-years)	$100's to $1000's

Figure 13:


Management Zones of Fish Lake
0.2
0
0.2
0.4 Miles
littoral wetlands
Management zone 4
Management zone 3
Management zone 2
Management zone 1
N

Proposed Aquatic Plant Management Zones

Aquatic Plant management zones shown in Figure 13 were determined based on plant species distribution, water depth and shoreline development (see also Figures 14 and 15). The proposed plant management zones are described below.

Zone 1: Eastern shore (Figure 13).
Characteristics: developed shoreline with narrow littoral zone. The highest density of wild celery is found here, one of the most important waterfowl foods. (Note: Management zones in Figure 13 follow the approximate 10-foot depth contour. Beyond 10 feet is the open water zone).

Management goals
Protect plant diversity and coverage, promote shoreline restoration.

Management actions

- Explore wake limitations.
- Educate lakeshore owners on value of native aquatic plants (see Appendix 3).
- Protect wild celery.
- Promote shoreline restoration.

Wake limitations will protect native plants from uprooting.

Zone 2: North to NW shoreline
Characteristics: This area is less developed, with the largest areas of littoral wetlands. It also has high concentrations of coontail and curlyleaf pondweed.

Management goals
Reduce curlyleaf pondweed coverage. Enhance native aquatic plant diversity and coverage. Maintain/protect littoral wetlands and floating aquatics.

Management actions

- Endothall application.
- Monitor to see if curlyleaf reduction leads to greater plant diversity and less algae.
- Explore wake limitations.

Zone 3: West and SW shoreline
Characteristics: similar to northern zone, with little development and a fairly wide littoral zone.

Management goals
Reduce curlyleaf pondweed coverage. Enhance native aquatic plant diversity and coverage. Maintain/protect littoral wetlands and floating aquatics.

Management actions

- Endothall application.
- Explore wake limitations.
- Protect emergent and floating plant communities.

Zone 4: Open water beyond littoral zone (>10 ft deep)
Management goal
Improve water quality and clarity. Maintain game fish populations.
Management actions
Open water areas will be addressed in the comprehensive lake management plan.

Littoral wetland areas
Management goals
Protect plant diversity and coverage, promote shoreline restoration.

Management actions
In low diversity areas, or areas with no emergent vegetation, restoration could

be undertaken. Although the focus of the Fish Lake Aquatic Vegetation Plan is on aquatic plants, emergent species (which are intermediate between aquatic and upland) should be protected as well.

Restoration activities in the littoral area should be done to increase species diversity, if proposed management actions do not have that affect alone. (Currently cattail and bulrush are the only abundant emergent plants). Actions could range from shoreline restoration on private lawns to restoration plantings in the less disturbed wetlands, located on the northern and northwestern shores.

Figure 14:
Fish Lake Plant Survey
May 15, 2003

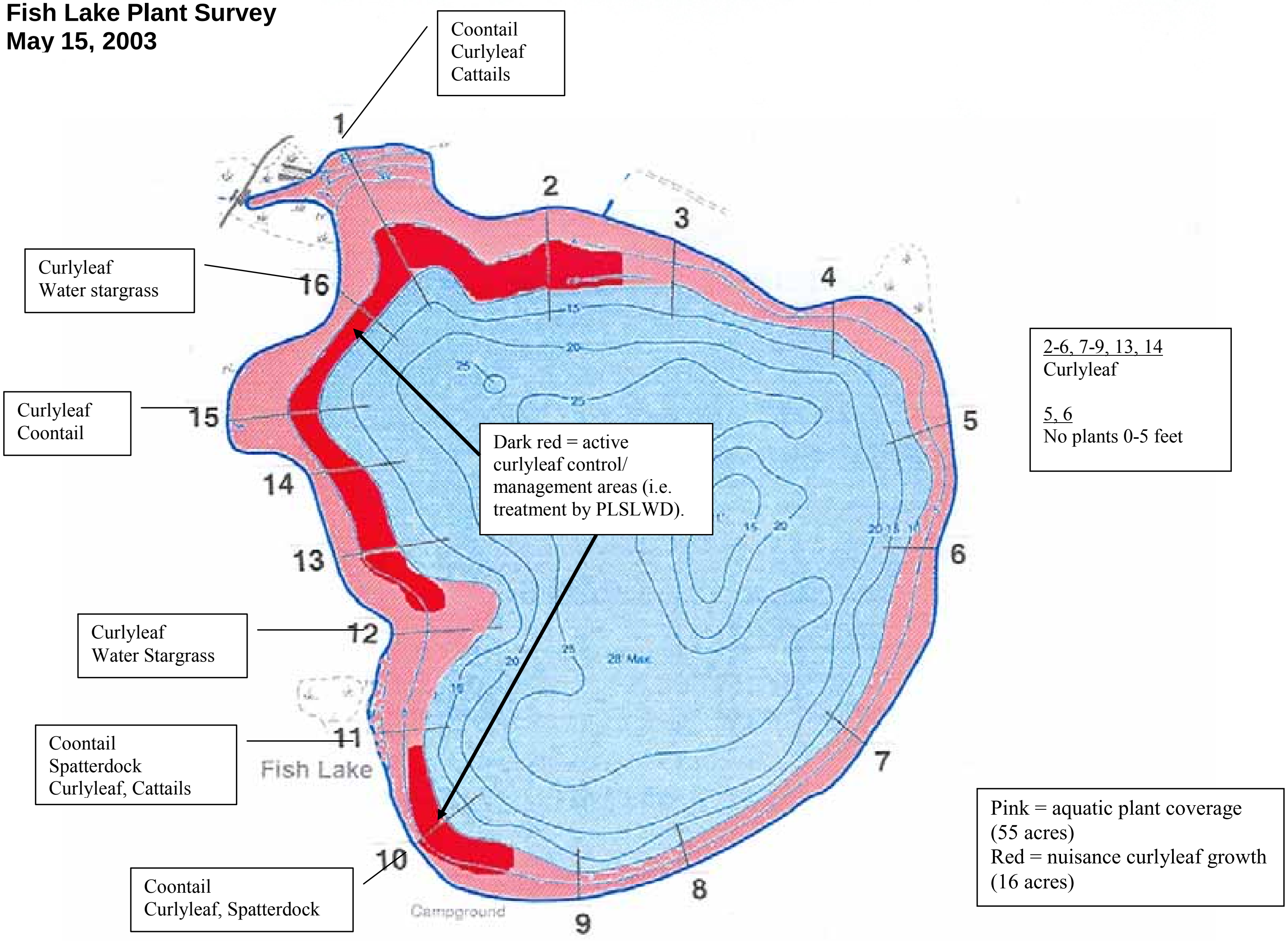
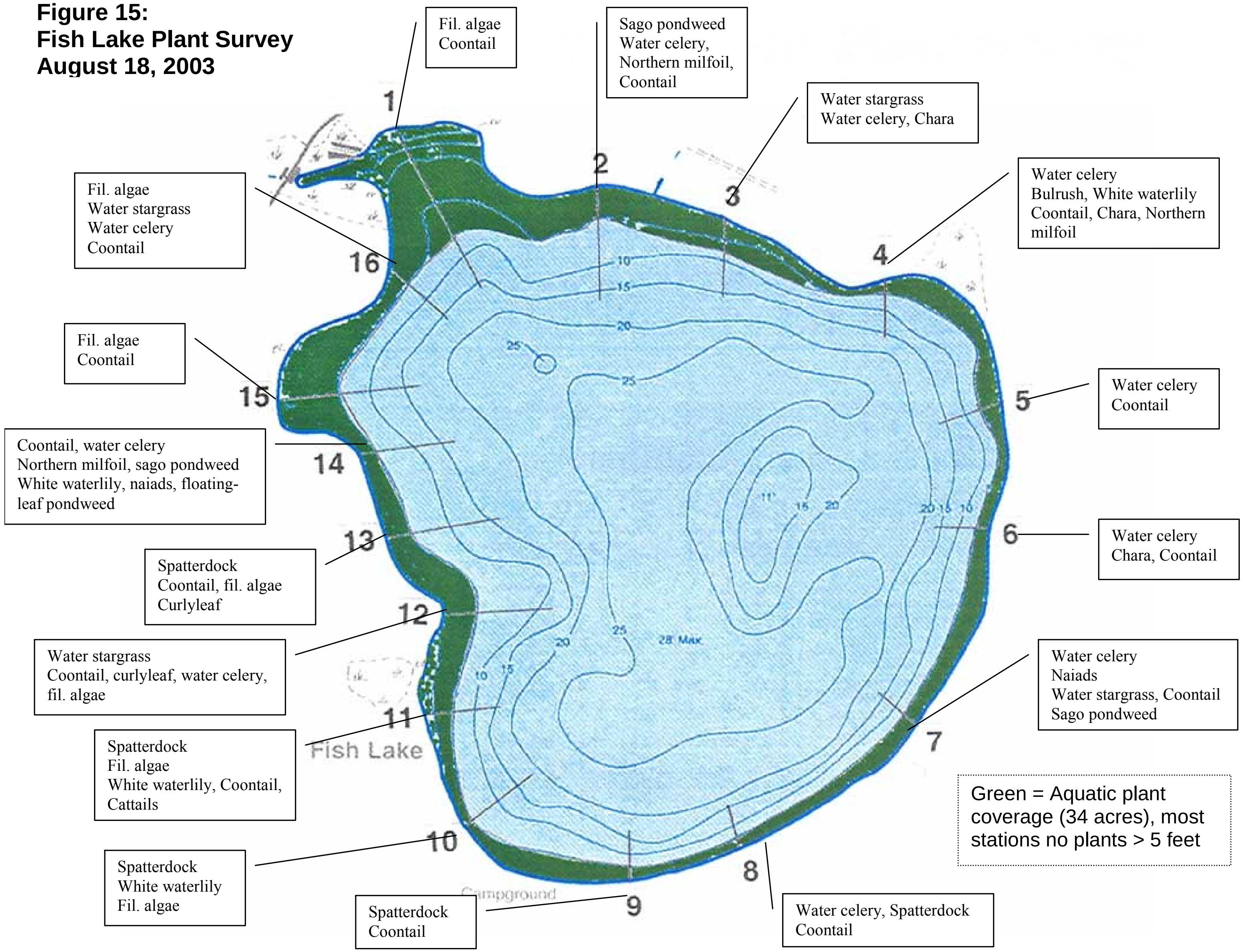


Figure 15:
Fish Lake Plant Survey
August 18, 2003



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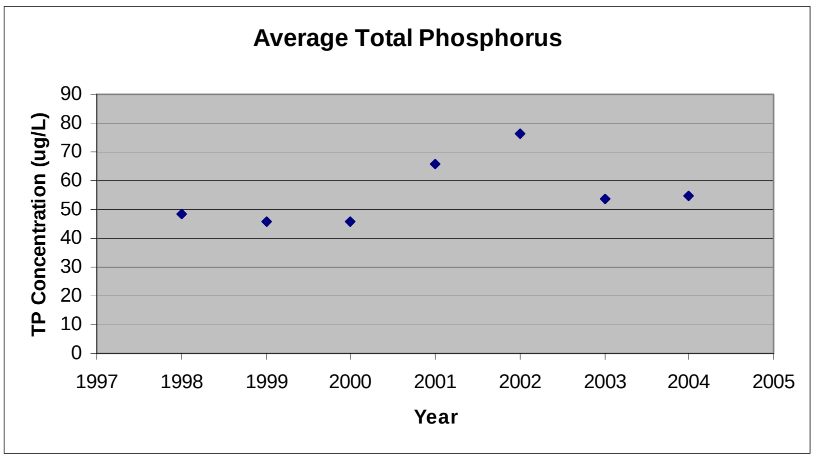
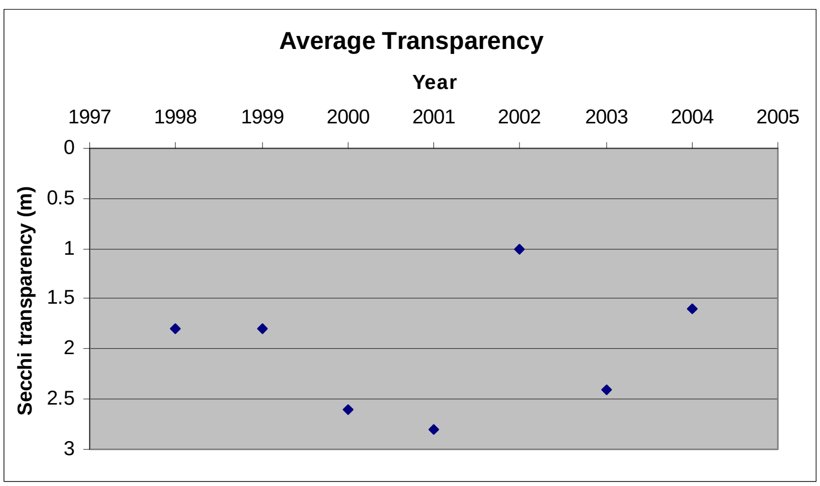
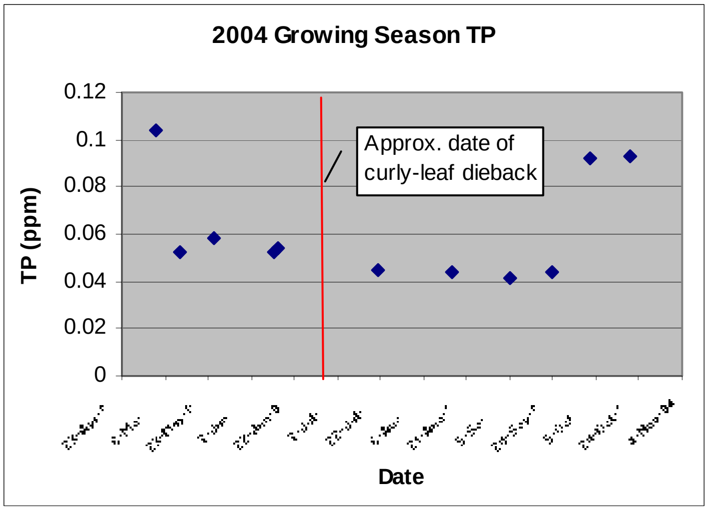
<u>Appendix 1: Summary of Fish Lake Water Quality (All Data from MPCA Database)</u>
Prepared by The Kestrel Design Group and Prior Lake-Spring Lake Watershed District

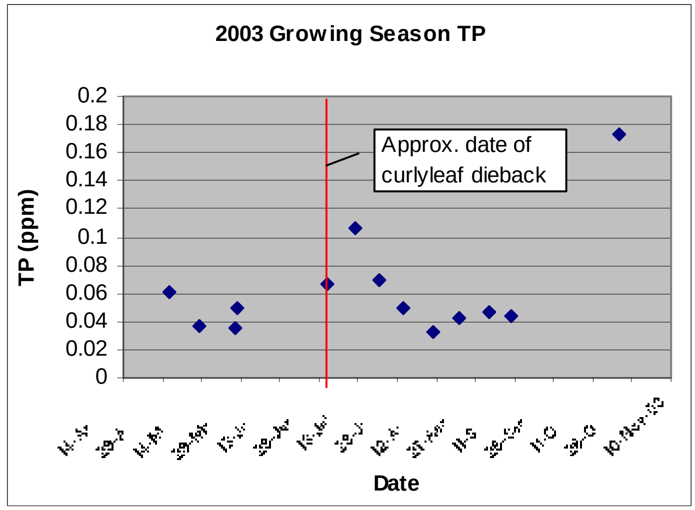
Table A1-1. Summary of Long-term Fish Lake Water Quality Data			
Water parameter	Reading	Units	Maximum/Minimum (number of measurements)
Alkalinity	126	ppm	Not reported (7)
Total Phosphorous	60	ppb	30/113 (51)
Mean Chlorophyll-*a*	33	ppb	1/81 (66)
Mean Secchi disk depth	1.6	meters	0/6 (51)

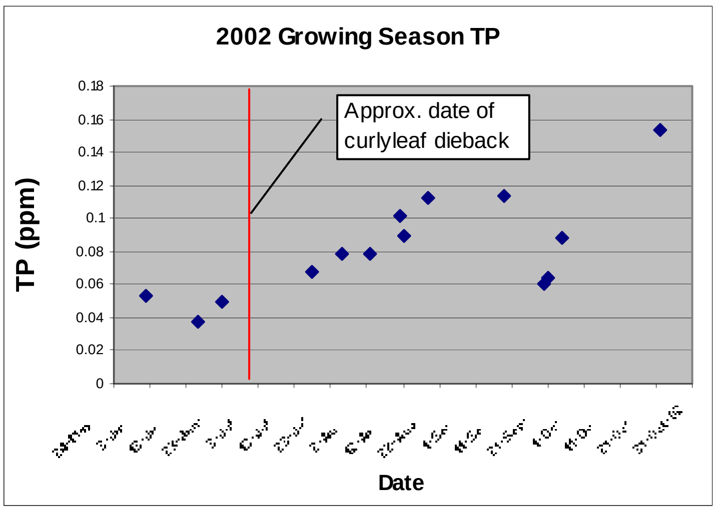
Table A1-2. Growing Season (May –Sept.) Average Lake Monitoring Results, 2000-2004				
Year	**Total Phosphorus, µg/L**	**Secchi disk, meters**	**Chlorophyll-a, µg/L**	**Trophic Status**
2004	54.9	1.6	18.9	58
2003	53.5	2.4	25	57
2002	76.4	1.0	37.5	74
2001	66	2.8	19	56
2000	46	2.6	18	55

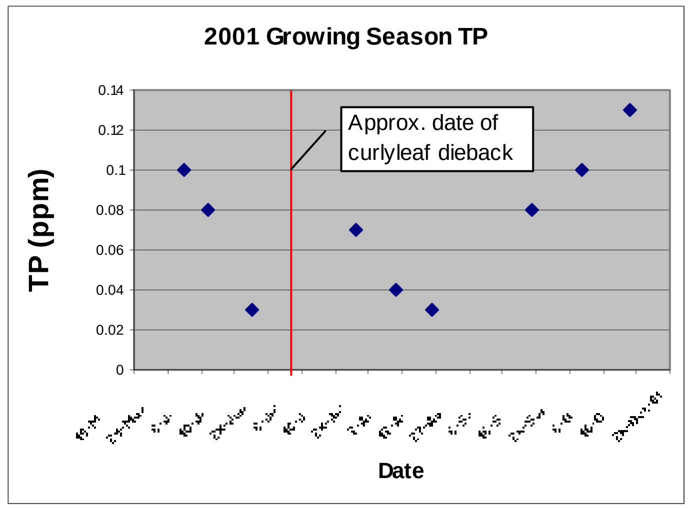





2004 Growing Season TP
TP (ppm)
Date
Approx. date of curly-leaf dieback


2003 Growing Season TP
TP (ppm)
Date
Approx. date of curlyleaf dieback


2002 Growing Season TP
TP (ppm)
Date
Approx. date of curlyleaf dieback


2001 Growing Season TP
TP (ppm)
Date
Approx. date of curlyleaf dieback

Appendix 2: Minnesota DNR summary of Fish Lake fisheries data (based on 1997 survey data) taken from the DNR LakeFinder web page at
http://www.dnr.state.mn.us/lakefind/showreport.html?downum=70006900

Fish Lake contains a quality walleye fishery, especially for a small metropolitan lake. The population exceeds the average level when comparing similar lakes. The average size walleye sampled was 16.7 inches long and weighed 2.0 pounds. Walleyes up to 27.0 inches in length were measured.

The northern pike population is currently at the lowest point recorded since 1975. However the size of the pike remaining is very respectable. The average size fish sampled was 28.7 inches long and weighed 5.5 pounds. The largest northern pike measured was approximately 32.0 inches in length.

Bluegill were very abundant. Their population exceeds the range that is considered average for this type of lake. The average length measured during the survey was 6.0 inches. Over 20% of all the bluegills measured were longer than 7 inches.

Both black and white crappies were of average abundance in Fish Lake. A larger sample was obtained in the trapnets. The average size of both species was 7.8 inches in length. One black crappie measured 14.4 inches.

Largemouth bass were not targeted during the summer portion of the survey and as a result only one was sampled in the trapnets. Shoreline seining was somewhat effective at sampling the bass population with 20 being captured during the fall portion of the survey.

Pumpkinseed sunfish were sampled within their normal range for this lake. Their average length was only 5.5 inches. The largest pumpkinseed sampled was 6.6 inches in length.

Appendix 3. Preliminary management recommendations from KDG, Inc., (October 2004). These goals were later revised following feedback from PLSLWD staff and the stakeholder group.

Potential Management goals for Fish Lake (October 2004)		
Category	**Goal**	**Rationale**
Water quality	Reduce phosphorous level to 40 µg/L	Restore lake to "swimmable use" level, reduce nutrient supply.
Exotic plant species	Reduce curlyleaf pondweed coverage to <4 acres (from 16).	Curlyleaf pondweed is a major source of phosphorous in mid summer causing algae blooms.
Algae-grazing plankton (*Daphnia*)	Reduce panfish populations by stocking more predatory fish (e.g. Northern pike, musky, bass).	Reducing panfish will increase numbers of algae-grazing Daphnia, thereby improving water clarity.
Eutrophication	Prevent switch to hypereutrophism. Lower TSI scores below 60	If a TSI score is below 60 it's classified as eutrophic not hypereutrophic.
Algae Blooms	Reduce frequency of nuisance algae blooms in summer	Algae blooms deter swimming and are aesthetically negative.
Fisheries	Maintain game fish populations and habitat (walleye, pike, bass)	Sportfishing is one of main recreational uses of lake.
Internal nutrient sources	Control internal recycling of phosphorous. This can be done with alum or other chemicals. Curlyleaf pondweed control also reduces mid-summer nutrient availability.	Pond sediments are major source of nutrients to water column and may contribute to eutrophication even after other nutrient sources have been controlled. Activities that stir-up and resuspend sediment should be avoided.
Watershed nutrient loading	Reduce watershed contributions of phosphorous (from current estimate of 0.05 lbs/acre)	External loading of nutrients must be controlled to reduce nuisance plant and algae growth.
* Management goals to be determined through stakeholder involvement process to be coordinated by the Prior Lake-Spring Lake Watershed District.		

Appendix 4: Guide to native aquatic plants of Fish Lake

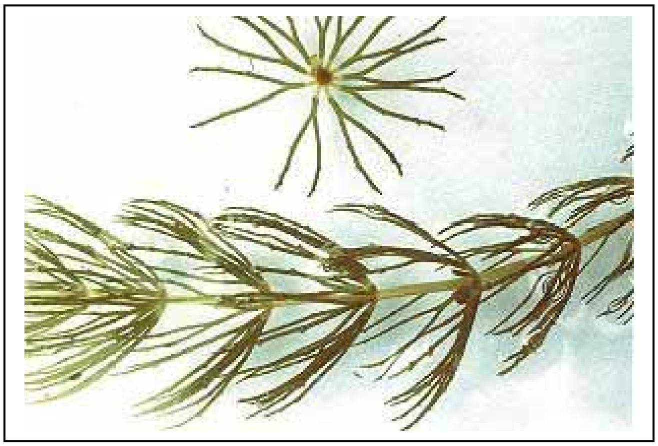
Submersed species (found in 2003 survey by S. McComas)

Common Name	Type	Location/Abundance (see Figures 14 & 15)	Functions/Significance	Mgmt. Category
Vascular, flowering plants				
Curlyleaf Pondweed *Potamogeton crispus*	Submersed (can form mats at the surface)	Widespread in lake in spring. Nuisance levels along west and northwest shoreline between 6 and 10 feet.	Exotic species. Can impact recreation if nuisance levels are reached, and summer dieback can promote algal growth. Provides some cover for fish, several waterfowl species feed on the seeds, diving ducks often eat the winter buds.	Reduce/ Control
Coontail (*Ceratophyllum demersum*)	Submersed (upper leaves can reach the surface)	Found in spring and late summer. Most abundant plant in lake in late summer -- found at all stations but 3, 10.	Many waterfowl species eat the shoots; provides cover for young bluegills, perch, largemouth bass and northern pike; supports insects that fish and ducklings eat. Can cause nuisance conditions when growing densely.	Maintain
Water Celery (*Vallisneria americana*)	Submersed	Not found in spring. Second most abundant plant in late summer. Dense beds at stations 4, 5, and 7.	Premiere source of food for waterfowl, particularly diving ducks. All parts of the plant are eaten. Beds are prime destination for canvasback ducks in the fall. Provides shade and shelter for bluegills, young perch and largemouth bass. Attracts muskrats, marsh birds and shore birds.	Promote
Water Stargrass (*Zosterella dubia*)	Submersed	Found in spring (13% occurrence) and late summer (25% occurrence). Dense growth at station 3 in late summer.	Generally a minor wildlife food -- consumed by ducks and wading birds but is not known as an important food item. Provides some valuable habitat for fish and serves as a source of macro-invertebrates for fish	Maintain
Northern Watermilfoil (native) (*Myriophyllum sibiricum*)	Submersed	Found in late summer at stations 2, 4, and 14 at low densities.	Provides cover for fish and invertebrates, supports insects and other small animals eaten by fish, waterfowl occasionally eat the fruit and foliage.	Maintain
Sago Pondweed (*Stuckenia pectinata*)	Submersed	Found in late summer at 3 stations (25% occurrence) at low-medium abundance.	Considered one of the top food producers for waterfowl -- swans, geese and diving ducks such as canvasbacks favor the tubers and seeds of this plant. Provide some cover for bluegills, perch northern pike and muskellunge; support aquatic insects and other small animals.	Promote
Naiads (*Najas sp.*)	Submersed	Low abundance at 2 stations in late summer.	Very important for waterfowl -- entire plants are eaten by waterfowl, especially mallards. Provide cover for largemouth bass and northern pike, and small bluegills and perch. Also important to a variety of marsh birds as well as muskrats.	Promote
Non-vascular plants (green algae)				
Chara *(Chara spp.)*	Submersed	Low abundance at 3 stations in late summer (stations 3, 4 and 6).	Stabilizes bottom sediments; provides food for waterfowl (it is a favorite waterfowl food) and cover for fish; also supports insects and other small aquatic animals that are important food for bluegills, smallmouth bass and largemouth bass.	Promote

Floating Species (found in 2003 survey by S. McComas)				
Vascular (flowering) plants				
Spatterdock (Yellow Water Lily) (*Nuphar variegatum*)	Floating	Found in spring and late summer. Third most abundant plant in late summer, with dense growth at stations 9, 10, 11, and 13 in late summer.	Fruits/seeds are eaten by waterfowl and muskrats; leaves, stems and flowers are grazed by deer; leaves provide shade and shelter for fish; underwater roots contain starch and are edible.	Maintain
White Waterlily (*Nymphaea tuberosa*)	Floating	Found in late summer at low densities at stations 4, 10, 11, 14.	Provides excellent habitat for largemouth bass and sunfish; seeds are eaten by waterfowl; rhizomes are eaten by deer, muskrat, beaver; highly decorative.	Promote
Non-vascular plants (algae)				
Filamentous Algae (green algae)	Floating and benthic (resting on lake bottom)	Third most abundant plant in late summer, with dense growth at stations 1, 15, 16.	Provides cover for small animals such as aquatic insects, snails and scuds, which are valuable fish food. Can shade out rooted aquatic plants, and create nuisance conditions. Often indicative of excessive nutrients.	Reduce/ Control

Emergent vegetation (found in 2003 survey by S. McComas)				
Cattails (*Typha sp.*)	Emergent	Found at 2 stations in spring 1 and 11) and 1 in late summer (11) at low density.	Helps stabilize marshy borders of lakes and ponds; helps protect shorelines from wave erosion; northern pike may spawn along shore behind the cattail fringe; provides cover and nesting sites for waterfowl and marsh birds; stalks and roots are eaten by muskrats, geese and beavers. Hybrid cattail may become invasive in some settings, but broadleaf cattail beneficial, particularly if limited emergent vegetation is present.	Maintain
Bulrush (*Scirpus sp.)*	Emergent	Found at one station (4) in late summer at low density.	Excellent fish habitat, providing spawning areas for northern pike and (in early spring) nesting cover for largemouth bass and bluegills. Attracts marsh birds and songbirds and provides food for ducks, geese and swans. Help anchor sediment and stabilize shorelines.	Promote
(Other species observed in littoral zone by Chris Lenhart, summer/fall 2004)				
Irises	Emergent	Found on western shore	Grazed by muskrat and water fowl	Promote
Sedges (*Carex sp.*)	Emergent	Found on west-northwestern shore.	Waterfowl food, shoreline stabilization, spawning areas in shallow water.	Promote
Willow *(Salix sp.)*	Woody	Observed on western shore	Shoreline stabilization and wildlife cover.	Maintain
Duckweed (*Lemna sp.)*	Floating	Common in littoral wetlands and other protected areas.	Good source of food for waterfowl. Removes nutrients from water.	Maintain

Coontail (Photo from University of Wisconsin Herbarium, Dennis Woodland)



Water Star Grass (Photo from UW Herbarium, Robert Freckman)

Najas (Photo from UW Herbarium, Robert Freckman)

Sago Pondweed, (Photo from UW Herbarium, R. W. Freckman)

Irises on Fish Lake shore
(photo by C. Lenhart)

Cattail marsh with duckweed and curlyleaf pondweed in foreground (photo by C. Lenhart)

PLAN APPROVAL

This Aquatic Vegetation Management Plan is hereby approved for a period of five years. At the end of this time period, the Plan will be updated and revised to reflect the most current data available on the Fish Lake aquatic plant community.

The Prior Lake-Spring Lake Watershed District (PLSLWD) will follow the guidelines set forth in this plan as it strives to protect and improve the water quality and plant community in Fish Lake. During the plan implementation period, the PLSLWD will periodically update the Department of Natural Resources (DNR) and Fish Lake stakeholders on the progress made in implementing the plan and the status of the plant community.

The PLSLWD understands that this approved plan does not take the place of aquatic vegetation permits issues by the DNR. The PLSLWD will apply for and obtain a DNR permit prior to undertaking any plant management activities in Fish Lake for which a permit is required.

4-4-05

Signature Date

Shannon Lotthammer
Administrator
PLSLWD

03/29/05

Signature Date

Dirk Peterson
Regional Manager – Fisheries
Minnesota DNR