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ENSR

# DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR THE CONTROL OF EURASIAN WATERMILFOIL IN EAGLE LAKE WITH FLURIDONE

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# SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR THE CONTROL OF EURASIAN WATERMILFOIL IN EAGLE LAKE WITH FLURIDONE

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## EXECUTIVE SUMMARY

Eurasian watermilfoil (Myriophyllum spicatum) is believed to have been first detected in Eagle Lake, Essex County, New York in 1982, with confirmation in 1987. This plant was found at locally excessive levels in a 1989 survey and has expanded throughout the littoral zone of the lake to the present time. Displacement of the native community by milfoil reduces biodiversity and habitat quality for a wide variety of water-dependent fauna. Dense growths of milfoil impair recreational utility and can adversely affect the local economy. Vigilance to detect milfoil and early management to eradicate this non-native nuisance species is highly desirable. As the infestation of Eagle Lake has passed this early stage, it is proposed that Sonar® (with fluridone as the active ingredient) be used in a whole lake treatment to remove the milfoil.

Advantages of Sonar® include minimal impacts on non-target organisms and the potential for complete eradication, while the primary disadvantage is the need to prolong exposure of the target areas despite significant water exchange. A Generic Environmental Impact Statement for the use of fluridone was prepared in 1995, and indicates substantial potential for this herbicide to effectively control milfoil in waters of New York State with minimal adverse impacts to non-target organisms and uses. This Supplemental Environmental Impact Statement has been prepared to address site-specific aspects of the proposed Eagle Lake treatment.

Among the alternatives for milfoil control, drawdown is not feasible for reasons of outlet limitations and problems with timely refill of the lake. Dredging is very expensive and suffers from technical limitations in Eagle Lake. Mechanical harvesting could limit interference of milfoil with boating and possibly swimming, but would not eradicate the plant from target areas and would not restore the native plant community. Other chemicals are either not as effective as fluridone or have restrictions that more greatly limit water use after treatment. Dyes would have to significantly reduce water clarity to be effective in Eagle Lake, and it would be logistically difficult to keep surface covers in place for a sufficient period of time. Grass carp are likely to eat many native plants before consuming milfoil, potentially intensifying milfoil dominance. Grass carp are also known to induce algal blooms in lakes where they effectively control rooted plants. The milfoil weevil is still an experimental technique and is very expensive on an areal basis. The weevil has yet to provide widespread control in a large lake after stocking, and no control of milfoil by natural populations has been documented in Eagle Lake to date. There are no viable milfoil pathogens currently available. Maintenance of a healthy native assemblage is viewed as a valuable preventive tool, but restoration of the native community where milfoil has become dominant requires other techniques.

Eagle Lake will receive the aqueous formulation of fluridone (Sonar® AS), most likely as a late spring treatment, but possibly as a fall treatment. The maximum concentration of the aqueous formulation will be <50 ppb, consistent with state regulations. However, applications will target a much lower continuous concentration of 10-20 ppb for approximately 40 days. A single treatment is expected to be adequate unless inflow is abnormally high or degradation of fluridone is rapid, in which case sequential additions of fluridone will be made to maintain the 10-20 ppb concentration. A monitoring program will be used to track fluridone levels during the treatment period. The program is consistent with the provisions of the GEIS.

The only anticipated major impact of fluridone application is the elimination of Eurasian watermilfoil in the treated areas. There could be some localized and largely temporary impact on native plant species, as there is limited documentation of effects on many of the submersed plants of Eagle Lake. However, re-establishment of a native assemblage in areas currently dominated by milfoil is expected within several months to a year, primarily by seed germination. No adverse impacts on aquatic fauna are expected. No impact from intermittent irrigation of lawns or gardens is expected at the target concentration. No impacts from passage through septic systems is expected. No risk to human health is anticipated. There will be temporary limitation of water use by humans (i.e., no swimming for 24 hours after application), but this represents minimal interference at the time of the planned treatment and successful control of milfoil will enhance longer term lake use. The economic wellbeing of the Eagle Lake area will not be harmed by the treatments, and would be enhanced by increased success of the overall milfoil control program.

A monitoring plan has been developed to track the treatments and assess impacts on the plant community. Pre-treatment monitoring has been conducted for three years already.

## PROJECT SETTING AND BACKGROUND INFORMATION

Eagle Lake is located in the southern portion of Essex County in the Towns of Ticonderoga and Crown Point, in the easternmost part of the Adirondack Mountains of New York State, west of Lake Champlain (Figures 1 and 2). Eichler and Madsen (1990) summarized most of what is known of the limnology of Eagle Lake, drawing on NYSDEC studies and their own investigations.

Eagle Lake has a surface area of 420 acres (170 ha) and a shoreline length of 7.8 miles (12.5 kilometers). The maximum depth is approximately 42 ft (12.8 meters) and the mean depth is 19 feet (5.8 meters). Eagle Lake has two distinct basins, the larger and deeper eastern basin and the smaller and shallower western basin, connected by a narrow channel under the causeway that supports NYS Route 74 (Figure 2). Water detention time is approximately 1.4 years. Eagle Lake is dimictic with summer stratification present from June into October and ice cover typically occurring from January through March.

The watershed of Eagle Lake covers about 1392 hectares (3452 acres). The soils of this steeply sloping watershed are generally nutrient-poor sandy to gravelly soils derived from glacial till. Land use is primarily forest, as steep slopes limit development potential, but there are residences around the lake, especially along the south shore of the eastern basin. Eagle Lake is a popular recreational lake and has a public boat launch at the western end of the lake. The lake supports a diverse fishery that includes both warm water and cold water game species.

Eagle Lake is considered to be oligotrophic; it has low fertility and does not support substantial phytoplankton growths. Total phosphorus in the upper waters of the lake rarely exceeds 10 ppb, although deep water values in late summer (after several months of stratification) can be as high as 26 ppb. Oxygen becomes depleted below a depth of about 10 meters by the end of August. Nitrate- and ammonium nitrogen are low, ranging between 10 and 20 ppb. The waters of Eagle Lake are soft (alkalinity of 29-37 ppm as $CaCO_3$), but the pH has been circumneutral during past summer samplings. It is not known whether there is any spring pH depression with the melting of acidic snow. Water clarity is moderate to high (7-9 m), with enough light for substantial plant growth at depths up to 20 ft and more limited growths to depths up to 30 ft.

Almost 50% of the lake area has the potential to support significant rooted plant growth based on depth (approximately 200 acres with water depth <20 feet). Observations of the plant community have been made in many years, but detailed plant surveys were conducted in 1932 and 1989, with another detailed survey of two selected areas of Eagle Lake in 1996-1998. The submersed aquatic plant communities of 1932 and 1989 were similar, except for the emerging dominance of Eurasian watermilfoil in 1989. Aside from Eurasian watermilfoil (*Myriophyllum spicatum*), the most abundant rooted plant species in Eagle Lake in 1989 were *Heteranthera dubia*, *Vallisneria americana*, *Potamogeton amplifolius*, *Potamogeton gramineus*, *Eriocaulon septangulare*, Najas flexilis, Elodea canadensis, *Potamogeton robbinsii, Potamogeton praelongus,* and *Nitella spp.*

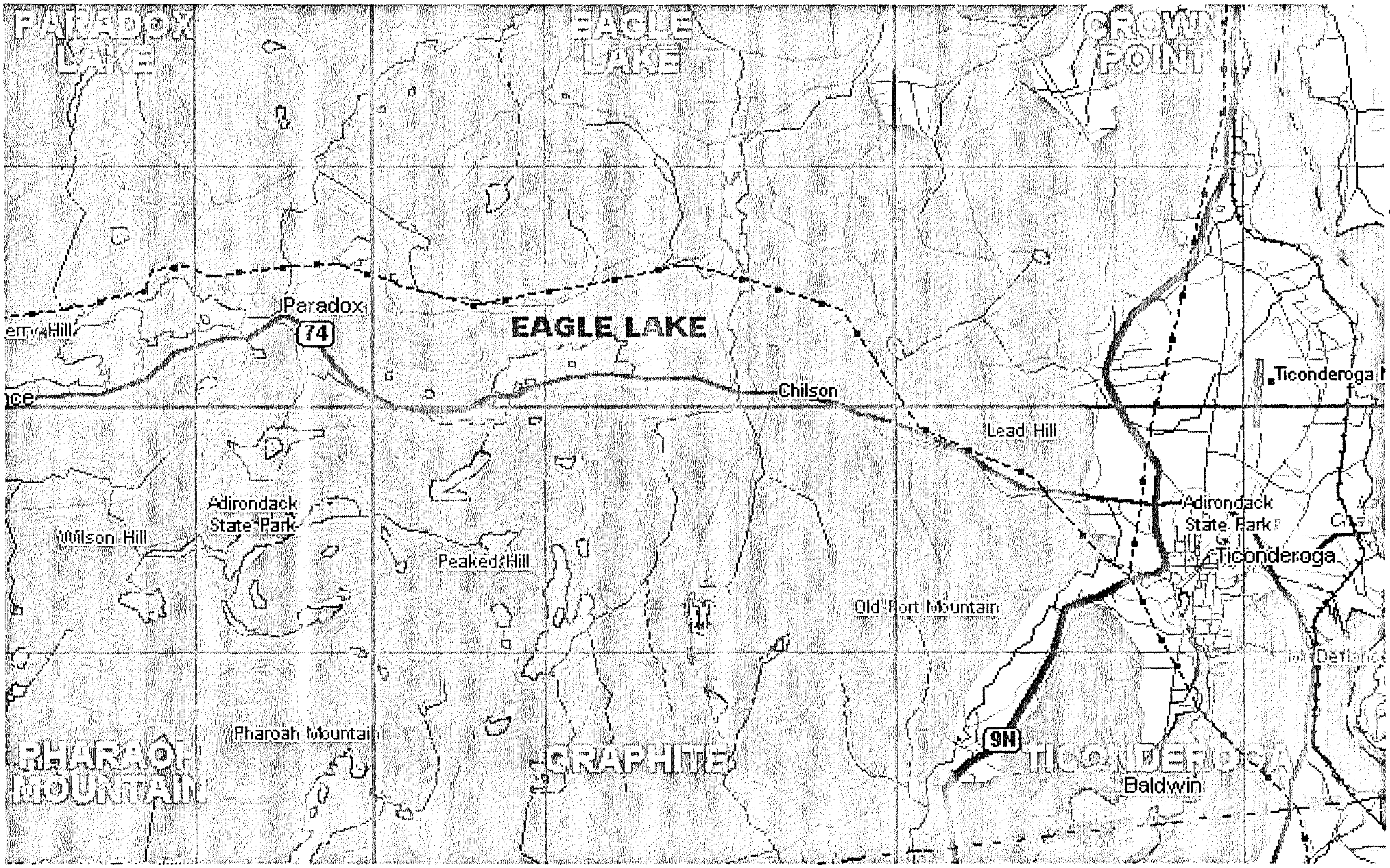



**FIGURE 1. EAGLE LAKE LOCATION**

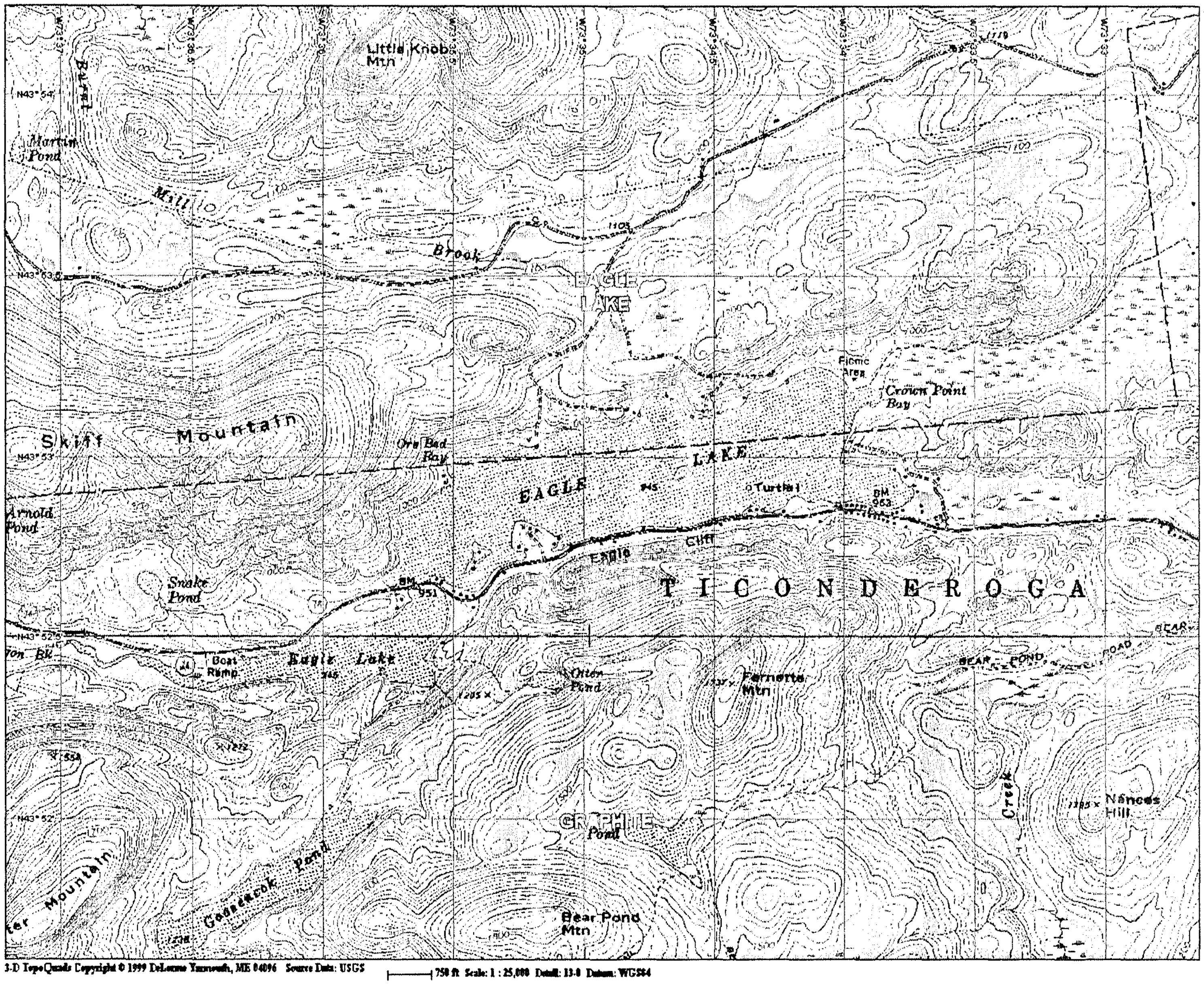
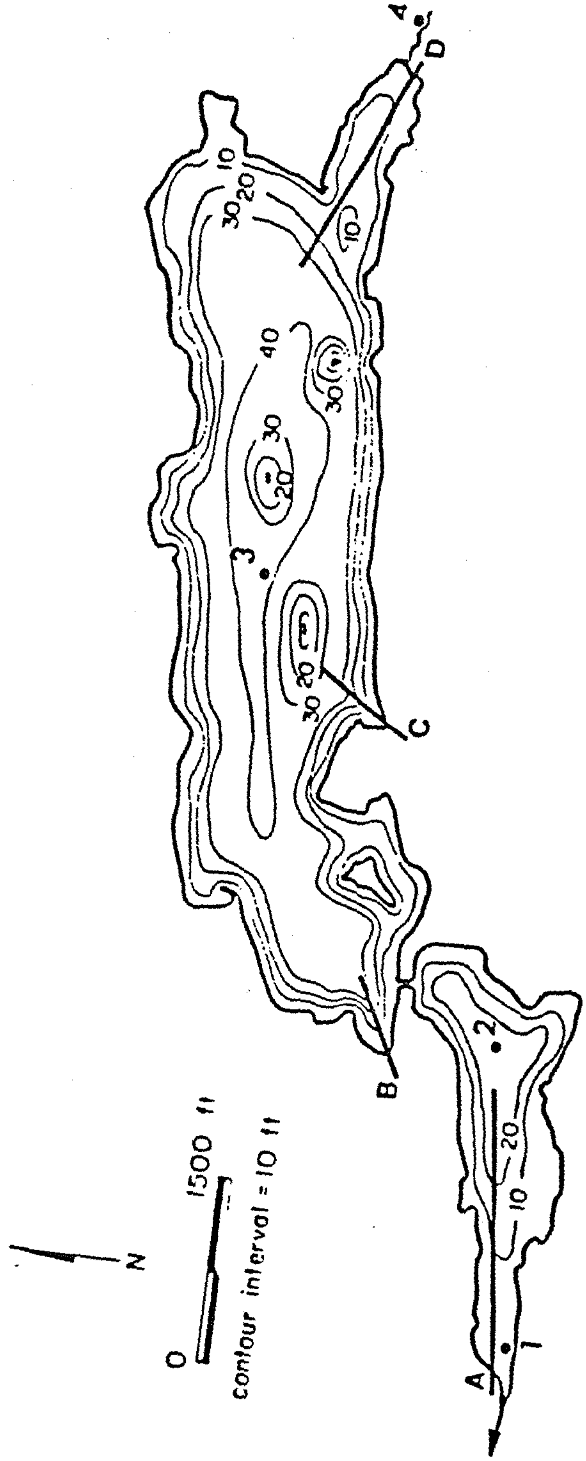



FIGURE 2. EAGLE LAKE AND IMMEDIATE VICINITY

Figure 3. Eagle Lake Bathymetry



The nuisance aquatic macrophyte *Myriophyllum spicatum*, or Eurasian watermilfoil, was initially identified in Eagle Lake in 1982 by Mr. Harland Stubbing and definitively confirmed in 1987 by personnel from the Darrin Fresh Water Institute (DFWI) of Rensselaer Polytechnic Institute. We will refer to Eurasian watermilfoil as milfoil in this document for convenience, but note that there are multiple milfoil species, some of which are native to the area (although no other milfoil species have been detected in Eagle Lake). The 1989 DFWI survey found extensive growths of milfoil in patches around the lake and on the central shoals. Annual visual inspections from 1994 to 1998 confirm the spread of milfoil throughout the littoral zone of Eagle Lake.

Concern by several groups involved with the lake, including the New York Department of Environmental Conservation, the Coalition of Lakes Against Milfoil (COLAM), and the Eagle Lake Association, prompted an effort to gain approval for the use of the herbicide Sonar® to control milfoil in Eagle Lake. New York State has approved the use of Sonar® (with fluridone as the active ingredient) in waters of New York, based partly on the Generic Environmental Impact Statement prepared by McLaren/Hart (1995). However, in order to use Sonar® in Eagle Lake, a Supplemental Environmental Impact Statement is needed under the State Environmental Quality Review (SEQR) process to address site-specific aspects of the treatment. This document is submitted in fulfillment of that requirement.

## THE NEED FOR MILFOIL CONTROL

Much has been written on the need for management of invading non-native species (Miller, 1994; Cunningham and Saigo, 1999), and specifically on the need for control of Eurasian watermilfoil (Newroth, 1979; Shireman et al., 1982; Hoyer and Canfield, 1997). Still more discussion has been held at a wide variety of symposia and workshops devoted to environmental management in general or aquatic plant management specifically (e.g., those of the North American Lake Management Society and Aquatic Plant Management Society). There are both ecological and economic reasons for controlling milfoil. Ecologically, this plant displaces native species and decreases biodiversity. It also provides limited habitat value when dominant, negatively affecting aquatic fauna. Economically, milfoil creates nuisance conditions which impair recreational use and reduce property value. Milfoil impacts should be considered on three scales: localized impacts, lakewide impacts, and regional impacts.

***Localized Impacts***

At the scale of the individual plant, milfoil is just one more species in a large assemblage in most lakes where it has just been introduced. If the native community persists and maintains dominance, scattered individual milfoil plants are not a major threat. They do not appear to add any appreciable structure to the community beyond that which most native plant species assemblages already possess, but an individual milfoil plant is only a problem for chance recreational encounters, due to entanglement. The problem is that rarely does the native community withstand milfoil invasion indefinitely, or even for more than a few years. Eurasian milfoil has become the dominant plant in the vast majority of lakes in which it has been introduced in less than 10 years (Carpenter, 1980; Wagner, pers. obs.). If not attacked aggressively in the early stages of establishment, the likelihood of expanded milfoil coverage is very high, with concurrent loss of native assemblages and associated habitat value.

The ecology of the species involves reproduction primarily by vegetative means, usually by fragmentation of plant tips or by root crown expansion. Root crown expansion appears to be the dominant means of local expansion, while fragments are the primary means of more distant dissemination and colonization (Madsen and Smith 1997). Both are highly effective means of propagation. Adventitious roots form on the plant tips, allowing rapid re-rooting and growth of new plants. Viable fragments may be produced by motorboat propellers, but fragmentation is naturally most prevalent in the autumn when assemblages of annual species dependent upon seed germination have died back, providing ample open substrate for the milfoil to colonize. Fragments persist through the northern winter, can grow with low light availability, and initiate rapid growth (as much as 1 ft per week) in the spring before many seeds have germinated. Likewise, established plants with expanded root crowns can send up new stems earlier in the spring than most other species in northern lakes. Rapid dominance is thereby ensured in most cases.

At the scale of the bed, milfoil is predominantly a recreational problem by virtue of its location. Occurrence of beds in shallow water in swimming or docking areas creates an impediment to human access and use which is usually evident by the start of more intensive spring use (post-Memorial Day). While other species can create nuisance conditions, the early appearance and severity of the milfoil nuisance are matched in northern waters only by fanwort (*Cabomba caroliniana*), another aggressive non-native species, and sometimes by curly-leaf pondweed (*Potamogeton crispus*), a species which declines by early July in most cases.

Dense beds have limited habitat value, but as part of a mosaic plant assemblage with different morphologies, a single milfoil bed is not a major detriment to aquatic ecology. Again, however, such a situation rarely persists. As Eurasian watermilfoil is a species with a "disturbance ecology" (i.e., it is well adapted to be opportunistic in response to disturbances which make habitat available), it normally becomes the dominant plant and can nearly exclude other species. This creates a transition to the lakewide scale of the problem represented by this species.

The pace at which milfoil became established in Eagle Lake appears slightly slow for this species, but a continuous record of expansion in the lake is lacking. Seventeen years after apparent first detection, it is one of the three most abundant species in the lake along with charophytes (advanced algae such as *Nitella*) and Robbins pondweed (*Potamogeton robbinsii*). Some additional expansion of milfoil is possible, but it is already the dominant species in water 2 to 4 m deep, the preferred depth range of this species.

Arguments are sometimes made in favor of letting milfoil invasions run their course, much like an epidemic of some sub-lethal virus. It has been postulated that invasive species are eventually brought under control by natural forces and become just one more species in the assemblage, but we have only scant information and a very short history with regard to most species. If eventual integration into the aquatic plant community occurs, existing evidence indicates that it will not be before great loss of biological diversity, habitat value, recreational utility, and economic benefit. Additionally, the timeframe for assimilation of a new, invasive species is unknown, but postulated to be on the order of a century or more. For Eurasian watermilfoil specifically, it is still a problem plant in lakes that have had this species in them since the 1950s. Unless we are willing to experience substantial and prolonged losses in the many facets of lake value, action is necessary.

Early and preventive action is much preferable to later large-scale restoration. Efficient milfoil control requires acting at the level of localized impacts, not waiting until there is a lakewide problem. Unfortunately, milfoil become dominant in Eagle Lake before any substantial action could be taken. Now it is necessary to deal with the problem on a lakewide basis to gain control of this nuisance exotic species.

***Lakewide Impacts***

On the lakewide level, dominance by milfoil is routinely equated with a loss of habitat value and major recreational impairment. The displacement of native plant species, particularly those with low-growing morphologies or high light requirements, has resulted in population reductions or elimination of certain species of benthic invertebrates, alteration of cover for fish, and a reduction in food quality for herbivorous waterfowl (Shireman et al., 1982; Keast, 1984; Baker et al., 1993). With specific regard to fish, the density of milfoil beds leads to excess survival of young of the year fish and subsequent intense competition for food resources, such that stunted populations or highly irregular year classes develop. Interest by fishery agencies in maintaining an aquatic plant community under pressure from recreational users to limit plant growths should not be centered on protecting milfoil (or other invasive species), but rather should focus on restoring the native assemblage at a density appropriate to the range of lake use objectives.

Many seed-producing species will become re-established when milfoil is eradicated. This has been demonstrated in nearby Lake George (Eichler et al., 1995). Milfoil control programs seek to eliminate milfoil, but this does not equate to the loss of the plant community. Rather, it is a pre-requisite for the restoration of the native community. There may be a temporary loss of plant cover and biomass, typically on the order of a season, but this is not even certain with lower dose Sonar® treatments, and re-growth of other species from seeds is invariably observed the following growing season.

The threat of lakewide infestation to recreational interests is severe. Although certain native species can indeed produce nuisance conditions (e.g., *Potamogeton amplifolius* or *Nymphaea odorata*), the density of milfoil exceeds that of virtually all native species and the potential for swimmers to become entangled is a real safety issue. Likewise, boat propellers can become immobilized by milfoil, but not by most native species. The utility of a waterbody for virtually all recreational uses can be seriously diminished by milfoil infestation.

Recreational impairment translates into economic loss. In Eagle Lake, as many as 80 hectares (200 acres) out of 170 hectares (420 acres) of lake area could be affected, although impacts are likely to be most severe in water <4 m deep, or about 40 hectares (100 acres). Very few shoreline areas are immune to the effects of milfoil infestation. As the shoreline and littoral zone is the most intensely used portion of most lakes, the economic damage that can be done is disproportionately large.

Property value on the east side of Cayuga Lake in New York, where milfoil was managed by a major dredging project, averaged $100,000/acre in the late 1980's. On the west side of the lake, where there was only limited harvesting, property value was just over $13,000/acre at the same time (BEC, 1989). Studies in Maine lakes have indicated major changes in property value as a function of lake condition (Boyle and Kahl, 1997). A recent study in Massachusetts (Jobin, 1997) revealed that two lakes of similar size but greatly differing condition (as a consequence of impacts and management approaches) imparted greatly different property value; the poorer quality lake was associated with a $14 million decline in the annual tax base.

Considering taste and odor issues and the potential to clog intakes, use as a potable water supply could also be impacted. Algal mats associated with milfoil growths in a Connecticut reservoir have been determined to be the cause of problem taste and odor in the water supply (ENSR, 1998a). Clogging of shallow supply intakes by milfoil in an irrigation pond has also impaired water supply (Fugro, 1995). Water supply issues are not major concerns for Eagle Lake at this time, but action is warranted to protect future use.

*Regional Impacts*
When multiple lakes in an area are impacted, as is often the case with a lack of management over time, milfoil becomes a regional problem, both ecologically and economically. The problem becomes more difficult to manage, based on sheer areal coverage and the necessary capital expense, and the impact becomes more severe, based on the lack of alternative lakes for water supply, recreation and habitat functions.

Milfoil is fairly hardy in its vegetative state, allowing transport among lakes and colonization of new aquatic systems. Transport on boats and associated trailers is often cited as a primary vector (Newroth, 1979; Johnstone et al., 1985), but movement with waterfowl is also strongly implicated in a number of cases where access to the lake by boats was limited or absent (Garrison, pers. comm.). Certainly milfoil is expected to move downstream with water flow out of an infected lake and into any downstream systems.

As Eagle Lake is the first in a chain of lakes extending downstream, this ability to colonize new lakes at substantial distance creates a regional threat that requires action across political boundaries. This is extremely difficult to orchestrate, but successful control on only the localized or lakewide scale will not prevent re-invasion by milfoil. This ties the regional management need back to early and localized control. Allowed to pass some threshold of areal coverage, either within a large lake, or over a series of smaller lakes (such as Eagle Lake), milfoil becomes exponentially more difficult and expensive to eradicate or even control. While the need for regional control is undeniable, the level of effective management action is on the localized to lakewide scale.

## PROPOSED ACTION

Fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4[1H]-pyridinone) is a systemic herbicide. It is absorbed by plant tissues and translocated throughout the plant. Fluridone, the active ingredient in Sonar®, was introduced in 1979 (Arnold, 1979), obtained Federal registration in 1986, and has been in widespread use outside New York since the late 1980s. Although special use based on local needs was possible in New York in 1993, full use in New York was not approved prior to 1995, and changes in label restrictions for New York have continued until the present time.

Sonar® currently comes in two formulations, an aqueous suspension (Sonar® AS) and a slow release pellet (Sonar® SRP). Sonar® AS is proposed for use in this project. This chemical inhibits carotene synthesis, which in turn exposes the chlorophyll (active photosynthetic pigment) to photodegradation. Most plants are negatively sensitive to sunlight in the absence of protective carotenes, resulting in chlorosis of tissue and death of the entire plant with prolonged exposure (up to 40 days) to a sufficient concentration of fluridone (as little as 5 ppb). Some plants, including Eurasian watermilfoil, are more sensitive to fluridone than others, allowing selective control at low dosages.

For susceptible plants, lethal effects are expressed slowly in response to treatment with fluridone. Existing carotenes must degrade and chlorosis must set in before plants die off; this takes several weeks to several months, with 30-90 days given as the observed range of time for die off to occur after treatment. Fluridone concentrations should be maintained in the lethal range for the target species for at least three weeks, and preferably for six weeks. This presents some difficulty for treatment in areas of substantial water exchange, but the slow rate of die off minimizes the risk of oxygen depletion.

The list of submersed vascular plants known from Eagle Lake (Table 1) includes 36 species. Two non-vascular species (macroalgae) are also listed. Comparison of this list with susceptibility evaluations compiled by the Vermont DEC (1995) and the current supplier of Sonar® (SePRO 1995) indicate that Eurasian watermilfoil and up to 11 other species would be susceptible to treatment with fluridone. Based on available information, there are 4 or 5 species that would be unharmed, leaving 22 species for which available information is insufficient to make any prediction of fluridone impact. Similar indications are provided by the data from Michigan as reported in the GEIS (Table 2). While the selectivity of fluridone for milfoil and certain other nuisance species has been demonstrated in many studies, there is apparently little documented experience with many of the plant species in Eagle Lake. Any information from monitoring plant species in any area treated might therefore be helpful to expand the database on fluridone effects.

**Table 1. Eagle Lake Submersed Vascular Plant Ranking According to Frequency of Occurrence and Species Susceptibility to Fluridone and Triclopyr.**

| Species [1] | West Basin Rank$_q$ [1] | East Basin Rank$_s$ [1] | Susceptibility to Fluridone [2] VTDEC | SePRO |
|---|---|---|---|---|
| Bidens beckii | 11 | 8 | | |
| Brasenia schreberi | ND | 16 | | I |
| Ceratophyllum demersum | 14 | 13 | S | S |
| Dulichium arudinaceum | ND | ND | | |
| Eleocharis acicularis | ND | ND | S/I | |
| Eleocharis palustris | ND | ND | | |
| Elodea canadensis | 8 | 11 | S | S |
| Eriocaulon septangulare | 15 | 17 | | |
| Heteranthera dubia | 12 | ND | | |
| Isoetes echinospora | ND | ND | | |
| Isoetes macrospora | ND | ND | | |
| Juncus pelocarpus | ND | ND | T | |
| Lobelia dortmanna | 13 | ND | | |
| Myriophyllum spicatum | 3 | 2 | S | S |
| Najas flexilis | 4 | 4 | S | |
| Nuphar luteum | ND | 18 | | I |
| Nymphaea odorata | ND | 10 | | I |
| Pontedaria cordata | ND | ND | | T |
| Potamogeton americanus | ND | ND | | |
| Potamogeton amplifolius | 5 | 12 | | |
| Potamogeton compressus | ND | ND | S | S |
| Potamogeton epihydrus | ND | ND | | |
| Potamogeton foliosus | ND | ND | S | S |
| Potamogeton gramineus | 7 | 9 | | |
| Potamogeton natans | ND | ND | S | S |
| Potamogeton perfoliatus | ND | ND | | |
| Potamogeton praelongus | 9 | 6 | | |
| Potamogeton pusillus | 6 | 5 | | |
| Potamogeton robbinsii | 2 | 3 | | |
| Potamogeton spirillus | ND | ND | | |
| Potamogeton vaseyii | ND | ND | | |
| Potamogeton zosterformis | ND | 14 | | |
| Sagittaria graminea | ND | 15 | | |
| Sparganium sp. | 16 | ND | | |
| Utricularia vulgaris | ND | ND | | |
| Vallisneria americana | 10 | 7 | S | T |
| **Macroalgae** | 1 | 2 | T | T |
| Chara sp. | | | | |
| Nitella sp. | | | | |

1 Adapted from *The Eagle Lake Baseline Aquatic Plant Monitoring report*. 1998. Rensselaer Fresh Water Institute.

2 Susceptibility Code: S=Susceptible, I=Intermediate, T=Tolerent

Rank$_q$ = rank based on cumulative % cover for west basin survey.

Rank$_s$ = rank based on cumulative % cover for east basin survey.

ND = not detected in 1998 Eagle Lake Aquatic Plant Survey of selected grid areas.

**Table 2. Sensitivity of Submerged Macrophyte Species to Sonar® Applied in Michigan Lakes. (Adapted from McLaren/Hart Environmental, 1995.)**

| Plant Species | Response During Year of Application | Response Following Year of Application |
|---|---|---|
| *Ceratophyllum demersum* | 4-5 | 2 |
| *Chara* and *Nitella* spp. | 1 | 2 |
| *Elodea canadensis* | 5 | 5 |
| *Heteranthera dubia* | 1 | 1 |
| *Myriophyllum sibiricum* | 5 | 3 |
| *Myriophyllum spicatum* | 5 | 0 |
| *Myriophyllum verticillatum* | 3 | 3 |
| *Najas* spp. | 4 | 2 |
| *Potamogeton amplifolius* | 3-4 | 2 |
| *Potamogeton crispus* | 5 | 1-5 |
| *Potamogeton illinoenis* | 3-4 | 2 |
| *Potamogeton pectinatus* | 4 | 1 |
| *Potamogeton robbinsii* | 1 | 3 |
| *Utricularia* spp. | 1 | 3 |
| *Vallisneria americana* | 2-5 | 3 |

Response During Year of Application

1 Production or Total Distribution Increased
2 Production or Total Distribution Slightly Increased
3 No Impact on Plant Production or Distribution
4 Production or Total Distribution Slightly Decreased
5 Production or Total Distribution Drastically Decreased

Response Following Year of Application

0 Production Virtually Eradicated by Previous Year Application
1 Production or Total Distribution Increased
2 Production or Total Distribution Slightly Increased
3 No Impact on Plant Production or Distribution
4 Production or Total Distribution Slightly Decreased
5 Production or Total Distribution Drastically Decreased

Sonar® is considered to have low toxicity to invertebrates, fish, other aquatic wildlife, and humans. It is not known to be a carcinogen, oncogen, mutagen or teratogen. Research on its degradation products initially suggested some possible effects, but further testing indicated no significant threat. Substantial bioaccumulation has been noted in certain plant species, but not to any great extent in animals. The USEPA has designated a tolerance level of 0.5 ppm (mg/l or mg/kg) for fluridone residues or those of its degradation products in fish or crayfish. The USEPA has set a tolerance limit of 0.15 ppm for fluridone or its degradation products in potable water. New York currently allows a maximum application rate of 0.05 mg/l (50 ppb) for Sonar® AS (liquid) and 0.15 mg/l (150 ppb) for Sonar® SRP (pellet).

Label restrictions for Sonar® AS include maintenance of a distance of one quarter mile (1320 ft) between treatment locations and potable water intakes for doses intended to result in concentrations of 20 ppb or more. However, there are no such restrictions on applications producing concentrations <20 ppb or on the use of treated water for potable purposes at concentrations <0.02 mg/l (20 ppb). There are no Federal label restrictions for non-potable uses of water treated with fluridone, including contact recreation, washing, and livestock watering. SePro suggests that effects from frequent irrigation are possible if concentrations exceed 10 ppb, but that effects from intermittent irrigation are unlikely at concentrations <20 ppb (Burns, pers. comm.). No major impact is expected from passage through septic systems, either on the microbes in the system or the soil microbes and plants with deep roots, mainly as a function of low expected concentration and known mode of action.

Beyond the Federal label restrictions, New York has added three restrictions:

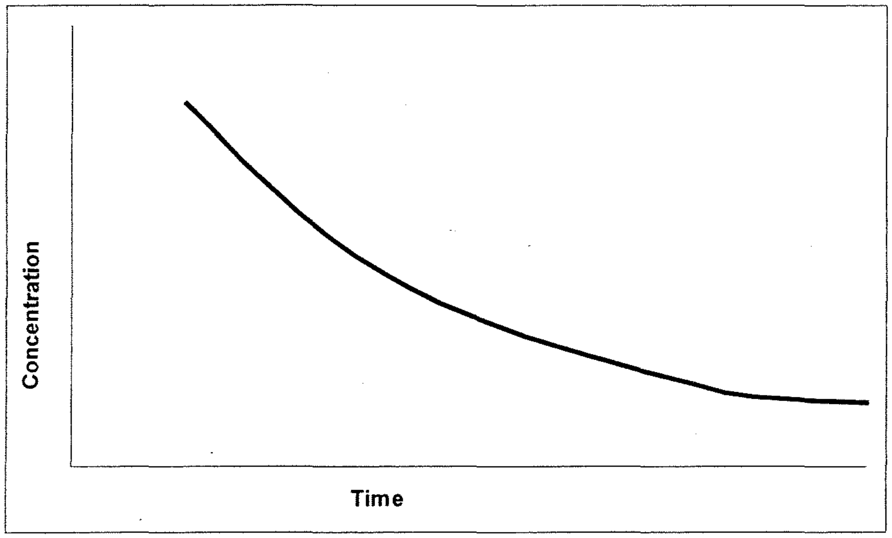
- Application is permitted at dosages equating to no more than 0.150 ppm, with an ambient concentration no greater than 0.05 ppm at any instant in time; this allows for slow release from pellets or sequential treatments with aqueous solutions
- Application of pellet formulations are permitted in water of no less than 2 ft of depth
- Swimming is prohibited in treated waters for 24 hours after application

Additionally, Sonar® AS is permitted only for the control of Eurasian watermilfoil, but as that is the target species in Eagle Lake, this is not an issue.

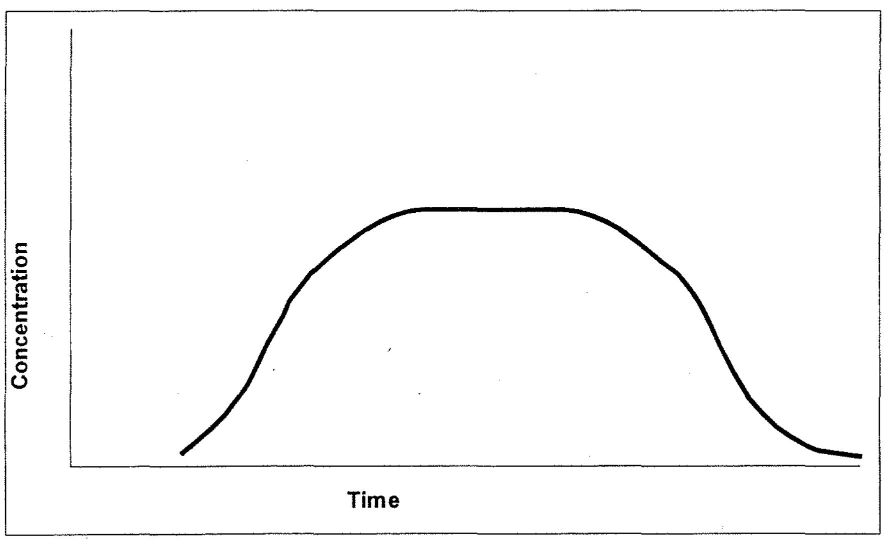
Eurasian watermilfoil has been controlled with Sonar® concentrations as low as 0.005 mg/l (5 ppb) in whole lake treatments, and doses above 0.02 mg/l (20 ppb) appear unnecessary as long as dilution is not a serious influence (Pullman, 1993; Netherland et al., 1997; Smith and Pullman, 1997). Many native species will survive these doses, which are well below the maximum of 0.05 mg/l (50 ppb) set for use in New York waters. Additionally, seeds are unaffected, and many of the desirable native species are seed-producing annuals. However, as fluridone works slowly, it is essential that an adequate concentration be maintained for multiple weeks. This presents a challenge to application where dilution effects are appreciable and the maximum allowable concentration is as limited as it is in New York.

The effectiveness of Sonar® AS will be limited by dilution (Figure 4A). Since the maximum allowable concentration is 0.05 mg/l, dilution by no more than tenfold and preferably no more than fivefold is needed. This has been a problem for small area treatments in larger water bodies,

**Figure 4: Conceptual Concentration of Two Forms of Fluridone Over Time After Treatment**




A: Sonar AS, a liquid formulation




B. Sonar SRP, slow release pellet formulation leading to the recommendation that Sonar® not be used to treat areas less than 5 acres unless the treated area includes the whole water body (i.e., ponds <5 acres). In order for a single Sonar® AS treatment to be most effective against milfoil, treated areas must have limited exchange of water during the critical period of herbicide-plant interaction (at least 20 and preferably 40 days).

Where dilution is a problematic factor, usually due to water exchange rates which are higher than desirable, Sonar® SRP has generally been the formulation of choice. Gradual release of fluridone, which is 5% of pellet content, can yield a relatively stable concentration (Figure 4B). The rate of release is partly dependent on the moisture content of the pellets, which is currently under study (Haller, pers. comm.), but release of nearly all fluridone from pellets is generally assumed to occur in about two weeks on average.

However, Sonar® SRP has been less effective in areas with highly organic, loose sediments than over sandy or otherwise firm substrates (Burns, pers. comm.; Canfield, pers. comm.). A phenomenon termed "plugging" has been observed, resulting in a failure of the active ingredient to be released from the pellet. While success in soft sediment areas has been achieved (ACT, 1994), this approach may be less efficient than the use of Sonar® AS in areas with extremely fine sediments.

A whole lake treatment is planned for Eagle Lake, as the entire littoral zone is impacted by milfoil. Sonar® AS is the formulation of choice in such a case, as long as overall flushing of the lake is limited. Although spring flushing can be substantial in Eagle Lake, it is possible to maintain the lake at a slightly lower level, then add flashboards to temporarily increase detention time during the treatment. No difficulty is currently expected in meeting the 40-day exposure time, but there are options for circumventing flushing problems.

Most treatments with Sonar® are conducted in the spring, when the milfoil is most actively growing. The physiological advantage of this time period is sometimes offset by the logistical disadvantage of higher flows and dilution effects during spring, however, and milfoil does continue to grow during summer and autumn and will take up the Sonar® during those seasons. In some cases, treatment has been postponed until summer or even autumn to minimize the volume of water that must be treated. Some successes have been achieved in this manner (ENSR, 1998b; Burns pers. comm.), and autumn treatments could be attempted at Eagle Lake. Treatment in early September, after the Labor Day holiday weekend, would limit interaction with summer lake users while providing adequate detention and exposure time for the herbicide to work. The greatest technical drawbacks of this approach are the greater biomass of milfoil that must be decomposed later in the season, and the potential for greater impacts to native plant species that are less abundant at the expected time of spring treatment. This is a more experimental approach, and would be preferred only if spring conditions were unsuitable or there was some financial incentive relating to research and development involving fluridone.

Alternatively, multiple low dose treatments with Sonar® AS have been successfully applied in areas where dilution could not be adequately controlled. Sequential treatment with Sonar® AS two to four times over a time period of up to a month, as needed to maintain a concentration near 0.01 mg/l (10 ppb), can mimic the action of slow release pellets. Sequential treatments may be in conflict with time restrictions for Eagle Lake, however, as treatment after the Memorial Day weekend is not preferred. There is no clear scientific basis for this date preference, merely an understandable desire to minimize risk. It may be necessary to treat through June for sequential treatments to be effective. Treatment should not begin before milfoil begins active growth, which can be as late as mid-May in Eagle Lake. It is expected, however, that a single application may be sufficient for Eagle Lake.

An immunoassay is available (Burns, pers. comm.) which allows field measurement of the fluridone concentration. This allows tracking of the fluridone concentration with additive treatment where and when necessary over a multi-week period. It is also possible to mimic the movement of fluridone with rhodamine dye, with additive treatments when the dye level declines below a set threshold indicative of the lowest desired concentration of fluridone.

Based on what is known of fluridone at this time, there appears to be negligible risk to human health or the aquatic environment from its appropriate use in Eagle Lake. There are a number of technical issues to be resolved, including the timing of treatment and how to handle possible dilution factors, but this herbicide appears to offer the features necessary to make it a valuable tool in the control of Eurasian watermilfoil in Eagle Lake.

Physical means are available to control milfoil as it is discovered in very small quantities, and to eliminate or reduce its presence in small patches of moderate to high density. However, there is not currently a tool in the management arsenal for Eagle Lake that would allow cost effective major reduction of milfoil over areas larger than about an acre at moderate to high densities. Fluridone offers this potential, and its use appears consistent with the goal of restoration of a healthy native plant assemblage in milfoil-infested areas of Eagle Lake.

The cost of fluridone treatments will vary with area treated, water depth, dose and the application mode. Experience elsewhere for areas >10 acres dictates a cost range of $400-750 for single treatments, exclusive of any special controls mandated by environmental constraints. Single treatments of smaller areas are expected to cost between $600 and $1500/acre, with multiple treatments resulting in costs of up to $2000/acre. Costs for educating residents regarding the treatments and for any preventive activities relating to water intakes are additional, and significant monitoring costs are anticipated.

The volume of water in Eagle Lake is slightly less than 10 billion liters. At a target concentration of 10-20 ug/L (ppb), 200 kg of active fluridone would be needed to achieve an initial concentration of 20 ppb. A dose of 100 kg would achieve the 10 ppb concentration that forms the lower limit of the target range.

However, if the treatment can be applied after stratification has set in, at least to a moderate degree, then the volume that will have to be treated would decrease to about 5 billion liters. This suggests a need for 100 kg of fluridone for a concentration of 20 ppb in the epilimnion of the lake. As the plants are in the littoral zone, which is in the epilimnion, the 100 kg dose is appropriate as long as mixing is limited to the epilimnion. If the lake is completely mixed at the time of treatment, the 100 kg fluridone treatment would produce a concentration of 10 ppb. This does not allow for much dilution or degradation, but is still an acceptable concentration for the control of milfoil.

A smaller dose could be applied if the fluridone could be restricted to the peripheral area where the water is shallow enough to support rooted plant growths, but the highly soluble and diffusive nature of fluridone makes such containment difficult without extensive curtains or other barriers to movement. The SRP formulation would allow release in the peripheral (littoral) zone, but rapid mixing with the rest of the lake would minimize exposure to concentrations sufficient to kill the milfoil.

Therefore, an initial dose of 100 kg as fluridone in the AS formulation is desirable, preferably at a time after stratification has begun to set in. If stratification has not begun, a dose of between 100 and 200 kg of fluridone will be needed. The treatment sequence as currently envisioned would involve the following steps:

- Maintain the lake at a level at least 1 ft below the normal spring level by not replacing all flashboards in the outlet after winter drawdown.
- At the start of the treatment period, replace the flashboards to hold water until the lake regains its normal spring level.
- Measure the temperature profile of the lake to ascertain the status of stratification.
- Post the area for use limitations.
- Add 100 to 200 kg of fluridone (active ingredient) in the AS formulation (based on degree of stratification and volume into which fluridone will be mixed) to the lake.
- Monitor the fluridone level after one week, three weeks and six weeks at 6 or more sites in the lake (including the 2 plant monitoring sites in the RPI monitoring program – see Appendix).
- If the fluridone level declines below 10 ppb as an average of the two stations at any time during the first 3 weeks, add enough fluridone as the AS formulation to raise the concentration to 15 ppb.
- Remove the postings after 6 weeks of treatment.

## ALTERNATIVES ANALYSIS

There are basically seven general approaches to the control of rooted aquatic plants, each of which has potential advantages and drawbacks that must be considered in each possible application scenario. Subdivision of these seven approaches provides a considerably longer list of detailed methods (Table 3), but the seven basic approaches remain evident. After a description of the "No Action" alternative, each plant management approach is outlined and its applicability to the Eagle Lake milfoil problem is discussed in the following sections.

### No Action Alternative

Eurasian watermilfoil (milfoil) has not been managed in many of the waterbodies in which it occurs, mostly out of neglect, but in some cases by intent. In its early to middle stages of colonization, milfoil can provide habitat structure of some value to aquatic life forms such as fish and macroinvertebrates, at least in contrast to the absence of plants (Pardue and Webb, 1985; Kilgore et al., 1989). Compared to many native species, however, the value of milfoil is inferior, and its tendency to form very dense growths limits its habitat value in later stages of colonization (Keast, 1984; Nichols and Shaw, 1986). Allowing milfoil to grow uncontrolled has resulted in damage to the native assemblage in most lakes (Madsen et al., 1991). Additionally, there is distinct potential for uncontrolled milfoil to provide a source of this plant for other, uninfested lakes in the region. If Eurasian milfoil infestation can be considered analogous to a disease, the no action alternative represents a failure to take action against a communicable disease among lakes.

In cases where milfoil has been monitored but no action taken, high densities of this plant are typically achieved within a decade (Carpenter, 1980). Expansion throughout the infested lake can occur in as little as 2 years (Wagner, pers. obs.), although colonization of all available areas in a very large lake could be expected to take much longer. Once dominant, milfoil populations appear to fluctuate in an unstable pattern, and in some cases milfoil has declined substantially for uncertain reasons after reaching peak densities in northern lakes (Carpenter, 1980; Painter and McCabe, 1988; Smith and Barko, 1990; Sheldon, 1995a). Smaller scale or temporary declines have been noted in many northern areas (Kimbel, 1982; Nichols and Shaw, 1983; Pullman, 1992). It has been speculated that observed milfoil declines are linked to factors including nutrient depletion, decreased light availability, insect or pathogen attacks, or unauthorized use of herbicides (Carpenter, 1980; Sheldon, 1995a). Insect herbivory has been of great interest in these declines, but despite substantial research in this regard, insect effects remain unpredictable.

The no action alternative is not a sound strategy for Eagle Lake. Lack of action in the mid- to late 1980's resulted in considerable expansion of milfoil coverage. Natural declines are not expected before nuisance densities over a large area are reached, and are then unpredictable and not at all guaranteed. The native plant assemblage of Eagle Lake provides far more habitat value than could any stage of milfoil growth, and reductions in the native plant assemblage have already been observed in Eagle Lake. No benefits, and considerable negative consequences, are expected under the no action alternative.

## TABLE 3. MANAGEMENT OPTIONS FOR CONTROL OF ROOTED AQUATIC PLANTS

| OPTION | MODE OF ACTION | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|
| **Physical Controls**<br>1) Benthic barriers | ♦ Mat of variable composition laid on bottom of target area, preventing plant growth<br>♦ Can cover area for as little as several months or permanently<br>♦ Maintenance improves effectiveness<br>♦ Not often intended for use in large areas, usually applied around docks, in boating lanes, and in swimming areas | ♦ Highly flexible control<br>♦ Reduces turbidity from soft bottoms<br>♦ Can cover undesirable substrate<br>♦ Can improve fish habitat by creating edge effects | ♦ May cause anoxia at sediment-water interface<br>♦ May limit benthic invertebrates<br>♦ Non-selective interference with plants in target area<br>♦ May inhibit spawning/feeding by some fish species |
| 1.a) Porous or loose-weave synthetic materials | ♦ Laid on bottom and usually anchored by sparse weights or stakes<br>♦ Removed and cleaned or flipped and repositioned at least once per year for maximum effectiveness | ♦ Allows some escape of gases which may build up underneath<br>♦ Panels may be flipped in place or removed for relatively easy cleaning or repositioning | ♦ Allows some growth through pores<br>♦ Gas may still build up underneath in some cases, lifting barrier from bottom |
| 1.b) Non-porous or sheet synthetic materials | ♦ Laid on bottom and anchored by many stakes, anchors or weights, or by layer of sand<br>♦ Not typically removed, but may be swept or "blown" clean periodically | ♦ Prevents all plant growth until buried by sediment<br>♦ Minimizes interaction of sediment and water column | ♦ Gas build up may cause barrier to float upwards<br>♦ Strong anchoring makes removal difficult and can hinder maintenance |

## TABLE 3. MANAGEMENT OPTIONS FOR CONTROL OF ROOTED AQUATIC PLANTS

| OPTION | MODE OF ACTION | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|
| 1.c) Sediments of a desirable composition | ♦ Sediments may be added on top of existing sediments or plants.<br>♦ Use of sand or clay can limit plant growths and alter sediment-water interactions.<br>♦ Sediments can be applied from the surface or suction dredged from below muck layer (reverse layering technique) | ♦ Plant biomass can be buried<br>♦ Seed banks can be buried deeper<br>♦ Sediment can be made less hospitable to plant growths<br>♦ Nutrient release from sediments may be reduced<br>♦ Surface sediment can be made more appealing to human users<br>♦ Reverse layering requires no addition or removal of sediment | ♦ Lake depth may decline<br>♦ Sediments may sink into or mix with underlying muck<br>♦ Permitting for added sediment may be difficult<br>♦ Addition of sediment may cause initial turbidity increase<br>♦ New sediment may contain nutrients or other contaminants<br>♦ Generally too expensive for large scale application |
| 2) Dredging | ♦ Sediment is physically removed by wet or dry excavation, with deposition in a containment area for dewatering/disposal<br>♦ Dredging can be applied on a limited basis, but is most often a major restructuring of a severely impacted system<br>♦ Plants and seed beds are removed and re-growth can be limited by light and/or substrate limitation | ♦ Plant removal with some flexibility<br>♦ Increases water depth<br>♦ Can reduce pollutant reserves<br>♦ Can reduce sediment oxygen demand<br>♦ Can improve spawning habitat for many fish species<br>♦ Allows complete renovation of aquatic ecosystem | ♦ Temporarily removes benthic invertebrates<br>♦ May create turbidity<br>♦ May eliminate fish community (complete dry dredging only)<br>♦ Possible impacts from containment area discharge<br>♦ Possible impacts from dredged material disposal<br>♦ Interference with recreation or other uses during dredging<br>♦ Usually very expensive |
| 2.a) "Dry" excavation | ♦ Lake drained or lowered to maximum extent practical<br>♦ Target material dried to maximum extent possible<br>♦ Conventional excavation equipment used to remove sediments | ♦ Tends to facilitate a very thorough effort<br>♦ May allow drying of sediments prior to removal<br>♦ Allows use of less specialized equipment | ♦ Eliminates most aquatic biota unless a portion left undrained<br>♦ Eliminates lake use during dredging |

## TABLE 3. MANAGEMENT OPTIONS FOR CONTROL OF ROOTED AQUATIC PLANTS

| OPTION | MODE OF ACTION | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|
| 2.b) "Wet" excavation | ♦ Lake level may be lowered, but sediments not substantially dewatered<br>♦ Draglines, bucket dredges, or long-reach backhoes used to remove sediment | ♦ Requires least preparation time or effort, tends to be least cost dredging approach<br>♦ May allow use of easily acquired equipment<br>♦ May preserve most aquatic biota | ♦ Usually creates extreme turbidity<br>♦ Tends to result in sediment deposition in surrounding area<br>♦ Normally requires intermediate containment area to dry sediments prior to hauling<br>♦ May cause severe disruption of ecological function<br>♦ Usually eliminates most lake uses during dredging |
| 2.c) Hydraulic removal | ♦ Lake level not reduced<br>♦ Suction or cutterhead dredges create slurry which is hydraulically pumped to containment area<br>♦ Slurry is dewatered; sediment retained, water discharged | ♦ Creates minimal turbidity and limits impact on biota<br>♦ Can allow some lake uses during dredging<br>♦ Allows removal with limited access or shoreline disturbance | ♦ Often leaves some sediment behind<br>♦ Cannot handle extremely coarse or debris-laden materials<br>♦ Requires sophisticated and more expensive containment area<br>♦ Requires overflow discharge from containment area |
| 3) Dyes and surface covers | ♦ Water-soluble dye is mixed with lake water, thereby limiting light penetration and inhibiting plant growth<br>♦ Dyes remain in solution until washed out of system.<br>♦ Opaque sheet material applied to water surface | ♦ Light limit on plant growth without high turbidity or great depth<br>♦ May achieve some control of algae as well<br>♦ May achieve some selectivity for species tolerant of low light | ♦ May not control peripheral or shallow water rooted plants<br>♦ May cause thermal stratification in shallow ponds<br>♦ May facilitate anoxia at sediment interface with water<br>♦ Covers inhibit gas exchange with atmosphere |

## TABLE 3. MANAGEMENT OPTIONS FOR CONTROL OF ROOTED AQUATIC PLANTS

| OPTION | MODE OF ACTION | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|
| 4) Mechanical removal | ♦ Plants reduced by mechanical means, possibly with disturbance of soils<br>♦ Collected plants may be placed on shore for composting or other disposal<br>♦ Wide range of techniques employed, from manual to highly mechanized<br>♦ Application once or twice per year usually needed | ♦ Highly flexible control<br>♦ May remove other debris<br>♦ Can balance habitat and recreational needs | ♦ Possible impacts on aquatic fauna<br>♦ Non-selective removal of plants in treated area<br>♦ Possible spread of undesirable species by fragmentation<br>♦ Possible generation of turbidity |
| 4.a) Hand pulling | ♦ Plants uprooted by hand ("weeding") and preferably removed | ♦ Highly selective technique | ♦ Labor intensive |
| 4.b) Cutting (without collection) | ♦ Plants cut in place above roots without being harvested | ♦ Generally efficient and less expensive than complete harvesting | ♦ Leaves root systems and part of plant for re-growth<br>♦ Leaves cut vegetation to decay or to re-root<br>♦ Not selective within applied area |
| 4.c) Harvesting (with collection) | ♦ Plants cut at depth of 2-10 ft and collected for removal from lake | ♦ Allows plant removal on greater scale | ♦ Limited depth of operation<br>♦ Usually leaves fragments which may re-root and spread infestation<br>♦ May impact lake fauna<br>♦ Not selective within applied area<br>♦ More expensive than cutting |
| 4.d) Rototilling | ♦ Plants, root systems, and surrounding sediment disturbed with mechanical blades | ♦ Can thoroughly disrupt entire plant | ♦ Usually leaves fragments which may re-root and spread infestation<br>♦ May impact lake fauna<br>♦ Not selective within applied area<br>♦ Creates substantial turbidity<br>♦ More expensive than harvesting |

## TABLE 3. MANAGEMENT OPTIONS FOR CONTROL OF ROOTED AQUATIC PLANTS

| OPTION | MODE OF ACTION | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|
| 4.e) Hydroraking | ♦ Plants, root systems and surrounding sediment and debris disturbed with mechanical rake, part of material usually collected and removed from lake | ♦ Can thoroughly disrupt entire plant<br>♦ Also allows removal of stumps or other obstructions | ♦ Usually leaves fragments which may re-root and spread infestation<br>♦ May impact lake fauna<br>♦ Not selective within applied area<br>♦ Creates substantial turbidity<br>♦ More expensive than harvesting |
| 5) Water level control | ♦ Lowering or raising the water level to create an inhospitable environment for some or all aquatic plants<br>♦ Disrupts plant life cycle by dessication, freezing, or light limitation | ♦ Requires only outlet control to affect large area<br>♦ Provides widespread control in increments of water depth<br>♦ Complements certain other techniques (dredging, flushing) | ♦ Potential issues with water supply<br>♦ Potential issues with flooding<br>♦ Potential impacts to non-target flora and fauna |
| 5.a) Drawdown | ♦ Lowering of water over winter period allows desiccation, freezing, and physical disruption of plants, roots and seed beds<br>♦ Timing and duration of exposure and degree of dewatering are critical aspects<br>♦ Variable species tolerance to drawdown; emergent species and seed-bearers are less affected<br>♦ Most effective on annual to once/3 yr. basis | ♦ Control with some flexibility<br>♦ Opportunity for shoreline clean-up/structure repair<br>♦ Flood control utility<br>♦ Impacts vegetative propagation species with limited impact to seed producing populations | ♦ Possible impacts on contiguous emergent wetlands<br>♦ Possible effects on overwintering reptiles and amphibians<br>♦ Possible impairment of well production<br>♦ Reduction in potential water supply and fire fighting capacity<br>♦ Alteration of downstream flows<br>♦ Possible overwinter water level variation<br>♦ Possible shoreline erosion and slumping<br>♦ May result in greater nutrient availability for algae |

## TABLE 3. MANAGEMENT OPTIONS FOR CONTROL OF ROOTED AQUATIC PLANTS

| OPTION | MODE OF ACTION | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|
| 5.b) Flooding | ♦ Higher water level in the spring can inhibit seed germination and plant growth<br>♦ Higher flows which are normally associated with elevated water levels can flush seed and plant fragments from system | ♦ Where water is available, this can be an inexpensive technique<br>♦ Plant growth need not be eliminated, merely retarded or delayed<br>♦ Timing of water level control can selectively favor certain desirable species | ♦ Water for raising the level may not be available<br>♦ Potential peripheral flooding<br>♦ Possible downstream impacts<br>♦ Many species may not be affected, and some may be benefitted<br>♦ Algal nuisances may increase where nutrients are available |
| **Chemical controls**<br>6) Herbicides | ♦ Liquid or pelletized herbicides applied to target area or to plants directly<br>♦ Contact or systemic poisons kill plants or limit growth<br>♦ Typically requires application every 1-5 yrs | ♦ Wide range of control is possible<br>♦ May be able to selectively eliminate species<br>♦ May achieve some algae control as well | ♦ Possible toxicity to non-target species of plants/animals<br>♦ Possible downstream impacts; may affect non-target areas within pond<br>♦ Restrictions of water use for varying time after treatment<br>♦ Increased oxygen demand from decaying vegetation<br>♦ Possible recycling of nutrients to allow other growths |
| 6.a) Forms of copper | ♦ Contact herbicide<br>♦ Cellular toxicant, suspected membrane transport disruption<br>♦ Applied as wide variety of liquid or granular formulations, often in conjunction with polymers or other herbicides | ♦ Moderately effective control of some submersed plant species<br>♦ More often an algal control agent | ♦ Toxic to aquatic fauna as a function of concentration, formulation, and ambient water chemistry<br>♦ Ineffective at colder temperatures<br>♦ Copper ion persistent; accumulates in sediments or moves downstream |

## TABLE 3. MANAGEMENT OPTIONS FOR CONTROL OF ROOTED AQUATIC PLANTS

| OPTION | MODE OF ACTION | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|
| 6.b) Forms of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) | ♦ Contact herbicide with limited translocation potential<br>♦ Membrane-active chemical which inhibits protein synthesis<br>♦ Causes structural deterioration<br>♦ Applied as liquid or granules | ♦ Moderate control of some emersed plant species, moderately to highly effective control of floating and submersed species<br>♦ Limited toxicity to fish at recommended dosages<br>♦ Rapid action | ♦ Non-selective in treated area<br>♦ Toxic to aquatic fauna (varying degrees by formulation)<br>♦ Time delays on use for water supply, agriculture and recreation<br>♦ Safety hazards for applicators |
| 6.c) Forms of diquat (6,7-dihydropyrido [1,2-2',1'-c] pyrazinediium dibromide) | ♦ Contact herbicide<br>♦ Absorbed by foliage but not roots<br>♦ Strong oxidant; disrupts most cellular functions<br>♦ Applied as a liquid, sometimes in conjunction with copper | ♦ Moderate control of some emersed plant species, moderately to highly effective control of floating or submersed species<br>♦ Limited toxicity to fish at recommended dosages<br>♦ Rapid action | ♦ Non-selective in treated area<br>♦ Toxic to zooplankton at recommended dosage<br>♦ Inactivated by suspended particles; ineffective in muddy waters<br>♦ Time delays on use for water supply, agriculture and recreation |
| 6.d) Forms of glyphosate (N-[phosphonomethyl glycine) | ♦ Contact herbicide<br>♦ Absorbed through foliage, disrupts enzyme formation and function in uncertain manner<br>♦ Applied as liquid spray | ♦ Moderately to highly effective control of emersed and floating plant species<br>♦ Can be used selectively, based on application to individual plants<br>♦ Rapid action<br>♦ Low toxicity to aquatic fauna at recommended dosages<br>♦ No time delays for use of treated water | ♦ Non-selective in treated area<br>♦ Inactivation by suspended particles; ineffective in muddy waters<br>♦ Not for use within 0.5 miles of potable water intakes<br>♦ Highly corrosive; storage precautions necessary |

## TABLE 3. MANAGEMENT OPTIONS FOR CONTROL OF ROOTED AQUATIC PLANTS

| OPTION | MODE OF ACTION | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|
| 6.e) Forms of 2,4-D (2,4-dichlorophenoxyl acetic acid) | ♦ Systemic herbicide<br>♦ Readily absorbed and translocated throughout plant<br>♦ Inhibits cell division in new tissue, stimulates growth in older tissue, resulting in gradual cell disruption<br>♦ Applied as liquid or granules, frequently as part of more complex formulations, preferably during early growth phase of plants | ♦ Moderately to highly effective control of a variety of emersed, floating and submersed plants<br>♦ Can achieve some selectivity through application timing and concentration<br>♦ Fairly fast action | ♦ Variable toxicity to aquatic fauna, depending upon formulation and ambient water chemistry<br>♦ Time delays for use of treated water for agriculture and recreation<br>♦ Not for use in water supplies |
| 6.f) Forms of fluridone (1-methyl-3-phenyl-5-[-3-{trifluoromethyl} phenyl]-4[IH]-pyridinone) | ♦ Systemic herbicide<br>♦ Inhibits carotenoid pigment synthesis and impacts photosynthesis<br>♦ Best applied as liquid or granules during early growth phase of plants | ♦ Can be used selectively, based on concentration<br>♦ Gradual deterioration of affected plants limits impact on oxygen level (BOD)<br>♦ Effective against several difficult-to-control species<br>♦ Low toxicity to aquatic fauna | ♦ Impacts on non-target plant species possible at higher doses<br>♦ Extremely soluble and mixable; difficult to perform partial lake treatments<br>♦ Requires extended contact time |
| 6.g Forms of triclopyr (3,5,6-trichloro-2-pyridinyloxyacetic acid) | ♦ Systemic herbicide, registered for experimental aquatic use by cooperators in selected areas only at this time<br>♦ Readily absorbed by foliage, translocated throughout plant<br>♦ Disrupts enzyme systems specific to plants<br>♦ Applied as liquid spray or subsurface injected liquid | ♦ Effectively controls many floating and submersed plant species<br>♦ Can be used selectively, more effective against dicot plant species, including many nuisance species<br>♦ Effective against several difficult-to-control species<br>♦ Low toxicity to aquatic fauna<br>♦ Fast action | ♦ Impacts on non-target plant species possible at higher doses<br>♦ Current time delay of 30 days on consumption of fish from treated areas<br>♦ Necessary restrictions on use of treated water for supply or recreation not yet certain |

## TABLE 3. MANAGEMENT OPTIONS FOR CONTROL OF ROOTED AQUATIC PLANTS

| OPTION | MODE OF ACTION | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|
| **Biological Controls**<br>7) Biological introductions | ♦ Fish, insects or pathogens which feed on or parasitize plants are added to system to affect control<br>♦ The most commonly used organism is the grass carp, but the larvae of several insects have been used more recently, and viruses are being tested | ♦ Provides potentially continuing control with one treatment<br>♦ Harnesses biological interactions to produce desired conditions<br>♦ May produce potentially useful fish biomass as an end product | ♦ Typically involves introduction of non-native species<br>♦ Effects may not be controllable<br>♦ Plant selectivity may not match desired target species<br>♦ May adversely affect indigenous species |
| 7.a) Herbivorous fish | ♦ Sterile juveniles stocked at density which allows control over multiple years<br>♦ Growth of individuals offsets losses or may increase herbivorous pressure | ♦ May greatly reduce plant biomass in single season<br>♦ May provide multiple years of control from single stocking<br>♦ Sterility intended to prevent population perpetuation and allow later adjustments | ♦ May eliminate all plant biomass, or impact non-target species more than target forms<br>♦ Funnels energy into largely unused fish biomass and algae<br>♦ May drastically alter habitat<br>♦ May escape to new habitats upstream or downstream<br>♦ May not always be sterile; population control uncertain |
| 7.b) Herbivorous insects | ♦ Larvae or adults stocked at density intended to allow control with limited growth<br>♦ Intended to selectively control target species<br>♦ Milfoil weevil is best known, but still experimental | ♦ Involves species native to region, or even targeted lake<br>♦ Expected to have no negative effect on non-target species<br>♦ May facilitate longer term control with limited management | ♦ Population ecology suggests incomplete control likely<br>♦ Oscillating cycle of control and re-growth likely<br>♦ Predation by fish may complicate control<br>♦ Other lake management actions may interfere with success |

## TABLE 3. MANAGEMENT OPTIONS FOR CONTROL OF ROOTED AQUATIC PLANTS

| OPTION | MODE OF ACTION | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|
| 7.c) Fungal/bacterial/viral pathogens | ♦ Inoculum used to seed lake or target plant patch<br>♦ Growth of pathogen population expected to achieve control over target species | ♦ May be highly species specific<br>♦ May provide substantial control after minimal inoculation effort | ♦ Largely experimental; effectiveness and longevity of control not well known<br>♦ Infection ecology suggests incomplete control likely<br>♦ Possible side effects not well understood |
| 7.d) Selective plantings | ♦ Establishment of plant assemblage resistant to undesirable species<br>♦ Plants introduced as seeds, cuttings or whole plants | ♦ Can restore native assemblage<br>♦ Can encourage assemblage most suitable to lake uses<br>♦ Supplements targeted species removal techniques | ♦ Largely experimental at this time; few well documented cases<br>♦ Nuisance species may eventually outcompete established assemblage<br>♦ Introduced species may become nuisances |

## Benthic Barriers

The use of benthic barriers, or bottom covers, is predicated upon the principles that rooted plants require light and can not grow through physical barriers. Applications of clay, silt, sand, and gravel have been used for many years, although plants often root in these covers eventually, and current environmental regulations make it difficult to gain approval for such fill deposition. An exception may exist in the reverse layering technique (KVA, 1991), in which sand is pumped from underneath a muck or silt layer and deposited as a new layer on top of the muck or silt. This is technically a re-organizing of the sediments, not new filling. Although expensive on a large scale and not applicable where the muck is not underlain by suitable materials, this technique restores the natural lake bottom of some previous time without sediment removal.

Artificial sediment covering materials, including polyethylene, polypropylene, fiberglass, and nylon, have been developed over the last three decades. A variety of solid and porous forms have been used. Manufactured benthic barriers are negatively buoyant materials, usually in sheet form, which can be applied on top of plants to limit light, physically disrupt growth, and allow unfavorable chemical reactions to interfere with further development of plants (Perkins et al., 1980).

In theory, benthic barriers should be a highly effective plant control technique, at least on a localized, area-selective scale. In practice, however, there have been many difficulties in the deployment and maintenance of benthic barriers, limiting their utility in the broad range of field conditions. Benthic barriers can be effectively used in small areas such as dock spaces and swimming beaches to completely terminate plant growth. The creation of access lanes and structural habitat diversity is also practical. Large areas are not often treated, however, because the cost of materials and application is high and maintenance can be problematic (Engel, 1984).

Benthic barrier problems of prime concern include long-term integrity of the barrier, billowing caused by trapped gases, accumulation of sediment on top of barriers, and growth of plants on porous barriers. Additionally, benthic barriers are non-selective, killing all plants over which they are applied. Oxygen depression and related chemical changes under the barrier result in reductions in the density and diversity of the benthic invertebrate community, but recovery is rapid once the barrier is removed (Ussery et al., 1997). One final problem is the tendency of products to come and go without much stability in the market. Few of the barrier materials on the market at any time continue to be available for more than 5 to 10 years; most need to be made in bulk to keep costs down, yet cost remains high enough to hinder demand and reduce bulk use.

Successful use is related to selection of materials and the quality of the application. As a result of field experience with benthic barriers in many lakes, including Lake George, several guidelines can be offered:

- Porous barriers will be subject to less billowing, but will allow settling plant fragments to root and grow; annual maintenance is therefore essential
- Solid barriers will generally prevent rooting in the absence of sediment accumulations, but will billow after enough gases accumulate; venting and strong anchoring are essential in most cases
- Plants under the barrier will usually die completely after about a month, with solid barriers more effective than porous ones in killing the whole plant; barriers of sufficient tensile strength can then be moved to a new location, although continued presence of solid barriers restricts recolonization.

Proper application requires that the screens be placed flush with the sediment surface and staked or securely anchored. This may be difficult to accomplish over dense plant growth, and a winter drawdown can provide an ideal opportunity for application. Late spring application has also been effective, however, despite the presence of plant growths at that time, and barriers applied in early May have been removed in mid-June with no substantial plant growth through the summer (Wagner, 1991). Scuba divers normally apply the covers in deeper water, which greatly increases labor costs. Bottom barriers will accumulate sediment deposits in most cases, which allows plant fragments to root. Barriers must then be cleaned, necessitating either removal or laborious in-place maintenance.

Recolonization of plants following benthic barrier application and removal in two swimming areas in Great Pond, Massachusetts, has also been studied (Wagner, 1991). These applications were for the purpose of improving swimming safety, and did not involve control of any invasive non-native species. In one swimming area, a plant community not differentiable from the original assemblage was restored mainly from seed germination within one to two years after barrier removal. Only one new species was detected, a native plant found in neighboring ponds, and then only as a very minor component of the post-treatment plant community. In the other swimming area, foot traffic in sections which were considered unusable prior to treatment resulted in continued minimal plant growth.

The ability of milfoil fragments to recolonize porous (mesh) benthic barriers has made porous barriers less useful for combating infestations by milfoil on any but the smallest scale, as sheets must be removed and cleaned at least yearly. Solid barriers have been more useful, although gas entrapment has been troublesome; billowing occurs without venting and anchoring, yet appropriate venting and anchoring creates problems for eventual maintenance or redeployment. Expense dictates that only limited areas be treated without re-use of deployed barrier. Nevertheless, benthic barriers are capable of providing control of milfoil on at least a localized basis (Engel, 1984; Perkins et al., 1980;, Helsel et al., 1996), and have such desirable side benefits as creating more edge habitat within dense plant assemblages and minimizing turbidity generation from fine bottom sediments.

Benthic barriers have been used at Lake George since 1986, with some success. However, benthic barriers have not eliminated milfoil and have not stopped its spread to new locations within the lake. Study of recolonization of areas of Lake George where benthic barriers have been removed (Eichler et al., 1995) reveals that both native species and milfoil were found to colonize exposed areas, but that milfoil dominance was not regained for at least two growing seasons. However, milfoil recolonization was not completely prevented in most cases. In Lake George, cover by plants was sparse for at least the first month after removal of the barrier and did not typically exceed 74% after two growing seasons, providing ample opportunity for milfoil invasion.

Actual barrier cost averaged $\$2.58/m^2$, or $\$0.24/ft^2$, but related supplies (mainly anchor weights) and labor costs raised this figure to $\$6.91/m^2$, or $\$0.64/ft^2$. This suggests a cost of almost $28,000/acre for first time benthic barrier application and about $18,000/acre for redeployment. This is a greater cost than typically cited (e.g., NYSDEC, 1990), but is lower than current estimates for commercial installations. Current (1999) costs for these materials are presented in Table 4, and suggest a cost per acre of between $35,000-41,000/acre for initial purchase and deployment and around $22,000/acre for redeployment. Bulk purchase and use of local labor could decrease costs to a level near the 1991 values reported above.

**Table 4. Current Costs[1] for Available Benthic Barriers**

| Type of Material | Material Cost ($/sq. ft.) | Anchoring & Installation ($/sq. Ft.) | Total Cost ($/sq. ft.) |
|---|---|---|---|
| Aqua Net™ - PVC coated fiberglass | $0.35 | $0.50 | $0.85 |
| EPDM - non-porous pond liner (4.5 mil) | $0.45 | $0.50 | $0.95 |
| Texel™ - Polyester geotextile (needle punched) | $0.30 | $0.50 | $0.80 |

[1] Retail costs assuming professional diver installation. Costs may be substantially less for large installation or use of local, less costly labor.

Dartek is no longer commercially available. Aquascreen is also no longer commercially available, but a very similar mesh product, Aqua Net™, is now on the market. Palco Pond Liner is now handled by a different supplier, but can be obtained as EPDM Liner. An additional product, Texel™, is a felt-like sheeting material that is potentially applicable and is slightly less costly than the other materials, but it is not easily movable once installed.

Based on experience at Lake George and what is known about benthic barriers in general, the application of solid barriers such as Palco Pond Liner is useful in controlling small (<1 acre) beds of milfoil where the material is left in place and where effort is expended on removing any peripheral growths of milfoil. Redeployment of barrier will reduce the overall cost of this approach and is consistent with the goal of restoring a native plant assemblage to areas infested with milfoil, but is likely to require additional effort at the original application site to prevent recolonization by milfoil. Such effort might include hand harvesting of milfoil for at least two growing seasons after removal of the barrier, or might involve augmentation of the native population in the formerly covered area.

Benthic barriers might prove useful at Eagle Lake once the milfoil infestation is brought under control, to limit future growths. However, at present milfoil coverage, this technique would be prohibitively expensive and time consuming. It is highly unlikely that the rate of milfoil colonization could be kept in check in treated areas while other areas were being treated with benthic barriers.

**Dredging Approaches**

Dredging works as a plant control technique when either a light limitation on growth is imposed through increased water depth or when enough "soft" sediment (muck, clay, silt and fine sand) is removed to reveal a less hospitable substrate (typically rock, gravel or coarse sand). The only exception may be suction dredging, whereby a target species can be reduced or possibly eliminated by removing whole plants and any associated seed banks. Suction dredging might more appropriately be considered a form of harvesting, however, as plants are extracted from the bottom by SCUBA divers operating the suction dredge and sediment is often returned to the lake. Extensive reviews of dredging by Peterson (1981) and Cooke et al. (1993) are available, but there are some specific considerations relating to rooted plant control which warrant mention.

The amount of sediment removed, and hence the new depth and associated light penetration, is critical to successful long-term control of rooted, submerged plants. There appears to be a direct relation between water transparency, as determined with a Secchi disk, and the maximum depth of colonization (MDC) by macrophytes. Canfield et al. (1985) provided equations to estimate MDC in Florida and Wisconsin from Secchi disk measurements:

| State | Equation |
|---|---|
| Florida | $\log MDC = 0.42 \log SD + 0.41$ |
| Wisconsin | $\log MDC = 0.79 \log SD + 0.25$ |

where SD = Secchi depth in meters

Partial deepening may limit the amount of vegetation that reaches the surface, but may also favor species tolerant of low light, some of which are non-native species with high nuisance potential, such as hydrilla and several species of milfoil. Where funding is insufficient to remove all soft sediment, it is more important to create a depth or substrate limitation in part of the lake than to remove some sediment from all target areas of the lake, if rooted plant control is the primary objective of dredging.

If the soft sediment accumulations that are supporting rooted plant nuisances are not especially thick, it may be possible to create a substrate limitation before a light-limiting depth is reached. If dredging exposes rock ledge or cobble, and all soft sediment can be removed, there will be little rooted plant growth. Yet such circumstances are rare to non-existent; either the sediments grade slowly into coarser materials, or it is virtually impossible to remove all fine sediments from the spaces around the rock or cobble. Consequently, some degree of regrowth is to be expected when light penetrates to the bottom. With successful dredging, this regrowth may be only 25% of the pre-dredging density or coverage, and will not contain more recently invading species at a dominant level. Yet some rooted plant regrowth is expected, and is indeed desirable for proper ecological function of the lake as a habitat and for processing of future pollutant inputs.

Experience with dredging for rooted plant control has had mixed results. Failures are invariably linked to incomplete pre-dredging assessment and planning. Control through light limitation appears more successful than control through substrate limitation, largely as a function of the difficulty of removing all soft sediment from shallow areas. Dry dredging projects appear to result in more thorough soft sediment removal, mainly because equipment operators can visually observe the results of dredging as it takes place. Hydraulic dredging in areas with dense weed beds can result in frequent clogging of the pipeline to the slurry discharge area, suggesting the need for some form of temporary plant control (most often herbicides or harvesting) prior to hydraulic dredging.

Dredging can be accomplished by multiple methods that can be conveniently grouped into four categories:

- Dry excavation, in which the lake is drained to the extent possible, the sediments are dewatered by gravity and/or pumping, and sediments are removed with conventional excavation equipment such as backhoes, bulldozers, or draglines.
- Wet excavation, in which the lake is not drained or only partially drawn down (to minimize downstream flows), with excavation of wet sediments by various bucket dredges mounted on cranes or amphibious excavators.
- Hydraulic dredging, requiring a substantial amount of water in the lake to float the dredge and provide a transport medium for sediment. Hydraulic dredges are typically equipped with a cutterhead which loosens sediments that are then mixed with water and transported as a pumped slurry of 80 to 90% water and 10 to 20% solids through a pipeline that traverses the lake from the dredging site to a disposal area.
- Pneumatic dredging, in which air pressure is used to pump sediments out of the lake at a higher solids content (reported as 50 to 70%). This would seem to be a highly desirable approach, given containment area limitation in many cases and more rapid drying with higher solids content. However, few of these dredges are operating within North America, and there is little freshwater experience upon which to base a review. Considerations are much like those for hydraulic dredging, but no further text will be devoted to this technique.

The depths of soft sediment encountered in Eagle Lake are typically in excess of 4 ft, yielding a minimum cost estimate of $64,000 per acre of area dredged if a hard substrate is to be reached. With about 1600 cubic yards in an acre-ft, this assumes a total cost of $10 per cubic yard of sediment dredged. Light limitation would not be reached in most locations without at least a 10 ft increase in water depth. Aside from cost considerations, the technical feasibility of dredging portions of Eagle Lake is difficult at best. Hydraulic dredging would be employed, as the lake cannot be drawn down sufficiently, creating the need for multiple and substantially large containment areas. The use of dredging as a primary management tool over the range of milfoil sites known for this lake is very limited on technical and financial grounds.

### Dyes and Surface Covers

Dyes are used to limit light penetration and therefore restrict the depth at which rooted plants can grow. They tend to reduce the maximum depth of plant growth, but have little effect in shallow water (<4 ft deep). They are only selective in the sense that they favor species tolerant of low light or with sufficient food reserves to support an extended growth period (during which a stem could reach the lighted zone). In lakes with high transparency but only moderate depth and ample soft sediment accumulations, dyes may provide open water where little would otherwise exist. Repeated treatment will be necessary, as the dye flushes out of the system. Dyes are typically permitted under the same process as herbicides, despite their radically different mode of action.

Surface shading has received little attention as a rooted plant control technique, probably as a function of potential interference with recreational pursuits which are a goal of most rooted plant control programs. Polyethylene sheets, floated on the lake surface, were used by Mayhew and Runkel (1962) to shade weeds. They found that two to three weeks of cover were sufficient to eliminate all species of pondweeds (*Potamogeton* spp.) for the summer if the sheets were applied in spring before plants grew to maturity. Coontail was also controlled, but the generally desirable macroalga *Chara* was not. This procedure should be a useful and inexpensive alternative to traditional methods of weed control in small areas such as docks and beaches, and could be timed to yield results acceptable to summer human users with minimal negative impacts to system ecology.

Although dyes and/or surface covers might reduce milfoil growth in Eagle Lake, they would be expected to impact the native pondweeds more, opening large areas for milfoil colonization at a later date. Although dyes are not especially expensive per unit area or volume treated, treatment of the whole lake would be necessary on a repeated basis. The color, although not unpleasant, is artificial and would be recognized as such by most Eagle Lake enthusiasts. This technique is not considered appropriate for use at Eagle Lake.

The use of surface covers over large areas would be logistically difficult in Eagle Lake, and would be expected to impede boat traffic. The potential for movement by wind and damage by boats limits the probability of success for surface covers in Eagle Lake on any scale larger than that on which benthic barriers are now used. The use of surface covers for control of current milfoil growths in Eagle Lake is therefore deemed impractical.

### Mechanical Removal

There are many variations on mechanical removal of macrophytes. Table 1 breaks these varied techniques into hand pulling, cutting without collection, harvesting with collection, rototilling, and hydroraking. Suction dredging, addressed in the dredging section, could also be included here, as it is primarily intended to remove plant biomass. Other classification systems are undoubtedly applicable; this is a diverse collection of methods linked by the commonality of physically attacking the targeted plants. These techniques are often cited as being analogous to mowing the lawn (cutting or harvesting), weeding the garden (hand pulling), or tilling the soil (rototilling or hydroraking), and these are reasonable comparisons. Mechanical management of aquatic plants is not much different from managing terrestrial plants, except for the complications imposed by the water.

***Hand Pulling***

Hand pulling is exactly what it sounds like; a snorkeler or diver surveys an area and selectively pulls out unwanted plants on an individual basis. This is a highly selective technique, and a labor intensive one. It is well suited to vigilant efforts to keep out invasive species which have not yet become established in the lake or area of concern. Hand pulling can also effectively address non-dominant growths of undesirable species in mixed assemblages, or small patches of plants targeted for removal. This technique is not suited to large scale efforts, especially when the target species or assemblage occurs in dense or expansive beds.

Hand harvesting has been the primary means for eliminating new growths of milfoil in Lake George, and has been a valuable tool in preventing the spread of milfoil. It has not been a useful technique in lakes or areas of lakes where milfoil has achieved dominance. Costs are on the order of $200 to $400 per acre for low densities of milfoil, and would escalate rapidly with increasing plant density as a function of labor expenses. Hand harvesting is ideally suited to providing a quick management response to scattered growths encountered during surveys and as a supplementary technique in combination with other approaches in a comprehensive management plan. By itself, it is not a viable approach to very large areas or moderate to dense growths.

***Augmented Pulling***

Hand pulling can be augmented by various tools, including a wide assortment of rakes, cutting tools, water jetting devices, nets and other collection devices. McComas (1993) provides an extensive and enjoyable review of options. Use of these tools transitions into the next two categories, macrophyte cutting and harvesting. Suction dredging is also used to augment hand pulling, allowing a higher rate of pulling in a targeted area, as the diver/snorkeler does not have to carry pulled plants to a disposal point.

The applicability of hand harvesting to scattered plants has been extended to higher density stands of milfoil through suction harvesting. In Lake George, suction harvesting has been restricted by permit to removal of plants pulled from the sediment by hand; actual dredging of sediment is not allowed. Suction harvesting therefore allows the efficiency of hand harvesting to be increased in a limited area. The suction dredge is a barge with a pump and filter system and suction hoses that can be operated by divers up to 100 ft away. It is positioned in the center of a roughly 200 ft circular area to be harvested, allowing the divers to feed hand harvested plants into the hoses. Plants are trapped in the filter bag, while water is released back to the lake. Resultant turbidity can be substantial as a result of intensive hand pulling in a localized area. The need to frequently reposition the suction harvester (barge) slows the process and increases costs.

Cost for suction harvesting in Lake George have been on the order of about $9150/acre, substantially higher than the figure of $4,000/acre reported for suction harvesting in New Zealand (Clayton, pers. comm.). Even if the lower rate could be achieved, the cost would be prohibitive on a large scale. Therefore, while suction harvesting is technically possible for larger areas, its practical utility on more than a small scale is clearly limited by cost. Additionally, supplementary and follow-up hand harvesting will been necessary in most cases, based on experience in Lake George.

*Mechanized Cutting*

Cutting is also exactly what it appears to be. A blade of some kind is applied to plants, severing the active apical meristem (location of growth) and possibly much more of the plant from the remaining rooted portion. Regrowth is expected, and in some species that regrowth is so rapid that it negates the benefits of the cutting in only a week or two. If the plant can be cut close enough to the bottom, or repeatedly, it will sometimes die, but this is more the exception than the rule. Cutting is defined here as an operation which does not involve collecting the plants once they are cut, so impacts to dissolved oxygen are possible in large scale cutting operations.

The most high technology cutting technique involves the use of mechanized barges normally associated with harvesting operations, in which plants are normally collected for out-of-lake disposal. In its use as a cutting technology, the "harvester" cuts the plants but does not collect them. A recent modification in this technique employs a grinding apparatus which ensures that viable plant fragments are minimized after processing. There is a distinct potential for dissolved oxygen impacts as the plant biomass decays, much like what would be expected from most herbicide treatments.

Harvesting may involve collection in nets or small boats towed by the person collecting the weeds, or can employ smaller boat-mounted cutting tools that haul the cut biomass into the boat for eventual disposal on land. It can also be accomplished with larger, commercial machines with numerous blades, a conveyor system, and a substantial storage area for cut plants. Offloading accessories are available, allowing easy transfer of weeds from the harvester to trucks that haul the weeds to a composting area. Choice of equipment is really a question of scale with most larger harvesting operations employing commercially manufactured machines built to specifications suited to the job. Some lake associations choose to purchase and operate harvesters, while others prefer to contract harvesting services to a firm that specializes in lake management efforts.

Cutting rates for commercial harvesters tend to range from about 0.2 to 0.6 acres per hour, depending on machine size and operator ability, but the range of possible rates is larger. Even at the highest conceivable rate, harvesting is a slow process that may leave some lake users dissatisfied with progress in controlling aquatic plants. Weed disposal is not usually a problem, in part because lakeshore residents and farmers often will use the weeds as mulch and fertilizer. Also, since aquatic plants are more than 90 percent water, their dry bulk is comparatively small.

Key issues in choosing a harvester include depth of operation, volume and weight of plants which can be stored, reliability and ease of maintenance, along with a host of details regarding the hydraulic system and other mechanical design features.

Rototilling and the use of cultivation equipment are newer procedures with a limited track record (Newroth and Soar, 1986). A rototiller is a barge-like machine with a hydraulically operated tillage device that can be lowered to depths of 10 to 12 feet for the purpose of tearing out roots. Also, if the water level in the lake can be drawn down, cultivation equipment pulled behind tractors on firm sediments can achieve 90 percent root removal. Potential impacts to non-target organisms and water quality are substantial, but where severe weed infestations exist, this technique could be appropriate.

Hydroraking involves the equivalent of a floating backhoe, usually outfitted with a York rake that looks like certain farm implements for tilling or moving silage. The tines of the rake attachment are moved through the sediment, ripping out thick root masses and associated sediment and debris. A hydrorake can be a very effective tool for removing submerged stumps, water lily root masses, or floating islands. Use of a hydrorake is not a delicate operation, however, and will create substantial turbidity and plant fragments. Hydroraking in combination with a harvester can remove most forms of vegetation encountered in lakes.

Most mechanical plant removal operations are successful in producing at least temporary relief from nuisance plants and in removing organic matter and nutrients without the addition of a potentially deleterious substance. Plant regrowth can be very rapid (days or weeks), however, and resultant open areas are candidates for colonization by invasive species.

A bay of LaDue Reservoir (Geauga County, Ohio) was harvested in July 1982 by the traditional method in which the operator treats the weed bed like a residential lawn and simply mows the area. Stumps of Eurasian watermilfoil plants about 0.5 to 3 inches in height were left, and complete regrowth occurred in 21 days. In contrast, the slower method of lowering the cutter blade about 1 inch into the soft lake mud produced season-long control of milfoil by tearing out roots (Conyers and Cooke, 1983). However, this cutting technique is of little value where sediments are very stiff or in deeper water where the length of the cutter bar can not reach the mud. There is evidence of a carry-over effect (less growth in the subsequent year), especially if an area has had multiple harvests in one season.

Some weed species are more sensitive to harvesting than others. Nicholson (1981) has suggested that harvesting was responsible for spreading milfoil in Chautauqua Lake, New York, because the harvester spread fragments of plants from which new growths could begin. On the other hand, milfoil has become the dominant plant in many northeastern lakes without harvesting programs in less than 5 years after initial appearance (Wagner, pers. obs.).

Harvesting techniques which present the opportunity for plant fragments to escape are generally not suited for longer term control of species which reproduce vegetatively, and may actually be counterproductive to control. While short-term control may be achieved in the target area, long-term control is rare and the escape of fragments often results in colonization of new sites. Any of the cutting techniques without collection, and often even with collection effort, can be expected to result in the spread of vegetatively reproducing species. For that reason, only harvesting approaches with a very low probability of fragments being left in the water are appropriate for controlling Eurasian watermilfoil, unless this plant is already dominant throughout the lake. Even then, long-term relief is only provided by repeated application at substantial cost and possibly with undesirable side effects.

**Drawdown**

Historically, water level drawdown has been used in waterfowl impoundments and wetlands for periods of a year or more, including the growing season, to improve the quality of wetlands for waterfowl breeding and feeding habitat (Kadlek, 1962; Harris and Marshall, 1963). It has also been a common fishery management method. Until a few decades ago, drawdowns of recreational lakes were primarily for the purpose of flood control and allowing access for clean ups and repairs to structures, with macrophyte control as an auxiliary benefit. While this technique is not effective on all submergent species, it does decrease the abundance of some of the chief nuisance species, particularly those that rely on vegetative propagules for overwintering and expansion (Cooke et al., 1993). If there is an existing drawdown capability, lowering the water level provides an inexpensive means to control some macrophytes. Additional benefits may include opportunities for shoreline maintenance and oxidation or removal of nutrient-rich sediments.

The ability to control the water level in a lake is affected by area precipitation pattern, system hydrology, lake morphometry, and the outlet structure. The base elevation of the outlet or associated subsurface pipe(s) will usually set the maximum drawdown level, while the capacity of the outlet to pass water and the pattern of water inflow to the lake will determine if that base elevation can be achieved and maintained. In some cases, sedimentation of an outlet channel or other obstructions may control the maximum drawdown level.

Several factors affect the success of drawdown with respect to plant control. While drying of plants during drawdowns in southern areas may provide some control, the additional impact of freezing is substantial, making drawdown a more effective strategy for northern lakes during late fall and winter. However, a mild winter or one with early and persistent snow may not provide the necessary level of drying and freezing. The presence of high levels of groundwater seepage into the lake may mitigate or negate destructive effects on target submergent species by keeping the area moist and unfrozen. The presence of extensive seed beds may result in rapid re-establishment of previously occurring or new and equally undesirable plant species. Recolonization from nearby areas may be rapid, and the response of macrophyte species to drawdown is quite variable.

Drawdown has a long and largely successful history, even if not always intended as a plant control technique (Dunst et al., 1974; Wlosinski and Koljord, 1996). Winter drawdowns of Candlewood Lake in Connecticut (Siver et al. 1986) reduced nuisance species by as much as 90% after initial drawdown. Drawdowns in Wisconsin lakes have resulted in reductions in plant coverage and biomass of 40 to 92% in targeted areas (Dunst et al., 1974). In one Wisconsin case, Beard (1973) reported that winter drawdown of Murphy Flowage opened 64 out of 75 acres to recreation and improved fishing.

The effect of drawdown is not always predictable or desirable, however. Reductions in plant biomass of 44 to 57% were observed in Blue Lake in Oregon (Geiger, 1983) following drawdown, but certain nuisance species actually increased and herbicides were eventually applied to regain control. Drawdown of Lake Bomoseen in Vermont (VANR, 1990) caused a major reduction in many species, many of which were not targeted for biomass reductions. Reviewing drawdown effectiveness in a variety of lakes, Nichols and Shaw (1983) noted the species-specific effects of drawdown, with a number of possible benefits and drawbacks. A system-specific review of likely and potential impacts is highly advisable prior to conducting a drawdown.

Undesirable possible side effects of drawdown include loss or reduction of desirable plant species, facilitation of invasion by drawdown-resistant undesirable plants, reduced attractiveness to waterfowl (considered an advantage by some), possible fishkills if oxygen demand exceeds re-aeration during a prolonged drawdown, altered littoral habitat for fish and invertebrates, mortality among hibernating reptiles and amphibians, impacts to connected wetlands, shoreline erosion during drawdown, loss of aesthetic appeal during drawdown, more frequent algal blooms after refill in some cases, reduction in water supply, impairment of recreational access during the drawdown, and downstream flow impacts (Nichols and Shaw, 1983; Cooke et al., 1993). Careful planning can often avoid many of these negative side effects, but managers should be aware of the potential consequences of any management action.

Inability to rapidly refill a lake after drawdown is a standard concern in evaluating the efficacy of a drawdown. There must be enough water entering the lake to refill it within an appropriate timeframe while maintaining an acceptable downstream flow. In northern lakes, the best time for refill is in early spring, when flows typically peak as the snowpack melts and rainfall on frozen ground yields the maximum runoff.

Impairment of water supply during a drawdown is a primary concern of groups served by that supply. Processing or cooling water intakes may be exposed, reducing or eliminating intake capacity. The water level in wells with hydraulic connections to the lake will decline, with the potential for reduced yield, altered water quality and pumping difficulties. Drawdowns of Cedar Lake and Forge Pond in Massachusetts resulted in impairment of well water supplies (Wagner, pers. obs.), but there is little mention of impairment of well production in the reviewed literature.

Recolonization by resistant vegetation is sometimes a function of seed beds and sometimes the result of expansion of shoreline vegetation. *Najas* recolonized areas previously overgrown with *Myriophyllum* after the drawdown of Candlewood Lake in Connecticut (Siver et al., 1986), apparently from seeds that had been in those areas prior to milfoil dominance. Cattails and rushes are the most commonly expanding fringe species (Nichols and Shaw, 1983; WDNR, 1989). Drawdowns to control nuisance submergent vegetation are usually recommended for alternate years to every third year to prevent domination by resistant plant species (Cooke et al., 1993), although drawdown may be practiced at a higher frequency to gain initial control of target species.

Recreational facilities and pursuits may be adversely impacted during a drawdown. Swimming areas will shrink and beach areas will enlarge during a drawdown. Boating may be restricted both by available lake area and by access to the lake. Again, winter drawdown will avoid most of these disadvantages, although lack of control over winter water levels can make ice conditions unsafe for fishing or skating. Additionally, outlet structures, docks and retaining walls may be subject to damage from freeze/thaw processes during overwinter drawdowns, if the water level is not lowered beyond all contact with structures.

Carefully planned water level fluctuation can be a useful technique to check nuisance macrophytes and periodically rejuvenate wetland diversity. Planned disturbance is always a threshold phenomenon; a little can be beneficial, while too much leads to overall ecosystem decline. The depth, duration, timing and frequency of the drawdown are therefore critical elements in devising the most beneficial program.

With specific regard to milfoil, drawdown is known to provide some degree of control through drying and freezing of overwintering vegetative plant parts. Success is linked to sufficient dewatering of exposed sediments and a weather pattern that promotes drying and freezing. Control of milfoil in the drawdown zone has often been observed. Eradication has rarely been achieved, however, mainly due to a common inability to lower the water level to the greatest depth of milfoil occurrence.

In the case of Eagle Lake, the existing outlet control is not capable of implementing a drawdown of the extent necessary to sufficiently impact the milfoil population. An annual drawdown is practiced, and does appear to keep milfoil out of the shallowest areas, but is not able to reduce milfoil densities in deeper waters. Greater drawdown may be possible with extensive outlet modification and possible dredging, but the cost and potential disadvantages do not suggest this as a preferred approach.

## Chemical Controls

There are few aspects of plant control which breed more controversy than chemical control through the use of herbicides, which are a subset of all chemicals known as pesticides. Part of the problem stems from pesticides which have come on the market, enjoyed widespread use, been linked to environmental or human health problems, and been banned from further use. Yet as chemicals are an integral part of life and the environment, it is logical to seek chemical solutions to such problems as infestations of non-native species which grow to nuisance proportions, just as we seek physical and biological solutions. Current pesticide registration procedures are far more rigorous than in the past. While no pesticide is considered unequivocally "safe", a premise of federal pesticide regulation is that the potential benefits derived from use outweigh the risks when the chemical is used according to label restrictions.

Fluridone, sold under the tradename Sonar®, is the preferred alternative for controlling larger areas of moderate to dense Eurasian watermilfoil coverage in Eagle Lake, and is discussed elsewhere. Among the variety of herbicides available today, four alternative chemicals have been demonstrated to be successful against Eurasian watermilfoil, although one is still an experimental herbicide. Westerdahl and Getsinger (1988a, 1988b) provide considerable discussion of these herbicides, much of which is summarized below.

### *Endothall*

Endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) is a contact herbicide acting on plant metabolism after adsorption onto outer cell membranes. Salts of endothall are marketed as Aquathol K and Hydrothol 191, but only the Aquathol K formulation is typically used for milfoil control. An Aquathol K concentration of 2-4 mg/l is considered optimal for control of milfoil, but will also result in the death of many native species.

Endothall acts quickly on susceptible plants, but does not kill roots with which it can not come into contact, and recovery of milfoil is often rapid. Rapid death of susceptible plants can cause oxygen depletion if decomposition exceeds re-aeration in the treated area, although this can be mitigated by conducting successive partial treatments. Endothall compounds break down readily and are not persistent in the aquatic environment. Toxicity to invertebrates, fish or humans is not expected to be a problem at the recommended dose, yet water use restrictions (i.e., 14 days) are mandated on the label.

### *Diquat*

Diquat (6,7-dihydrodipyrido [1,2-a:2',1-c] pyrazinediium dibromide) is another contact herbicide. Diquat is marketed under the tradename Reward. Like endothall, it is a fast acting contact herbicide, producing results within 2 weeks of application. It is not an especially selective herbicide, and can be toxic to invertebrates, fish, mammals, birds and humans. Domestic water use restrictions (i.e., 7 days) apply. Only portions of the plant with which the herbicide can come into contact are killed. Regrowth of milfoil has been rapid (often within the same year) after treatment with diquat in many cases.

The goal of a chemical control program for Eagle Lake would be to eradicate moderate to dense stands of milfoil, or at least to reduce milfoil in that area to a level controllable by physical means, with minimal hazard to anything but the milfoil. Given the non-selective nature of both endothall and diquat and the water use restrictions attached to each, these herbicides are not well suited for use in Eagle Lake. Additionally, the inability of these chemicals to eliminate the whole plant suggests that repeated treatments will be necessary to achieve any lasting control.

**2,4-D**

2,4-D (2,4-dichlorophenoxyacetic acid) is a systemic chemical which affects target plants by inhibiting critical metabolic pathways after uptake through roots, leaves or shoots. 2,4-D is the active ingredient in a variety of commercial herbicide products and has been in use for over 30 years despite claims of undesirable environmental side effects and potential human health effects. This is a systemic herbicide; it is absorbed by roots, leaves and shoots and disrupts cell division throughout the plant. Vegetative propagules such as winter buds, if not connected to the circulatory system of the plant at the time of treatment, are generally unaffected and can grow into new plants. It is therefore important to treat plants early in the season, after growth has become active but before such propagules form.

2,4-D is sold in liquid or granular forms as sodium and potassium salts, as ammonia or amine salts, and as an ester. Doses of 50 to 150 pounds per acre are usual for submersed weeds, most often of the dimethylamine salt or the butoxyethanolester (BEE). This herbicide is particularly effective against Eurasian watermilfoil (granular BEE applied to roots early in the season) and as a foliage spray against water hyacinth. 2,4-D has a short persistence in the water but can be detected in the mud for months.

Experience with granular 2,4-D in the control of nuisance macrophytes has been generally positive, with careful dosage management providing control of such non-native nuisance species as Eurasian watermilfoil with only sublethal damage to many native species (Miller and Trout, 1985; Helsel et al., 1996). Recovery of the native community from seed has also been successful. 2,4-D has variable toxicity to fish, depending upon formulation and fish species. The 2,4-D label does not permit use of this herbicide in water used for drinking or other domestic purposes, or for irrigation or watering of livestock. Concentrations in treated water should not exceed 0.1 mg/L.

Use of 2,4-D to provide the desired level of control over milfoil without impact to other plant species is consistent with the goals of the milfoil control program at Eagle Lake, but label restrictions prevent its use in this system.

***Triclopyr***

The herbicide Garlon 3A, with triclopyr (triclopyr triethylamine), as its active ingredient, is currently experimental for aquatic habitats. If successfully registered for aquatic use, it will be marketed under the tradename Renovate. It is highly selective and effective against Eurasian milfoil at a dose of 1-2.5 mg/l. Experimental treatments of aquatic environments (Netherland

and Getsinger, 1993) have revealed little or no effect on most monocotyledonous naiads and pondweeds (the bulk of the native plant assemblage in Eagle Lake). Its mode of action is to prevent synthesis of plant-specific enzymes, resulting in disruption of growth processes. This herbicide is most effective when applied during the active growth phase of young plants.

Triclopyr is not known to be a carcinogen, oncogen, mutagen or teratogen, and all lethal effects on tested animal populations have occurred at concentrations over 100 times the recommended dosage rate. The experimental label calls for concentrations in potable water of no more than 0.5 mg/l, suggesting that care must be taken to allow sufficient dilution between the point of application and any potable water intakes. Garlon 3A has been applied to areas as small as 1 acre, with the recommendation that small areas be rectangular in shape.

Considering the plant species in Eagle Lake and the known or presumed tolerance of many of those species to triclopyr, this herbicide has distinct potential for control of milfoil in Eagle Lake while encouraging re-establishment of native species in impacted areas. Use restrictions would probably be placed on any potable water intakes during the treatment period, and may be more stringent than those currently in place or contemplated for fluridone. Triclopyr has not yet received full registration by the USEPA, and would presumably then have to be additionally evaluated and approved for use in New York. It is not certain when this herbicide will be available for use, but it is likely to be at least several years and probably longer in New York.

**Biological Controls**

Biological control has the objective of achieving control of plants without introducing toxic chemicals or using machinery. It suffers from one ecological drawback; in predator-prey (or parasite-host) relationships, it is rare for the predator to completely eliminate the prey. Consequently, population cycles or oscillations are typically induced for both predator and prey. It is not clear that the magnitude of the upside oscillations in plant populations will be acceptable to human users, and it seems likely that a combination of other techniques with biocontrols may be necessary to achieve lasting, predictable results.

Biological controls include herbivorous fish such as *Ctenopharyngidon idella* (the grass carp), insects such as the aquatic milfoil weevil (*Euhrychiopsis lecontei*), and experimental fungal pathogens. Aside from consumptive approaches (grazing, parasitism), it is also possible to exert competitive pressures, limiting invasive species by maintaining a healthy native assemblage.

***Grass Carp***

The grass carp is a non-native fish (imported around 1962) known to be a voracious consumer of many forms of macrophytes. It has a very high growth rate (about 6 pounds per year at the maximum rate; Smith and Shireman, 1983). This combination of broad diet and high growth rate can produce control or even eradication of plants within several seasons. However, grass carp do not consume aquatic plant species without preference. Generally, they avoid alligatorweed, water hyacinth, cattails, spatterdock, and water lily. These fish prefer plant species such as elodea, pondweeds and hydrilla. Low stocking densities can produce selective grazing on the preferred plant species while other less preferred species, including milfoil, may even increase. Overstocking, on the other hand, may eliminate all plants, contrary to the ecological axiom of oscillating population cycles described previously. Feeding preferences are listed in Nall and Schardt (1980), Van Dyke et al. (1984), and Cooke and Kennedy (1989).

Cooke et al. (1993) describe many important considerations for the use of grass carp in weed control efforts. Critical controls include restrictions on the ability of the fish to reproduce (sterile triploid fish vs. reproductive diploid fish) and inlet and/or outlet controls to prevent emigration. Stocking rate calculations are based primarily on qualitative and quantitative characteristics of the lake, with adjustment by region. Rates of up to 70 fish per acre have been used for intended removal of dense assemblages of unpalatable plants, while rates of only 1-2 fish per acre have been used in lakes with a low density of more palatable vegetation. Stocked fish are normally 10-12 inches in length to avoid predation losses. Stocking is typically performed on a 6-year cycle linked to fish mortality.

Success with grass carp has been achieved in many cases, but the definition of success varies. Introduction of 3-5 fish per acre into Lake Conway in Florida resulted in greatly reduced densities of hydrilla, nitella and pondweeds after two years, while non-targeted water celery (*Vallisneria*) was largely unaffected (Miller and King, 1984). However, algal biomass increased, indicating the potential of fish to affect productivity in the water column (see the algal control section of this chapter). In contrast, stocking of about 13 fish per acre (30/acre if only vegetated acres are counted) in Lake Conroe, Texas, eliminated all submersed plants in under 2 years, increased algal biomass, and changed the algal composition to less desirable forms (Martyn et al., 1986; Maceina et al., 1992). In small Lake Parkinson in New Zealand, grass carp eradicated the invasive, non-native Brazilian elodea (*Egeria densa*), were themselves then removed by netting and rotenone poisoning, and a native flora was naturally re-established from the existing seed bed (Tanner et al., 1990). Failure of this technique to yield desirable results has generally been a function of fish diet not matching targeted plant species, inappropriate stocking rates, and lack of patience (essential with biological techniques) before taking additional action.

The use of grass carp is likely to drastically alter the ecology of a lake. Stocked to reduce vascular plant density, grass carp typically cause a shift toward algal blooms and increased turbidity which becomes a self-sustaining alternative lake condition. This condition is often unsuitable for desirable gamefish production and may be more objectionable to human users than the original rooted plant density.

The grass carp, while successful in controlling certain weeds in the southern United States and in small ponds in more northern climates, is not recommended by the State of New York for use in larger lakes. Among the problems with this species is selective feeding in which non-target species may become the preferred diet; in Eagle Lake this could result in more available substrate for milfoil growth. Coupled with the tendency to foster algal blooms, grass carp would seem highly undesirable in Eagle Lake.

*Milfoil Weevil*

The use of insects to control rooted plants has historically centered on introduced, non-native species. Despite some successes, the track record for biological problem-solving through introduced, non-native species is poor (as many problems seem to have been created as solved), and governmental agencies tend to prefer alternative controls unless there is no practical choice. However, the use of native species in a biomanipulative approach is usually acceptable. Combining biological, chemical and mechanical controls is the basis of integrated pest control, and takes advantage of as many avenues of control as possible for maximum effectiveness. The development of native insects as aquatic plant controls is still in its infancy, but several promising developments have occurred in the last decade, mainly in northern states. The use of larvae of midgeflies, caddisflies, beetles and moths have been explored with some promise (Cooke et al. 1993). However, the activities of the aquatic weevil *Euhrychiopsis lecontei* have received the most attention in recent years.

*Euhrychiopsis lecontei* is a native North American species believed to have been associated with northern watermilfoil (*Myriophyllum sibericum*), a species largely replaced by non-native, Eurasian watermilfoil (*M. spicatum*) since the 1940's. The weevil is able to switch plant hosts within the milfoil genus, although to varying degrees and at varying rates depending upon genetic stock and host history (Solarz and Newman, 1996). It does not utilize non-milfoil species. Its impact on Eurasian watermilfoil was been documented (Creed and Sheldon, 1995; Sheldon and Creed, 1995; Sheldon and O'Bryan, 1996a) through five years of experimentation under USEPA sponsorship. In controlled trials, the weevil clearly has the ability to impact milfoil plants through structural damage to apical meristems (growth points) and basal stems (plant support). Adults and larvae feed on milfoil, eggs are laid on it, and pupation occurs in burrows in the stem.

Field observations link the weevil to natural milfoil declines in nine Vermont lakes. Additional evidence of weevil-induced crashes without introduction or population augmentation exists for lakes outside Vermont (Creed, 1998). Lakewide crashes have generally not been observed in cases where the weevil has been introduced into only part of the lake, although localized damage has been substantial and such widespread control may require more time than current research and monitoring has allowed. As with experience with introduced insect species in the south, the population growth rate of the weevil is usually slower than that of its host plant, necessitating supplemental stocking of weevils for more immediate results. Just what allows the weevil to overtake the milfoil population in the cases where natural control has been observed is still unknown.

Densities of 1-3 weevils per stem appear to collapse milfoil plants, and raising the necessary weevils is a major operation. The State of Vermont devoted considerable resources to rearing weevils for introduction over a two-year period, using them all for just a few targeted sites (Hanson et al., 1995). Weevils are now marketed commercially as a milfoil control, with a recommended stocking rate of 3000 adults per acre. Release is often from cages or onto individual stems; early research involved attaching a stem fragment with a weevil from the lab onto a milfoil plant in the target lake, which was highly labor-intensive. A minimum cost of $3000/acre is anticipated for successful use of the milfoil weevil at this time.

Although weevils may be amenable to use within an integrated milfoil management approach, interference from competing control techniques has been suggested as a cause for sub-optimal control by weevils (Sheldon and O'Bryan, 1996b). Harvesting may directly remove weevils and reduce their density during the growing season. Also, adults are believed to overwinter in debris along the edge of the lake, and techniques such as drawdown, bottom barriers, or sediment removal could negatively impact the weevil population. Extension of lawns to the edge of the water and application of insecticides also represent threats to these milfoil control agents. These do not appear to be major issues at Eagle Lake, yet there is no evidence of a significant natural weevil population or of any milfoil population crashes which might be due to the weevil. If population augmentation is necessary, high cost will be a major impediment, and there is no guarantee of success.

***Plant Pathogens***

Plant pathogens remain largely experimental, despite a long history of interest from researchers. Properties of plant pathogens which make them attractive (Freeman, 1977) include:

- High abundance and diversity
- High host specificity
- Non-pathogenicity to non-target organisms
- Ease of dissemination and self-maintenance
- Ability to limit host population without elimination

Fungi are the most common plant pathogens investigated, and control of water hyacinth, hydrilla or Eurasian watermilfoil by this method has been extensively evaluated (Charudattan et al., 1989; Theriot, 1989; Gunner et al., 1990; Joye, 1990). Results have not been consistent or predictable in most cases, and problems with isolating effective pathogens, overcoming evolutionary advantages of host plants, and delivering sufficient inoculum have limited the utility of this approach to date. However, combination of fungal pathogens and herbicides has shown some recent promise as an integrated technique (Nelson et al., 1998).

There is no commercially marketed plant pathogen suitable for use against milfoil at this time, so the use of this technique in Eagle Lake is not currently practical.

***Resistance by the Native Community***

Although invasive nuisance plant species are just what the name implies, there is evidence that the presence of a healthy, desirable plant community can minimize or slow infestation rates. Most invasive species are favored by disturbance, so a stable plant community should provide a significant defense. Unfortunately, natural disturbances abound, and almost all common plant control techniques constitute disturbances. Therefore, if native and desirable species are to regain dominance after disturbance, it may be necessary to supplement their natural dissemination and growth with seeding and plantings. The use of seeding or planting of vegetation is still a highly experimental procedure, but if native species are employed it should yield minimal controversy.

Experiments conducted in Texas (Doyle and Smart, 1995) indicate that the addition of dried seeds to an exposed area of sediment will result in rapid germination of virtually all viable seeds and rapid cover of the previously exposed area. However, if this is not done early enough in the growing season to allow plants to mature and produce seeds of their own, the population of annual plants will not sustain itself into the second growing season. Transplanting mature growths into exposed areas was found to be a more successful means of establishing a seed producing population. The use of cuttings gathered by a harvester (Helsel et al., 1996) was not successful in establishing native species in areas previously covered by benthic barrier in Wisconsin.

In nearby Lake George, where the native plant community is diverse and dense, colonization by Eurasian watermilfoil has been much slower than in many other area lakes (Wagner and Clear, 1996). Sediment features provide an alternative explanation for inhospitality to milfoil, but it has also been noted that when milfoil is cleared from an area and a native assemblage restored, regrowth by milfoil is greatly diminished (Eichler et al., 1995). More research is needed in this area, but establishment of desired vegetation is entirely consistent with the primary plant management axiom; if light and substrate are adequate, plants will grow.

Preservation of the native community is an important goal of plant management in Eagle Lake. However, where milfoil has become established, a technique is needed to rid the area of milfoil so that the native community can become re-established.

## IMPACT EVALUATION AND MITIGATION MEASURES

Based on numerous public meetings, discussions with agency personnel and other interested parties, and the Scoping Session conducted in accordance with the SEQR process, concerns over the treatment of Eagle Lake with fluridone for the control of Eurasian watermilfoil include demonstration of an actual need for control and the following possible impacts:

Potential Impacts of Fluridone on Aquatic Fauna
Potential Impacts of Fluridone on Eurasian Watermilfoil
Potential Impacts of Fluridone on Non-target Plant Species
Potential Impacts of Fluridone on Potable Water Supplies and Human Health
Potential Impacts of Fluridone on General Water Quality
Potential Impacts of Fluridone on Recreational Pursuits and Economic Stability
Potential Impacts of Fluridone on Aesthetics and Human Perceptions

The need for milfoil control has been addressed in a separate section earlier in this document. The potential impacts of fluridone in the aquatic environment in general and in Eagle Lake specifically are addressed below.

**Potential Impacts of Fluridone on Aquatic Fauna**

The Generic Environmental Impact Statement for the use of fluridone in New York State (McLaren/Hart, 1995) addresses the impacts of fluridone to the aquatic fauna. The following is a brief summary of the results reported in the GEIS.

The impacts of fluridone on zooplankton species do not appear to be substantial, although in cases of considerable concentrations (1.0 ppm) decreases in zooplankton species have been observed. At reduced levels of 0.3 ppm, well above the 0.05 ppm limit of fluridone applications in potable waters in NYS, zooplankton populations were unaffected. Where zooplankton populations were exposed to fluridone concentrations of 1.0 ppm, zooplankton populations returned to pretreatment levels within 43 days. Results from static water $LC_{50}$ toxicity testing using *Daphnia magna* show that fluridone concentrations of 6.3 ppm are required to invoke an acute response. Chronic toxicity testing results involving *D. magna* showed no observed effects at concentrations less than 0.6 ppm. $LC_{50}$ Sonar® concentrations of 12.0, 8.0, 13.0 and 13.0 ppm were reported for the microcrustaceans *Diaptomus* sp., *Eucyclops* sp., *Alonella* sp, and *Cypria* sp., respectively.

Impacts of fluridone to freshwater fish populations appear at concentrations much greater than those suggested for the control of Eurasian watermilfoil in Eagle Lake. The 96 hour $LC_{50}$ for rainbow trout (*Salmo gairdneri*) and bluegill (*Leopomis macrochirus*) is reported to be 11.7 and 12 ppm respectively. Fish abundance and community structure remained unchanged in a pond exposed to a fluridone concentration level of 0.125 ppm. An average fluridone concentration of $10.4 \pm 3.9$ ppm was reported as the 96 hour $LC_{50}$ for the fish species rainbow trout (*Salmo gairdneri*), fathead minnow (*Pimephales promelas*), channel catfish (*Ictalurus punctatus*), bluegill (*Leopomis macrochirus*), and sheepshead minnow (*Cyprinodon variegatus*). Chronic toxicity testing results show that catfish fry exposed to 0.5 ppm of fluridone were not significantly effected, although catfish fry growth was reduced at concentrations of 1.0 ppm. Chronic exposure of fathead minnow to concentrations of 0.48 ppm did not produce adverse effects, but exposures of fathead minnow to concentrations of 0.95 and 1.9 ppm resulted in reduced survival within 30 days of hatching.

When benthic organisms were exposed to fluridone levels of 1.0 ppm, the total number of organisms was greatly reduced when compared to unexposed controls. However, fluridone levels of 0.3 ppm did not significantly reduce total benthic organism numbers. Similar results were observed using the amphipod *Hyalella azteca* with fluridone concentrations of 1.0 and 0.3 ppm.

Relatively little is known of the possible impact on amphibians and reptiles, but no concerns have been raised in any scientific study performed to date. Likewise, waterfowl are not known to be affected by fluridone. A wide variety of alternative sites would be available during the treatment process, but there is no reason to believe that the treatment would interfere with feeding, breeding or other waterfowl activities.

Elimination of milfoil is not viewed as a threat to the habitat of any aquatic animal life in Eagle Lake. To the contrary, the restoration of a native plant community intended to follow milfoil eradication in any given area is expected to benefit all desirable forms of aquatic fauna.

As Eagle Lake will be subjected to target concentrations of fluridone less than 0.02 ppm, there appears to be negligible risk of immediate or long term negative impacts to the aquatic fauna of Eagle Lake. Specific data for zooplankton, fish and benthic invertebrate communities indicate no impact at such concentrations, and the mobility of reptiles, amphibians, and waterfowl suggest no threat.

**Potential Impacts of Fluridone on Eurasian Watermilfoil**

The intent of the project is to eliminate milfoil from the lake. Impacts are therefore desired in this regard, and the central question revolves around the effectiveness of fluridone under the expected treatment conditions.

Eurasian watermilfoil has been controlled with Sonar® concentrations as low as 0.005 mg/l (5 ppb) in whole lake treatments, and doses above 0.03 mg/l (30 ppb) appear unnecessary as long as dilution is not a serious influence (Pullman, 1993). Many native species will survive these doses, which are well below the maximum of 0.05 mg/l set for use in New York waters. However, as fluridone works slowly, it is essential that a concentration of roughly 0.01-0.03 mg/l (10-30 ppb) be maintained for multiple weeks. This presents a challenge to application where dilution effects are appreciable and the maximum allowable concentration is as limited as it is in New York, but if sufficient exposure to an adequate concentration is maintained, the lethality of fluridone to Eurasian watermilfoil is virtually certain.

The effectiveness of Sonar® AS will be limited by dilution. Since the maximum target concentration will be 0.02 mg/l, dilution by no more than twofold to threefold can be tolerated to maintain an effective concentration. This has been a problem for small area treatments in larger water bodies, leading to the recommendation that Sonar® not be used to treat areas less than 5 acres unless the treated area includes the whole water body (i.e., ponds <5 acres). In order for a single Sonar® AS treatment to be most effective against milfoil, treated areas must have limited exchange of water during the critical period of herbicide-plant interaction (at least three weeks). Eagle Lake will be treated in its entirety, so the only dilution issue relates to flushing from the lake. Assuming a spring treatment, flushing will be minimized by keeping the lake slightly below full during the spring refill period (following winter drawdown) and then replacing the final flashboard(s) at the time of treatment. If a fall treatment is conducted, flows are expected to be naturally low enough to minimize flushing at that time.

**Potential Impacts of Fluridone on Non-targeted Plant Species**

The list of submersed vascular plants known from Eagle Lake (Table 1) includes 36 species. Two non-vascular species are also listed, the macro algae *Chara* and *Nitella*. Comparison of this list with susceptibility evaluations compiled by the Vermont DEC (1995) and the current supplier of Sonar® (SePRO 1995) indicate that Eurasian watermilfoil and up to 11 other species would be susceptible to treatment with fluridone. Based on available information, there are 4 or 5 species that would be unharmed, leaving 22 species for which available information is insufficient to make any prediction of fluridone impact. The only listed regionally rare species in Eagle Lake, *Isoetes macrospora,* is not listed as being susceptible to fluridone. While the selectivity of fluridone for milfoil and certain other nuisance species has been demonstrated in many studies, there is apparently little documented experience with many of the plant species in Eagle Lake. It is therefore important to monitor to expand the database on fluridone effects.

It is not certain how non-target susceptible plants in Eagle Lake will be affected at the doses planned for the target treatment areas. It is possible that at doses <20 ppb there will be no impacts. If impacts do occur, plants may be temporarily impacted in a vegetative form (with vegetative recovery), eliminated in vegetative form but restored through seed germination, or eliminated in vegetative form until recolonization from an untreated area occurs. Of the 32 species with known or potential susceptibility, 29 are known to reproduce by seed, greatly enhancing the probability of recovery from any impact within a year.

Table 2 gives the response of 15 plant species to whole-lake fluridone treatments in Michigan. Nine of the plants listed are found in Eagle Lake. During the first year of treatment, 6 species, including Eurasian watermilfoil, exhibited declines in distribution. Of those 6 affected species, 3 were shown to increase distribution the following year, while Eurasian watermilfoil was virtually eradicated from the system. The other two species were observed to decrease or remain at similar distributions following the fluridone treatments. For these observations, fluridone had been applied at concentrations of 8-29 ppb. The macroalgae listed for Eagle Lake are considered tolerant to fluridone application and populations have been reported to rapidly increase following fluridone treatments (Pullman, 1993).

Only one species of submergent aquatic plant found in Eagle Lake is listed on the New York list of rare native plants. The term "rare" is defined as a plant having from 20 to 35 extant sites or 3,000 to 5,000 individuals statewide. The rare plant listed for Eagle Lake is *Isoetes macrospora,* and is not considered to be locally abundant in Eagle Lake (Table 1). However, *Isoetes macrospora* is known to be resistant to fluridone. Eradication as a non-target impact of fluridone is very unlikely.

Following the removal of the target species, Eurasian watermilfoil, from the water column there will be newly exposed sediments available for colonization. Although the response will not be immediate, it is expected that the remaining unaffected native plant community will colonize the available habitat within the current or following growing season. Studies in Lake George involving the recolonization of disturbed sediments following benthic barrier installation and suction harvesting show that recolonization of areas previously supporting dense milfoil populations is fairly rapid (Eichler et al., 1993; 1995). At each benthic barrier site, fairly rapid colonization occurred with 9 to 12 species observed 30 days after barrier removal, although density of the plants was low. Sixty days after barrier removal (August) the numbers of species and percent coverage reached their peak. Late season evaluation showed a decrease in these numbers, but was attributed to seasonal die back of plants in the fall.

Although recolonization varied from site to site, generally native seed-producing or turion-forming species were the first to become established (e.g. *Najas flexilis, Potamogeton robbinsii, Elodea canadensis,* and *Heteranthera dubia*, all present in Eagle Lake). Similar results were observed following suction harvesting whereby the first native species to recolonize were seed producers. While some recolonization by milfoil is possible, natural restoration of the native plant assemblage from seed is expected.

Native plant species tolerant of fluridone (Tables 1 and 2) and in close proximity to the treatment area are expected to expand their populations by recolonizing at least part of the newly available habitat. The macroalgae *Chara* and *Nitella* are the prime candidates in this case. If native species are able to recolonize open sediments before new milfoil arrives, the appearance of milfoil may be delayed, or most optimistically, prevented. Open or bare sediments produce the most favorable conditions for any species to establish itself, and if this sediment area is quickly colonized by native species through seeds present in the sediment, milfoil will encounter an area less inviting to establishment. On the other hand, the vegetative fragmentation scheme employed by milfoil makes it a strong candidate for colonizing bare substrates if seeds do not quickly germinate. The post-treatment monitoring program is designed to investigate recolonization of treated areas.

Outside of the lake, impacts on terrestrial vegetation are expected to be negligible at fluridone concentrations of <10 ppb even with prolonged exposure, and intermittent exposure at concentrations of <20 ppb are not expected to produce any observable effect (Burns, pers. comm.). Irrigation should probably be avoided for 24 hours after application, to ensure that mixing is complete in the lake, but there is no label restriction in this regard. Any fluridone passing through septic systems and into the ground is expected to be dilute enough to avoid impacts to plants with deep root systems.

### Potential Impacts of Fluridone on Potable Water Supplies and Human Health

The pilot fluridone application for Eagle Lake will not include applications within 1/4 mile of water intakes, as is required for use of Sonar®in New York. The drinking water standard established in NYS for all chemical compounds not specifically identified is 50 ppb. Since the application rate of aqueous fluridone in New York is limited to 50 ppb, there does not appear to be potential for exceeding drinking water standards during the pilot treatments in Eagle Lake. There is no label restriction on contact use, other than the swimming prohibition for 24 hours after application. A similar prohibition on use in showers is recommended.

The targeted scheduling of fluridone application for May will act to mitigate human exposure during the pilot treatment in Eagle Lake. The cold early season water temperatures do not encourage contact recreation in Eagle Lake until mid-June, thereby reducing the possibility of public exposure to fluridone concentrations at the treatment sites. Treated areas will be posted as such, with use restrictions listed. Additionally, many summer camps which use lake water are not yet occupied during the proposed application period. Fluridone residues are expected to persist for up to 2 months, but only at very low to non-detectable levels. Some overlap between human users and the treatment period is expected, but no health hazards are apparent under the planned program. Should a fall treatment be conducted, similarly minimal interaction with humans is expected.

### Potential Impacts of Fluridone on General Water Quality

Rapid defoliation of aquatic plants can depress dissolved oxygen levels. The combined loss of oxygen input from plant production and the biological degradation of the organic material can decrease dissolved oxygen to undesirable levels. However, it is not expected that this will occur with the use of fluridone in Eagle Lake. Fluridone is a slow acting systemic herbicide and 30 to 90 days are needed before plant die-off occurs. This slow addition of organic material to the water column and sediment surface does not create an immediate intense oxygen demand, and therefore adequate oxygen can be resupplied to the water column through atmospheric diffusion and wind-activated mixing.

In addition to the slow action of fluridone, the cold waters of Eagle Lake in the spring and early summer are nearly saturated with oxygen and would be able to sustain any minor oxygen depletion. Slightly less oxygen would be available in the fall, but no significant oxygen depression is expected. Field tests have been conducted in which aqueous fluridone applications up to 1.0 ppm have been shown to create no changes in many water quality parameters including dissolved oxygen, total phosphorus, pH, specific conductance, nitrate, and turbidity (McLaren/Hart, 1995).

In lakes, the average half life of fluridone is 20 days under aerobic conditions; greater sunlight penetration into the water and higher sunlight intensity reduce the actual half life. The maximum concentration of fluridone following the addition of the aqueous solution (AS form) is during the first day.

**Potential Impacts of Fluridone on Recreational Pursuits and Economic Stability**

Eagle Lake is part of a large regional service-based economy, whereby the lake is an economic focal point. Eagle Lake has only a small residential population, but has a public boat ramp and is a popular recreation site. The lake and much of its surrounding natural setting is the basis for multiple recreational pursuits including but not limited to water sports, boating, fishing, hiking, diving and sightseeing. The lake region is enjoyed by visitors throughout the year, but primarily in the summer season.

Since its discovery in 1982, the impact of Eurasian watermilfoil on Eagle Lake has been of great concern to residents. Fears of lowered property values and decreased enjoyment of the lake by residents and visitors are but a few of the foreseen problems of the increasing milfoil infestation in Eagle Lake. Concern over milfoil in Eagle Lake should be viewed in the larger context of the region as well, as it represents a source of milfoil for other lakes, many with distinct economic value.

Eagle Lake will have a 24 hour prohibition of swimming following the initial and any subsequent fluridone treatments as required by the restricted use product limitations of the NYSDEC. The lake will be posted to restrict swimming for the required 24-hour period. This restriction should cause minimal if any inconvenience as the late spring or fall water temperature of Eagle Lake effectively eliminates swimming as a recreational option.

There is expected to be negligible, if any, negative economic impacts associated with the fluridone treatment in Eagle Lake, and then only as a temporary consequence. Protection of long-term economic health is intended by this program. No long-term negative economic impacts are conceivable, and any temporary impacts will be very small and likely unmeasurable.

**Potential Impacts of Fluridone on Aesthetics and Human Perceptions**

The use of fluridone to control Eurasian watermilfoil is expected to improve the human perception of the lake in those areas of its use. The lake currently contains dense areas of milfoil growth where the plant is at or near the water surface during summer. This condition is not considered the norm in Eagle Lake. Furthermore, these dense milfoil growths can prohibit water sports from occurring in affected areas and can cause the fouling of boat motors. The fluridone treatment in Eagle Lake is intended to eliminate Eurasian watermilfoil from the water column, leaving the majority of the lower growing native plant assemblage intact or at least allowing rapid recovery. With reduced plant biomass in the water column, swimming and boat access can be restored, thus improving the human experience at the lake.

A brief period of cloudy conditions is expected immediately upon introduction of the fluridone to the water as the AS formulation (which is milky), but water clarity should improve within a few hours. There are no unpleasant odors expected to be associated with the fluridone application. Some lake users may have their impression of the lake impaired just by the knowledge of herbicide use, as this connotes degraded conditions to some people. Some public relations effort may be necessary to counteract such negative perceptions, but the Eagle Lake Association supports this program. Dissent will be handled through the SEQR process, but there is strong scientific support for the benefits of milfoil control through fluridone and little substantive evidence of any significant risks under the proposed treatment program. SEQR hearings are expected to offer the opportunity for questions to be addressed in accordance with individual perceptions.

**Mitigation of Impacts**

There is currently no detailed mitigation plan proposed in association with the pilot fluridone treatment program, as there is no anticipated significant adverse impact from that program. Any plausible adverse impacts are expected to be temporary and highly localized, and the monitoring program calls for evaluation for over a year following treatment. No impacts requiring immediate action are expected, based on much available information and the design of the program. Should there be a need for action, possible contingencies include:

- Seeding or transplanting of native vegetation to establish a plant community where none has formed after at least a year (preferable to allow natural recovery with monitoring).
- Replacement of any faunal losses through off-site propagation or translocation (need extremely unlikely and action may be undesirable).
- Provision of water of an adequate quality as replacement for lost supply (need extremely unlikely).
- Payment of damages for any loss of property or utility (need extremely unlikely).

As none of these actions seems remotely likely to be needed, no specific contingency plan is offered. The program is designed to minimize any adverse impact, and to monitor those limited negative impacts that are conceivable (such as the loss of some native vegetation). The only major impact expected is the decline of milfoil in the treated areas, which is considered a benefit and requires no mitigation.

## MONITORING PLAN

### Fluridone Monitoring

Fluridone monitoring will be utilized to ensure proper fluridone levels are maintained for optimum effectiveness in the control of milfoil in Eagle Lake. The need for follow-up treatments will need to be identified quickly so as not to create any significant lapses in fluridone contact time with the target species. The fluridone sampling approach will include collection of water from the two plant monitoring locations and at least four additional sites one week, three weeks and six weeks after treatment. The SePro Fast-Test method will be used to assess fluridone concentration.

### Plant Community Assessment

There have been several assessments of the plant community over the years, including detailed assessments of two sites as part of this program. In preparation for the treatment program, grid systems of 1 $m^2$ plots were installed at each of two sites (Figure 4) and the aquatic community within the grid system was assessed. Monitoring of the grid was conducted in September of 1996 and in August of 1997 and 1998. Diver swim-over surveys were also conducted within the target area but outside the grid, to document any less common species, in September of 1996. Details of the grid systems, locations, survey techniques and plant community are contained in the pre-treatment monitoring report by Eichler and Howe (1998), provided as Appendix A. An overview is provided below.

A grid system has been placed in two areas where milfoil dominates. Both grid systems contain 54 plots of 1 $m^2$ each and were monitored annually in 1996, 1997 and 1998. Swim-over surveys were conducted only in 1996, and involved characterization of the percent cover by each identified species over a range of water depths from 0-8 m (0-27 ft) at 1 m intervals.

Eurasian watermilfoil (*Myriophyllum spicatum*) was dominant or co-dominant at all monitored sites, although coverage by milfoil varied from 0 to 100% in individual grid plots. A total of 23 species of plants were identified within the monitoring areas. Other relatively common species (>15% average cover) include Charophytes and *Potamogeton robbinsii.* The regionally rare *Isoetes macrospora* is known from Eagle Lake but not the monitoring areas.

Measurements of plant community characteristics will again be collected immediately prior to treatment and then again three months and one year following treatment. Additional annual montoring is desirable, but has not yet been arranged. This sampling scheme allows measurement of fluridone effectiveness in controlling milfoil as well as its effects on the native plant assemblage. It allows both an assessment of impacts within the target area and comparison of community features among treatment and control areas.

## Figure 5. Eagle Lake Monitoring Stations

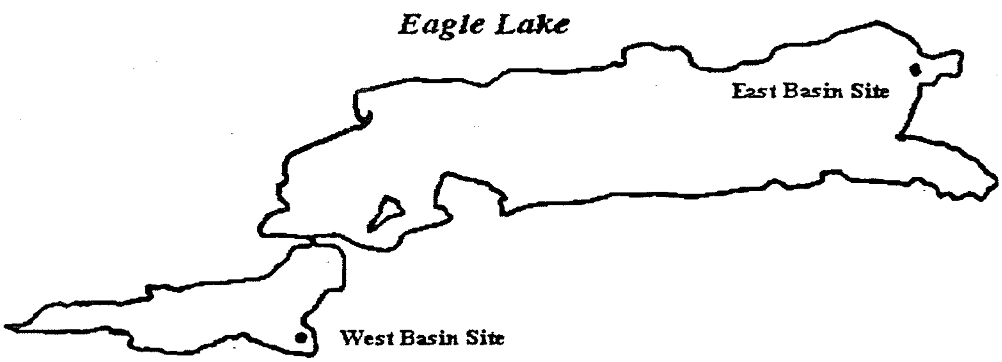
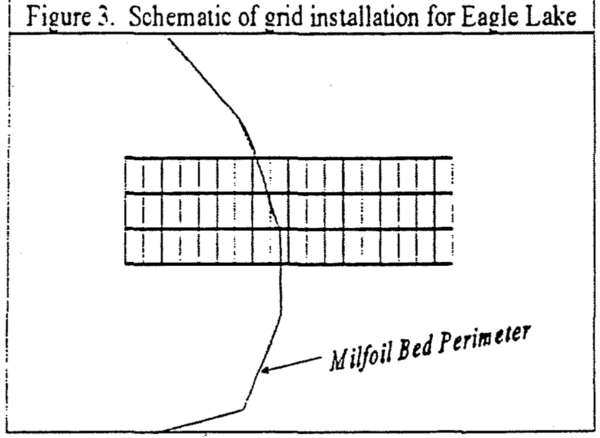



Figure 3. Schematic of grid installation for Eagle Lake



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# APPENDIX

# RESULTS OF PRE-TREATMENT MONITORING OF PROPOSED PILOT SITES

# Darrin Fresh Water Institute
AT LAKE GEORGE

**BASELINE AQUATIC PLANT MONITORING: PRE-TREATMENT FOR A SONAR® DEMONSTRATION PROJECT AT EAGLE LAKE, NEW YORK**

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DFWI Technical Report 98-9

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## Summary

Eurasian watermilfoil (*Myriophyllum spicatum*), an invasive exotic plant species, was reported in Eagle Lake, Essex County, New York in 1987. A survey of aquatic plants in Eagle Lake was completed in 1989 and indicated extensive growth of this nuisance species. Annual visual inspections from 1994 through 1998 confirmed that Eurasian watermilfoil had spread throughout Eagle Lake.

In 1996, an aquatic plant management program keyed to treatment of Eurasian watermilfoil with the herbicide Sonar was proposed for Eagle Lake. This program will be conducted under the auspices of the New York State Department of Environmental Conservation. A whole lake application of the herbicide Sonar is proposed for the spring of 1999.

As part of the aquatic plant management project, the effectiveness of Sonar for control of Eurasian watermilfoil and the impact of Sonar on native aquatic plants will be evaluated. Test plots of semi-permanent grids were established in each of the two sub-basins of the lake in 1996. Aquatic plant diversity and abundance was determined annually from 1996 through 1998 in these test plots. Historical data indicates that Eagle Lake supports a diverse assemblage of native plants, with 37 species reported. Twenty-three species were observed in the test plots in 1998. These baseline data will be used to document effects of the herbicide on native plants and Eurasian watermilfoil populations.

Future surveys are proposed immediately prior to herbicide treatment in the Spring of the year, 3 months and 1 year post-treatment. Coupled with pre-treatment survey data, the effectiveness of the herbicide for Eurasian watermilfoil control and the impact of the treatments on native aquatic plants can be evaluated.

## Introduction

Eurasian watermilfoil (*Myriophyllum spicatum*), an invasive exotic plant species, was reported in Eagle Lake, Essex County, New York in 1987. A survey of aquatic plants in Eagle Lake was completed in 1989 and indicated extensive growth of this nuisance species. Annual visual inspections from 1994 through 1998 confirmed that Eurasian watermilfoil had spread throughout Eagle Lake.

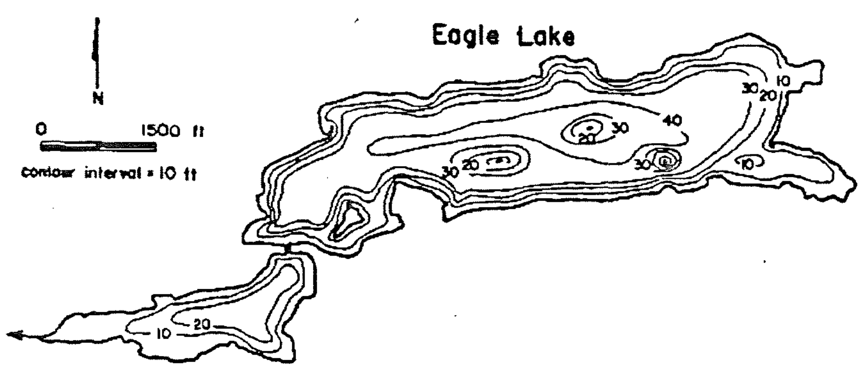
In 1996, an aquatic plant management program keyed to treatment of Eurasian watermilfoil with the herbicide Sonar was proposed for Eagle Lake. This program will be conducted under the auspices of the New York State Department of Environmental Conservation. A whole lake application of the herbicide Sonar is anticipated in the spring of 1999.

As part of the project, the effectiveness of Sonar for control of Eurasian watermilfoil and the impact of Sonar on native aquatic plants will be evaluated. An aquatic plant survey of Eagle Lake was conducted by the Darrin Fresh Water Institute and the New York State Department of Environmental Conservation. The focus of the survey and current report is the status of Eurasian watermilfoil in Eagle Lake, prior to herbicide application. Test plots were established in each of the sub-basins of the lake in 1996. Aquatic plant diversity and abundance were determined annually from 1996 through 1998. This baseline data will be used to document effects of the herbicide on native plants and Eurasian watermilfoil populations.

## Background

Eagle Lake is located in the southern portion of Essex County in the Towns of Ticonderoga and Crown Point. The lake's watershed is located in the foothills of the

**Figure 1. Depth (bathymetric) map of Eagle Lake**



Adirondack Mountains in the Hudson River drainage system. Elevations within the watershed range from 944 feet at the surface of the lake to 1860 feet above sea level.

The lake has a surface area of 420 acres and a steeply sloping watershed of 3452 acres (Mikol and Polsinelli, 1985). Eagle Lake has a maximum depth of 12.8 meters (42 feet) and a mean depth of 5.8 meters (19 feet). Located on the western margin is the only outlet, which is dammed and used to maintain the level of the lake. The lake bottom slopes rapidly away from the shoreline in most places, with limited areas for the growth of aquatic plants.

The lake is separated into two distinct basins (East and West) by a shallow, narrow channel which is confined by a highway bridge for NYS Route 74. Eagle Lake is a soft water, low alkalinity water body typical of many lakes in the Adirondack region of New York. It is dimictic, exhibiting both summer and winter thermal stratification. The lake is best classified as oligotrophic; nutrients necessary for the growth of algae and, subsequently, the myriad of organisms that feed on these plants, are low.

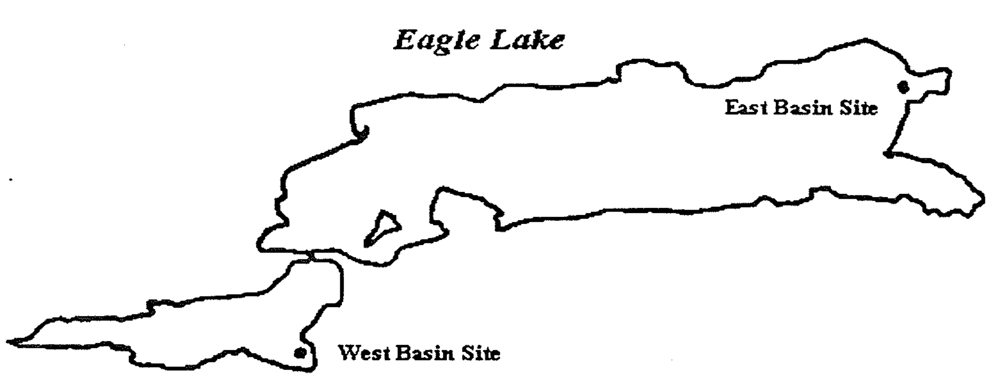
The surficial geology is primarily glacial till, a sand and gravel soil without exposed bedrock. The soil associations are Tunbridge-Lyman and Becket-Tunbridge deposits consisting of loam, fine sands and cobblestones. Drainage in these deposits is rapid and their ability to furnish lime, nitrogen and phosphorus to terrestrial plants is poor.

Eagle Lake is a residential/recreational lake with boating, fishing and swimming as the primary uses. Public access is available via a NYS DEC maintained launch ramp and the NYS Route 74 causeway.

## Methods

Two sites at Eagle Lake were selected for plant community composition analysis. One site was chosen for each sub-basin of Eagle Lake (Figure 2). Plant community composition was determined by relative percent cover of each species within a series of gridded plots installed at each location. Each grid consisted of 18 contiguous $1m^2$ plots. Three grids were placed at each survey site for a total of 54 plots per survey site.

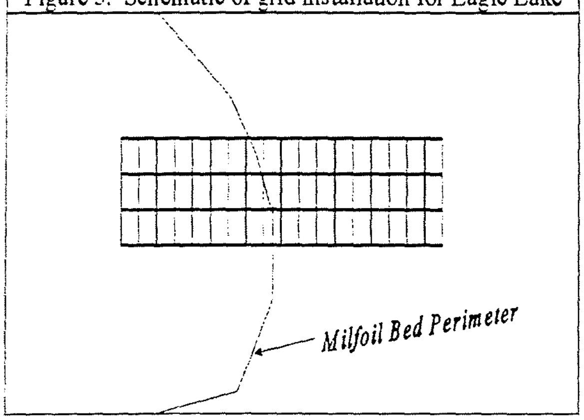
**Figure 2. Map of sampling sites for Eagle Lake.**



Grids were installed in September of 1996 at each sampling location. Divers trained in aquatic plant identification recorded percent cover by species for each square meter using a modified Daubenmire (1959; 1968) scale of percent cover. The grid systems were also surveyed in August of 1997 and 1998, as treatment had not yet occurred. All taxonomic nomenclature is based on Fassett (1957).

**East Basin.** The East Basin sampling site was located adjacent to a rocky outcropping at the eastern end of the lake. This area supports an extensive area of dense growth of Eurasian watermilfoil. Grids consisting of 54 contiguous $1m^2$ plots were installed on September 17, 1996. Grids were installed such that approximately one half of the grid squares were within a dense growth area of Eurasian watermilfoil (Figure 3). The remainder of the grid squares covered areas dominated by native aquatic plants. Sediments in this area were a sand/silt mixture with a thin layer (~5 cm) of silt on the surface. Water depth ranged from 3 to 4 meters.

Figure 3. Schematic of grid installation for Eagle Lake




**West Basin.** The West Basin sampling site was located in a small bay on the southwestern shoreline of the lake. This area supports an extensive area of dense growth of Eurasian watermilfoil. Grids consisting of 54 contiguous $1m^2$ plots were installed on September 17, 1996. Grids were installed such that approximately one half of the grid squares were within a dense growth area of Eurasian watermilfoil (Figure 3). The remainder of the grid squares covered areas dominated by native aquatic plants. Sediments in this area were mainly fine silt overlying sandy soils. Water depth ranged from 2 to 4 meters.

In addition to grid surveys, diver swimover surveys were included at each site to evaluate the rare species which may not appear in the grids. At each location, all aquatic plant species and their relative abundance were recorded at one meter depth intervals using the following abundance classes: abundant (greater than 50% cover), common (25 to 50% cover), present (15 to 25% cover), occasional (5% to 15% cover) and rare (less than 5% cover). Centroid values for each of the abundance classes were used to develop overall community cover. These data provide average depth distributions of plants and an estimate of the relative abundance of all species within the survey area. Swimover surveys were conducted in September of 1996.

**Aquatic Plant Populations**

Aquatic plant species present and their relative abundance were recorded for two locations in Eagle Lake, Essex County, New York. A list of all submersed and floating-leafed aquatic plant species observed is given in Table 1. A total of 23 species were observed. Of these, one group is a macroscopic alga, or charophyte, typically of the genera *Chara* and *Nitella*, three are floating-leafed species (*Brasenia, Nuphar* and *Nymphaea*), three are emergent species (*Eriocaulon*, *Sparganium,* and *Pontederia*) and the remaining 16 species are submersed.

The large number of species observed indicates excellent species richness, typical of low-elevation Northeastern lakes (Madsen et al., 1989). For instance, Lake George has 47 submersed species (RFWI et al., 1988) and 33 were observed in Lake Luzerne in 1989 (Eichler and Madsen, 1990). In both of these lakes, this species richness is threatened by further growth and expansion of an exotic plant species, Eurasian watermilfoil, which will have negative implications for the health of the lakes as a whole (Madsen et al., 1989, 1990).

Surveys of aquatic plants in Eagle Lake were conducted in 1932 (NYS Conservation Dept., 1932), 1989 (Eichler and Madsen, 1990), and 1996-1998 (the current survey). The species lists for the three surveys are similar. Twenty six aquatic plant species were reported in 1932 and twenty seven in 1989. The current survey reported 23 species. Among the three surveys, a total of 37 species of aquatic plants are reported for Eagle Lake.

One major difference in the surveys is the absence of Eurasian watermilfoil in 1932. First reported in 1987, this species was listed in the top twelve species based upon relative abundance in 1989. Other differences in the three surveys generally are in the less common and emergent species which may have been intentionally excluded from the exclusively aquatic plant surveys of 1989 and 1998. American Three Square Sedge (*Dulicium arudinaceum*), for instance, is an extremely common emergent species. Generally associated with marshlands peripheral to the lake, this species was reported in 1932, but not in 1989 or 1998.

The composition of the species list for Eagle Lake was similar to that of other nearby lakes. For instance, all of the species observed in Eagle Lake have been noted for other regional lakes (Ogden et al, 1973; Madsen et al., 1989). Fifteen species are typical for a lake of this type in New York State (Taggett and Boylen, 1990).

One of the plant species observed (*Isoetes macrospora*) is on the New York State Rare Plant list (Mitchell, 1986; Clemants, 1989; Young, 1992). This species generally is found in deeper waters, to 4 meters in Eagle Lake, and thus is easily missed by surveys. Its presence on the rare plant list may be a result of lack of survey data rather than scarcity.

**Table 1. Eagle Lake Aquatic Plant Surveys - 1932 thru 1998**

| Species | Common Name | 1998 | 1989 | 1932 |
|---|---|---|---|---|
| *Bidens beckii* | Water Marigold | X | X | X |
| *Brasenia schreberi* | Water Shield | X | X | X |
| *Ceratophyllum demersum* | Coontail | X | X | |
| *Charophytes* | Chara or Stonewort | X | X | |
| *Dulicium arudinaceum* | Three Way Sedge | | | X |
| *Eleocharis acicularis* | Spike Rush | | X | X |
| *Eleocharis palustris* | Spike Rush | | | X |
| *Elodea canadensis* | Waterweed | X | X | X |
| *Eriocaulon septangulare* | Pipewort | X | X | X |
| *Heteranthera dubia* | Water Stargrass | X | X | |
| *Isoetes echinospora* | Quillwort | | | X |
| *Isoetes macrospora* | Quillwort | | X | |
| *Juncus pelocarpus* | Dwarf Rush | | X | |
| *Lobelia dortmanna* | Water Lobelia | X | X | X |
| *Myriophyllum spicatum* | Eurasian Watermilfoil | X | X | |
| *Najas flexilis* | Water Naiad | X | X | X |
| *Nuphar luteum* | Yellow Water Lily | X | | X |
| *Nymphaea odorata* | White Water Lily | X | X | X |
| *Pontedaria cordata* | Pickerelweed | | X | X |
| *Potamogeton americanus* | American Pondweed | | | X |
| *Potamogeton amplifolius* | Large Leaf Pondweed | X | X | X |
| *Potamogeton compressus* | Pondweed | | | X |
| *Potamogeton epihydrus* | Leafy Pondweed | | X | X |
| *Potamogeton foliosus* | Leafy Pondweed | X | | |
| *Potamogeton gramineus* | Variable Pondweed | X | X | X |
| *Potamogeton natans* | Pondweed | | | X |
| *Potamogeton perfoliatus* | Heart Pondweed | X | | |
| *Potamogeton praelongus* | Large-leaf Pondweed | X | X | X |
| *Potamogeton pusillus* | Pondweed | X | X | X |
| *Potamogeton robbinsii* | Robbins' Pondweed | X | X | X |
| *Potamogeton spirillus* | Pondweed | | X | |
| *Potamogeton vaseyii* | Vasey's Pondweed | | X | |
| *Potamogeton zosteriformes* | Flat-stem Pondweed | X | X | |
| *Sagittaria graminea* | Arrowhead | X | X | X |
| *Sparganium sp.* | Bur-reed | X | X | X |
| *Utricularia vulgaris* | Giant Bladderwort | | | X |
| *Vallisneria americana* | Duck Celery | X | X | X |

## Grid Enumeration

The permanent grids were evaluated annually over a three-year period (1996 – 1998). Aquatic plant presence and relative abundance for all grids are included as Appendix I. The total number of species found within the grid systems ranged from 13 species in 1996 to 14 species in 1997 and 10 species in 1998. The number of species per square meter ranged from 1 to 5 with a mean of 2.5 (± 1.3 SD). Little difference was observed in the average number of species per square meter among survey years (Table 2).

Eurasian watermilfoil dominated the lake bottom in the area of the grids. At the West Basin site, 87% of the grid squares contained some milfoil in 1996. This percentage increased to 91% in 1997 and 1998. The East Basin site ranged from 96% in 1996 to 100% in 1997 and 94% in 1998.

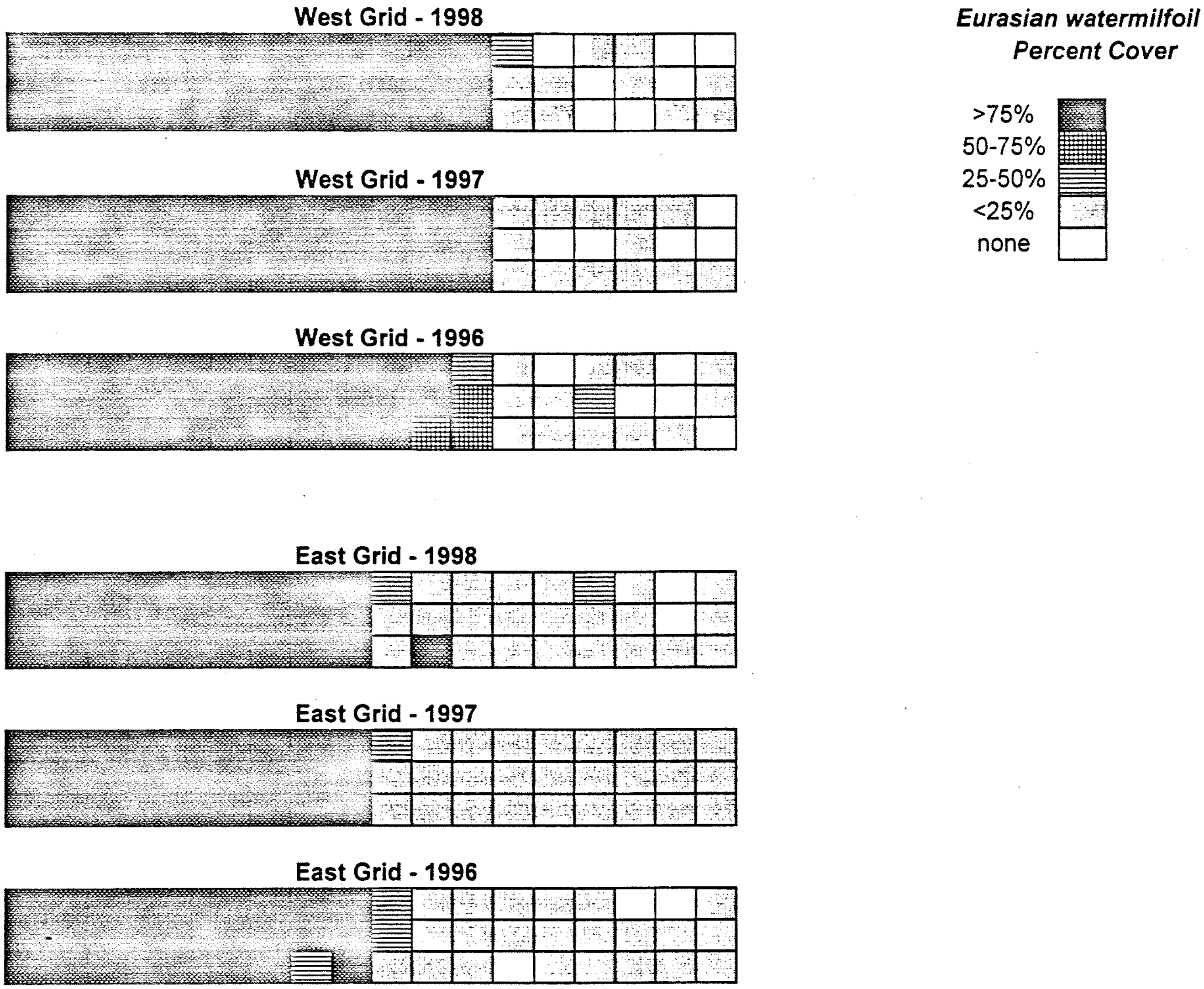
The sub-grids located within the dense growth areas of Eurasian watermilfoil (Sub-Grid #'s 1 & 2) generally produced fewer species per square meter than the sub-grids dominated by native plants (grid #3). The loss of aquatic plant species diversity under a Eurasian watermilfoil canopy is a frequently reported phenomena (Madsen et al., 1991; Boylen et al., 1999).

**Table 2. Grid information for Eagle Lake.**

| Grid Site | Sub-Grid # | Average number of species per $m^2$ | | | Average number of species per grid (54 $m^2$) | | |
|---|---|---|---|---|---|---|---|
| | | 1996 | 1997 | 1998 | 1996 | 1997 | 1998 |
| East | 1 | 1.3 | 1.5 | 1.0 | 5.3 | 6.0 | 4.0 |
| East | 2 | 3.4 | 3.1 | 2.1 | | | |
| East | 3 | 3.2 | 3.8 | 3.5 | | | |
| West | 1 | 2.7 | 2.6 | 1.3 | 5.7 | 5.7 | 4.0 |
| West | 2 | 2.6 | 1.8 | 1.4 | | | |
| West | 3 | 2.8 | 3.7 | 3.1 | | | |

Average percent cover data for all grid squares is provided in Appendix I. Relative percent cover of Eurasian watermilfoil is included as Figure 4. The extent of dense growth of Eurasian watermilfoil has remained relatively constant in the grid system over the past 3 years in Eagle Lake.

Figure 4. Relative percent cover of Eurasian watermilfoil in the grids.



## Diver Swimover Survey

Diver swimover surveys were designed to include less common plants which may not show up in the grid surveys. These surveys also cover a wider range of water depths and sediment types, thus assuring a more complete picture of the aquatic plant species present in the survey area.

**Table 3. Percent cover for the west basin diver swimover survey.**

| Diver Swimover | Depth (m) 0-1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | 7-8 | Cumulative % cover | Average % cover | Mean % cover |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Charophytes | 2.5 | 2.5 | 10 | 10 | 75 | 37.5 | 37.5 | 37.5 | 212.5 | 26.6 | 26.6 |
| Potamogeton robbinsii | | | 2.5 | 37.5 | 37.5 | 75 | 2.5 | 2.5 | 157.5 | 19.7 | 26.3 |
| Myriophyllum spicatum | | 2.5 | 37.5 | 75 | 2.5 | 2.5 | | | 120 | 15 | 24 |
| Najas flexilis | 2.5 | 10 | 10 | 37.5 | 20 | 2.5 | 2.5 | | 85 | 10.6 | 12.1 |
| Potamogeton amplifolius | | 10 | 20 | 37.5 | 2.5 | | | | 70 | 8.75 | 17.5 |
| Potamogeton pusillus | | | 2.5 | 10 | 20 | 20 | 2.5 | | 55 | 6.88 | 11 |
| Potamogeton gramineus | 10 | 20 | 10 | 10 | 2.5 | | | | 52.5 | 6.56 | 10.5 |
| Elodea canadensis | 2.5 | 10 | 10 | 10 | 2.5 | 2.5 | 2.5 | 2.5 | 42.5 | 5.31 | 5.31 |
| Potamogeton praelongus | | | 10 | 20 | 2.5 | | | | 32.5 | 4.06 | 10.8 |
| Vallisneria americana | | 2.5 | 10 | 10 | 2.5 | | | | 25 | 3.13 | 6.25 |
| Bidens beckii | | | 2.5 | 10 | 2.5 | 2.5 | | | 17.5 | 2.19 | 4.38 |
| Heteranthera dubia | 10 | 2.5 | 2.5 | 2.5 | | | | | 17.5 | 2.19 | 4.38 |
| Lobelia dortmanna | 10 | 2.5 | | | | | | | 12.5 | 1.56 | 6.25 |
| Ceratophyllum demersum | | 2.5 | 2.5 | 2.5 | | | | | 7.5 | 0.94 | 2.5 |
| Eriocaulon septangulare | 2.5 | 2.5 | | | | | | | 5 | 0.63 | 2.5 |
| Sparganium sp. | 2.5 | 2.5 | | | | | | | 5 | 0.63 | 2.5 |

average percent cover is based on all depth intervals surveyed
mean percent cover is based on only the depth intervals where the species occurred

At the west basin site (see Table 3), charophytes were the most common species. These macroalgae were present throughout the depth ranges surveyed and dominated the plant community beyond a depth of 4 meters. Another deep water species, *Potamogeton robbinsii*, ranked second in abundance, reaching it's maximum abundance in depths of 5 to 6 meters. Eurasian watermilfoil, *Myriophyllum spicatum* ranked third and reached maximum abundance in water depths of 2 to 4 meters. Within this depth range, no other species achieved a cover rating in excess of 50%. A total of sixteen species were observed at this site during the 1996 survey.

**Table 4. Percent cover for the east basin diver swimover survey.**

| Diver Swimover | Depth (m) 0-1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | 7-8 | Cumulative % cover | Average % cover | Mean % cover |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Myriophyllum spicatum | 2.5 | 10 | 75 | 75 | 2.5 | | | | 165 | 20.6 | 33 |
| Charophytes | 2.5 | 2.5 | | | 20 | 75 | 20 | 2.5 | 122.5 | 15.3 | 20.4 |
| Potamogeton robbinsii | | 2.5 | 2.5 | 20 | 75 | 10 | 2.5 | | 112.5 | 14.1 | 18.8 |
| Najas flexilis | 2.5 | 20 | 10 | 2.5 | 2.5 | 2.5 | 2.5 | | 42.5 | 5.31 | 6.07 |
| Potamogeton pusillus | | 2.5 | 2.5 | 10 | 20 | 2.5 | | | 37.5 | 4.69 | 7.5 |
| Potamogeton praelongus | | | 10 | 20 | 2.5 | | | | 32.5 | 4.06 | 10.8 |
| Vallisneria americana | | 20 | 10 | | | | | | 30 | 3.75 | 15 |
| Bidens beckii | | | 2.5 | 10 | 10 | 2.5 | | | 25 | 3.13 | 6.25 |
| Potamogeton gramineus | 2.5 | 2.5 | 10 | 2.5 | 2.5 | | | | 20 | 2.5 | 4 |
| Nymphaea odorata | | 20 | | | | | | | 20 | 2.5 | 20 |
| Elodea canadensis | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | | 17.5 | 2.19 | 2.5 |
| Potamogeton amplifolius | | 2.5 | | 2.5 | 2.5 | | | | 7.5 | 0.94 | 2.5 |
| Ceratophyllum demersum | | 2.5 | 2.5 | 2.5 | | | | | 7.5 | 0.94 | 2.5 |
| Potamogeton zosteriformes | | 2.5 | 2.5 | 2.5 | | | | | 7.5 | 0.94 | 2.5 |
| Sagittaria graminea | 2.5 | 2.5 | | | | | | | 5 | 0.63 | 2.5 |
| Brasenia schreberi | 2.5 | 2.5 | | | | | | | 5 | 0.63 | 2.5 |
| Eriocaulon septangulare | 2.5 | | | | | | | | 2.5 | 0.31 | 2.5 |
| Nuphar luteum | | | | 2.5 | | | | | 2.5 | 0.31 | 2.5 |

average percent cover is based on all depth intervals surveyed
mean percent cover is based on only the depth intervals where the species occurred

For the east basin site (see Table 4), Eurasian watermilfoil, *Myriophyllum spicatum* dominated and reached maximum abundance in water depths of 2 to 4 meters. Charophytes ranked second with maximum abundance in depths of 5 to 6 meters. *Potamogeton robbinsii* ranked third in abundance, reaching it's maximum abundance in depths of 4 to 5 meters. A total of 18 species were observed at this site during the 1996 survey.

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## APPENDIX I. Aquatic Plant Survey Data

**All percent cover values are centroid or median values of observed ranges.**

## EAGLE LAKE SONAR DEMONSTRATION PROJECT - GRID PERCENT COVER ANALYSIS

| | | | | GRID SQUARE NUMBER | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Date | Basin | Grid | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| Chara/Nitella | 17-Sep-96 | East | N | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 85 | 97.5 | 85 | 15 | 37.5 | 15 | 15 | 97.5 | 85 | 85 | 37.5 | 85 | 97.5 |
| Potamogeton gramineus | 17-Sep-96 | East | N | 15 | 37.5 | 37.5 | 15 | 15 | 15 | 15 | 15 | 15 | 2.5 | 15 | 15 | | 15 | 15 | | 15 | 15 |
| Myriophyllum spicatum | 17-Sep-96 | East | N | | 15 | 2.5 | | | 2.5 | 15 | 15 | 2.5 | 15 | 15 | | 2.5 | 15 | | 15 | 2.5 | 15 |
| Najas flexilis | 17-Sep-96 | East | N | | | | | | | | | | | 2.5 | 15 | | 15 | 15 | | 15 | |
| Potamogeton pusillus | 17-Sep-96 | East | N | | | | | | | | | | | | 2.5 | 2.5 | | 2.5 | 2.5 | | |
| Elodea canadensis | 17-Sep-96 | East | N | | | | | | | | | | 2.5 | | | | | | | | |
| Ceratophyllum demersum | 17-Sep-96 | East | N | | | | | 2.5 | | | | | | | | | | | | | |
| Chara/Nitella | 17-Sep-96 | East | C | 37.5 | | | 37.5 | | | 15 | | | 62.5 | 37.5 | 62.5 | 97.5 | 85 | 85 | 97.5 | 97.5 | 85 |
| Potamogeton gramineus | 17-Sep-96 | East | C | | | | | | | | | | | 15 | 15 | 15 | 15 | 15 | 2.5 | 15 | 37.5 |
| Myriophyllum spicatum | 17-Sep-96 | East | C | 85 | 85 | 97.5 | 37.5 | 97.5 | 97.5 | 85 | 97.5 | 85 | 15 | 37.5 | 37.5 | 15 | 15 | 15 | 15 | 15 | 15 |
| Potàmogeton amplifolius | 17-Sep-96 | East | C | | | | 15 | | | 15 | 15 | 15 | 15 | 15 | 37.5 | 15 | 15 | 15 | | 2.5 | |
| Ceratophyllum demersum | 17-Sep-96 | East | C | | | 2.5 | 15 | 2.5 | 15 | 2.5 | 2.5 | 2.5 | | | 2.5 | | | 2.5 | | 2.5 | |
| Najas flexilis | 17-Sep-96 | East | C | | | | | | | | | | 2.5 | | | | 2.5 | | | | |
| Potamogeton pusillus | 17-Sep-96 | East | C | | | | | | | | | | | 2.5 | | | | | | | |
| Myriophyllum spicatum | 17-Sep-96 | East | S | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 |
| Ceratophyllum demersum | 17-Sep-96 | East | S | | | 2.5 | | 15 | | 2.5 | | | 2.5 | | 15 | | 15 | | | | |
| Potamogeton robbinsii | 17-Sep-96 | West | W | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 15 | 37.5 | 37.5 | 15 | 37.5 | 15 | 37.5 | 37.5 | 15 | 37.5 | 15 | 15 | 15 |
| Chara/Nitella | 17-Sep-96 | West | W | 37.5 | 15 | 62.5 | 37.5 | 37.5 | 85 | 37.5 | 62.5 | 85 | 62.5 | 62.5 | 85 | 37.5 | 37.5 | 15 | 37.5 | 37.5 | 15 |
| Potamogeton pusillus | 17-Sep-96 | West | W | | | | | | 2.5 | 2.5 | | | | | 2.5 | 15 | | | | 15 | |
| Myriophyllum spicatum | 17-Sep-96 | West | W | 15 | 15 | 15 | 15 | 15 | | 15 | 37.5 | 15 | 15 | | 15 | 15 | | | | 15 | 15 |
| Najas flexilis | 17-Sep-96 | West | W | | | | | | | | | | | | 15 | | | | | | |
| Myriophyllum spicatum | 17-Sep-96 | West | C | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 85 | 62.5 | 85 | 97.5 | 62.5 | 62.5 | 37.5 |
| Potamogeton robbinsii | 17-Sep-96 | West | C | | | 15 | | 15 | | 15 | | | | | | 15 | 15 | 15 | 15 | 15 | 37.5 |
| Chara/Nitella | 17-Sep-96 | West | C | | | | | | | | | | | | | | | | 15 | 15 | 15 |
| Bidens beckii | 17-Sep-96 | West | C | | | | | | | | | | | | | 15 | | | 15 | | |
| Najas flexilis | 17-Sep-96 | West | C | | | | | | | | | | 15 | | | | | 15 | | 15 | 15 |
| Vallisneria americana | 17-Sep-96 | West | C | 15 | 15 | 15 | | 15 | | | | | 15 | 15 | | 15 | 15 | | | 15 | 15 |
| Myriophyllum spicatum | 17-Sep-96 | West | E | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 |
| Vallisneria americana | 17-Sep-96 | West | E | 2.5 | 15 | | | 15 | | | | 15 | | | | 15 | | | | | 15 |
| Potamogeton robbinsii | 17-Sep-96 | West | E | 15 | 15 | 15 | | | | 15 | | | | | | 15 | | 15 | 15 | | 15 |
| Bidens beckii | 17-Sep-96 | West | E | | | | | | | | | | | | | | | | 37.5 | 15 | 15 |
| Potamogeton amplifolius | 17-Sep-96 | West | E | | | | | | | | | | | | | | 15 | 15 | | | |
| Potamogeton praelongus | 17-Sep-96 | West | E | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | | 15 | 15 | | | | 15 | | | |

## EAGLE LAKE SONAR DEMONSTRATION PROJECT - GRID PERCENT COVER ANALYSIS

| | | | | GRID SQUARE NUMBER | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Date | Basin | Grid | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| Chara/Nitella | 28-Aug-97 | East | N | 97.5 | 97.5 | 97.5 | 62.5 | 85 | 85 | 97.5 | 2.5 | 2.5 | 37.5 | 37.5 | 2.5 | 97.5 | 85 | 97.5 | 62.5 | 97.5 | 97.5 |
| Potamogeton gramineus | 28-Aug-97 | East | N | | | | | | | | | | | | | | | | | | |
| Myriophyllum spicatum | 28-Aug-97 | East | N | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Najas flexilis | 28-Aug-97 | East | N | | | | | 2.5 | 2.5 | | 2.5 | 2.5 | 2.5 | 2.5 | 15 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Potamogeton pusillus | 28-Aug-97 | East | N | 15 | 15 | 15 | 2.5 | 2.5 | 15 | 15 | 15 | 15 | 15 | 2.5 | 2.5 | 15 | 2.5 | | 15 | 2.5 | 37.5 |
| Potamogeton amplifolius | 29-Aug-97 | East | N | | 2.5 | | | | | | | | | | | | | | | | |
| Potamogeton zosteriformes | 29-Aug-97 | East | N | | | | | | | | | | | | | | | | 2.5 | | |
| Elodea canadensis | 28-Aug-97 | East | N | | | | | | | 2.5 | | | | | | | | | | | |
| Ceratophyllum demersum | 28-Aug-97 | East | N | | | | 2.5 | | | | | | | | | | | | | | |
| Chara/Nitella | 28-Aug-97 | East | C | | | | | | | | | | 85 | 85 | 62.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 |
| Potamogeton gramineus | 28-Aug-97 | East | C | | | | | | | | | | 15 | 15 | 15 | | 15 | 15 | | 15 | 15 |
| Myriophyllum spicatum | 28-Aug-97 | East | C | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 15 | 15 | 37.5 | 15 | 15 | 15 | 15 | 15 | 15 |
| Potamogeton amplifolius | 28-Aug-97 | East | C | | | | 15 | | 15 | 15 | 15 | | 15 | 15 | | 15 | 15 | 15 | | 15 | |
| Ceratophyllum demersum | 28-Aug-97 | East | C | | | | 15 | 15 | | 15 | | 15 | | | 15 | | | | 2.5 | | |
| Potamogeton pusillus | 28-Aug-97 | East | C | | | | | | | | | | | 15 | | | | | | | |
| Elodea canadensis | 28-Aug-97 | East | C | 15 | | | | | | 15 | 15 | | 15 | | | | | | | | |
| Myriophyllum spicatum | 28-Aug-97 | East | S | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 |
| Ceratophyllum demersum | 28-Aug-97 | East | S | 15 | | | 15 | 15 | | 15 | | 15 | | 15 | | | 15 | | 15 | | 15 |
| | | | | | | | | | | | | | | | | | | | | | |
| Potamogeton robbinsii | 28-Aug-97 | West | W | 37.5 | 37.5 | 62.5 | 62.5 | 37.5 | 15 | 62.5 | 62.5 | 37.5 | 37.5 | 15 | 37.5 | 15 | 2.5 | 15 | 2.5 | 2.5 | 15 |
| Chara/Nitella | 28-Aug-97 | West | W | 15 | 2.5 | 2.5 | 62.5 | 37.5 | 62.5 | 15 | 2.5 | 15 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Potamogeton pusillus | 28-Aug-97 | West | W | 2.5 | | | | 2.5 | | 15 | | | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Myriophyllum spicatum | 28-Aug-97 | West | W | 15 | 2.5 | 15 | 2.5 | | 2.5 | 2.5 | | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | | 2.5 | 2.5 | | |
| Najas flexilis | 28-Aug-97 | West | W | 2.5 | 2.5 | 15 | | | | | | 2.5 | | | 2.5 | | | | | | |
| Bidens beckii | 29-Aug-97 | West | W | | | 2.5 | | | | | | | | | | | | | | | |
| Myriophyllum spicatum | 28-Aug-97 | West | C | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 85 | 85 | 85 |
| Potamogeton robbinsii | 28-Aug-97 | West | C | | | | | | | | | | | | | 15 | 15 | | 15 | 15 | 15 |
| Chara/Nitella | 28-Aug-97 | West | C | | | | | | | | | | | | | | | | 15 | | |
| Vallisneria americana | 28-Aug-97 | West | C | | | 15 | | | | | | | | 15 | | 15 | 15 | 15 | 15 | 15 | 15 |
| Myriophyllum spicatum | 28-Aug-97 | West | E | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 |
| Vallisneria americana | 28-Aug-97 | West | E | | 2.5 | | 15 | | 15 | 2.5 | 2.5 | 2.5 | | | | | | 2.5 | 15 | | |
| Potamogeton robbinsii | 28-Aug-97 | West | E | 15 | 2.5 | 15 | 2.5 | 15 | 15 | 2.5 | 2.5 | 2.5 | | | | | 2.5 | 2.5 | 2.5 | | 15 |
| Heteranthera dubia | 28-Aug-97 | West | E | 2.5 | | | | | | | | | | | | | | | | | |
| Potamogeton pusillus | 29-Aug-97 | West | E | 15 | | | | | | | | | | | | | | | | | |
| Potamogeton amplifolius | 28-Aug-97 | West | E | | | 15 | | | | 15 | | | | | | | | | | | |
| Potamogeton praelongus | 28-Aug-97 | West | E | | 2.5 | 15 | 15 | 2.5 | | | | | | | 15 | | | | | | |

## EAGLE LAKE SONAR DEMONSTRATION PROJECT - GRID PERCENT COVER ANALYSIS

| Species | Date | Basin | Grid | GRID SQUARE NUMBER 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chara/Nitella | 28-Aug-98 | East | N | 97.5 | 97.5 | 97.5 | 85 | 62.5 | 15 | 15 | 37.5 | 85 | 37.5 | 37.5 | 62.5 | 85 | 85 | 85 | 97.5 | 97.5 | 62.5 |
| Potamogeton gramineus | 28-Aug-98 | East | N | 2.5 | | 2.5 | 2.5 | 15 | 37.5 | 37.5 | 15 | | 37.5 | 15 | | 2.5 | 2.5 | 2.5 | | 2.5 | 15 |
| Myriophyllum spicatum | 28-Aug-98 | East | N | 2.5 | 2.5 | 15 | 15 | 15 | 2.5 | 37.5 | 2.5 | 15 | 2.5 | 15 | 15 | | | 2.5 | 2.5 | 2.5 | 2.5 |
| Najas flexilis | 28-Aug-98 | East | N | | | | | | | | 2.5 | | 2.5 | | | 2.5 | 2.5 | 2.5 | | | 2.5 |
| Potamogeton pusillus | 28-Aug-98 | East | N | | | | | | 2.5 | | | | 2.5 | | | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 15 |
| Potamogeton amplifolius | 28-Aug-98 | East | N | | | | | 15 | | | | | | | | | | | | | |
| Chara/Nitella | 28-Aug-98 | East | C | | | | | | | | | 2.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 2.5 | 97.5 | 97.5 | 97.5 |
| Potamogeton gramineus | 28-Aug-98 | East | C | | | | | | | | | | 37.5 | | | | | | 2.5 | 2.5 | 2.5 |
| Myriophyllum spicatum | 28-Aug-98 | East | C | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 85 | 37.5 | 15 | 15 | 2.5 | 15 | 97.5 | 2.5 | 2.5 | 2.5 |
| Potamogeton amplifolius | 28-Aug-98 | East | C | | | | | | | | | 2.5 | | 2.5 | | | 2.5 | | | 2.5 | 2.5 |
| P. zosteriformes | 28-Aug-98 | East | C | | | | | | | | | | | | | | | | | | 2.5 |
| Myriophyllum spicatum | 28-Aug-98 | East | S | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 |
| | | | | | | | | | | | | | | | | | | | | | |
| Potamogeton robbinsii | 28-Aug-98 | West | W | 37.5 | 62.5 | 85 | 37.5 | 15 | 37.5 | 15 | 15 | 62.5 | 37.5 | 15 | 37.5 | 15 | 2.5 | 37.5 | 15 | 2.5 | |
| Chara/Nitella | 28-Aug-98 | West | W | 15 | 15 | 37.5 | 62.5 | 85 | 37.5 | 85 | 37.5 | 37.5 | 85 | 37.5 | 85 | 15 | 15 | 62.5 | 15 | 37.5 | 62.5 |
| Potamogeton pusillus | 28-Aug-98 | West | W | 2.5 | | | | | | 2.5 | | 2.5 | | | | | | 2.5 | | 2.5 | 2.5 |
| Myriophyllum spicatum | 28-Aug-98 | West | W | 15 | 15 | 37.5 | 2.5 | 2.5 | | | | 2.5 | | 2.5 | 2.5 | 2.5 | | | 2.5 | 2.5 | |
| Najas flexilis | 28-Aug-98 | West | W | | | | | | | | 2.5 | | 2.5 | | | | | | | | |
| Myriophyllum spicatum | 28-Aug-98 | West | C | 85 | 85 | 85 | 97.5 | 97.5 | 97.5 | 85 | 85 | 85 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 |
| Potamogeton robbinsii | 28-Aug-98 | West | C | | | | | | | | | | | | | | | | 2.5 | | 2.5 |
| Vallisneria americana | 28-Aug-98 | West | C | | | | | | | 2.5 | 2.5 | 2.5 | | | | | 2.5 | | 2.5 | | 2.5 |
| Myriophyllum spicatum | 28-Aug-98 | West | E | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 |
| Vallisneria americana | 28-Aug-98 | West | E | | 2.5 | | | | 2.5 | | | | | | | | | | | | |
| Potamogeton perfoliatus | 28-Aug-98 | West | E | | 2.5 | | | | 2.5 | | | | | | | | | | | | |
| P. zosteriformes | 28-Aug-98 | West | E | | | | | | 2.5 | | | | | | | | | | | | |

EAGLE LAKE SONAR DEMONSTRATION PROJECT - DIVER SWIMOVER SURVEY

| | | | Depth (m) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| SPECIES | DATE | BASIN | 0-1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | 7-8 |
| Chara/Nitella | 17-Sep-96 | West | 2.5 | 2.5 | 10 | 10 | 75 | 37.5 | 37.5 | 37.5 |
| Potamogeton gramineus | 17-Sep-96 | West | 10 | 20 | 10 | 10 | 2.5 | | | |
| Myriophyllum spicatum | 17-Sep-96 | West | | 2.5 | 37.5 | 75 | 2.5 | 2.5 | | |
| Potamogeton amplifolius | 17-Sep-96 | West | | 10 | 20 | 37.5 | 2.5 | | | |
| Ceratophyllum demersum | 17-Sep-96 | West | | 2.5 | 2.5 | 2.5 | | | | |
| Najas flexilis | 17-Sep-96 | West | 2.5 | 10 | 10 | 37.5 | 20 | 2.5 | 2.5 | |
| Potamogeton pusillus | 17-Sep-96 | West | | | 2.5 | 10 | 20 | 20 | 2.5 | |
| Eriocaulon septangulare | 17-Sep-96 | West | 2.5 | 2.5 | | | | | | |
| Lobelia dortmanna | 17-Sep-96 | West | 10 | 2.5 | | | | | | |
| Vallisneria americana | 17-Sep-96 | West | | 2.5 | 10 | 10 | 2.5 | | | |
| Elodea canadensis | 17-Sep-96 | West | 2.5 | 10 | 10 | 10 | 2.5 | 2.5 | 2.5 | 2.5 |
| Bidens beckii | 17-Sep-96 | West | | | 2.5 | 10 | 2.5 | 2.5 | | |
| Heteranthera dubia | 17-Sep-96 | West | 10 | 2.5 | 2.5 | 2.5 | | | | |
| Potamogeton praelongus | 17-Sep-96 | West | | | 10 | 20 | 2.5 | | | |
| Potamogeton robbinsii | 17-Sep-96 | West | | | 2.5 | 37.5 | 37.5 | 75 | 2.5 | 2.5 |
| Sparganium sp. | 17-Sep-96 | West | 2.5 | 2.5 | | | | | | |
| | | | | | | | | | | |
| Chara/Nitella | 17-Sep-96 | East | 2.5 | 2.5 | | | 20 | 75 | 20 | 2.5 |
| Potamogeton gramineus | 17-Sep-96 | East | 2.5 | 2.5 | 10 | 2.5 | 2.5 | | | |
| Myriophyllum spicatum | 17-Sep-96 | East | 2.5 | 10 | 75 | 75 | 2.5 | | | |
| Potamogeton amplifolius | 17-Sep-96 | East | | 2.5 | | 2.5 | 2.5 | | | |
| Ceratophyllum demersum | 17-Sep-96 | East | | 2.5 | 2.5 | 2.5 | | | | |
| Najas flexilis | 17-Sep-96 | East | 2.5 | 20 | 10 | 2.5 | 2.5 | 2.5 | 2.5 | |
| Potamogeton pusillus | 17-Sep-96 | East | | 2.5 | 2.5 | 10 | 20 | 2.5 | | |
| Eriocaulon septangulare | 17-Sep-96 | East | 2.5 | | | | | | | |
| Sagittaria graminea | 17-Sep-96 | East | 2.5 | 2.5 | | | | | | |
| Vallisneria americana | 17-Sep-96 | East | | 20 | 10 | | | | | |
| Elodea canadensis | 17-Sep-96 | East | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | |
| Bidens beckii | 17-Sep-96 | East | | | 2.5 | 10 | 10 | 2.5 | | |
| Potamogeton praelongus | 17-Sep-96 | East | | | 10 | 20 | 2.5 | | | |
| Potamogeton robbinsii | 17-Sep-96 | East | | 2.5 | 2.5 | 20 | 75 | 10 | 2.5 | |
| Nymphaea odorata | 17-Sep-96 | East | | 20 | | | | | | |
| Potamogeton zosteriformes | 17-Sep-96 | East | | 2.5 | 2.5 | 2.5 | | | | |
| Brasenia schreberi | 17-Sep-96 | East | 2.5 | 2.5 | | | | | | |
| Nuphar luteum | 17-Sep-96 | East | | | | 2.5 | | | | |

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