6.1 AQUATIC PLANT CHARACTERIZATION

EURASIAN MILFOIL IDENTIFICATION

Species: *Myriophyllum spicatum L.*, Eurasian milfoil, Eurasian watermilfoil
Family: Haloragaceae

Eurasian watermilfoil (Figure 6.1) is an invasive "exotic" species listed on the state noxious weed list. Exotic means that it is not native to this area, but it is native to Europe, Asia and Northern Africa. Figure 6.2 illustrates the range of Eurasian watermilfoil throughout the United States.

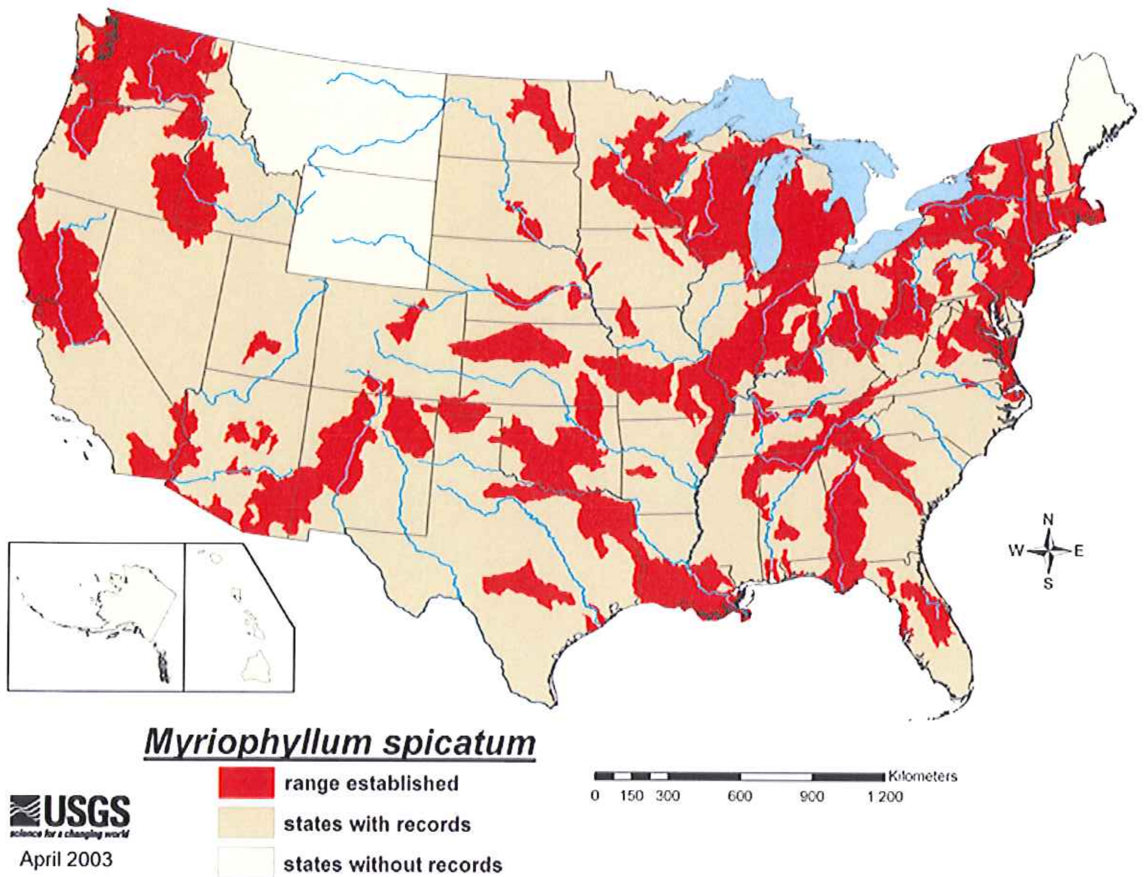


Figure 6.2 Range of Eurasian watermilfoil (Jacono and Richerson, 2003)

Eurasian watermilfoil is a perennial, rooted plant. It is mostly submerged, but can grow as an emergent in situations where the water level slowly recedes and strands the plants on higher ground. Typically, Eurasian milfoil can be found in depths to 20± feet. The stem is highly branched near the water surface. New leafy growth appears red early in the growing season. In late summer, most of the plant's mass is concentrated at the surface, forming characteristic floating mats. Either plants over winter in a dormant state or

remain evergreen in milder climates. They are usually well established by mid-spring, flowering in June or July, and in full vegetative growth by August. Die back occurs during the fall to early winter season. Plant fragments are viable at all times of the year. Left undisturbed, Eurasian milfoil "auto-fragments" in the fall, when the plant becomes brittle and comes apart on its own. Sometimes sparse new green growth continues to be produced until December or January, at which time the plants become dormant or near dormant. Eurasian Milfoil can tolerate a large variation in environmental conditions, sediments, pH conditions, and fresh to brackish water (Daniel and Freeland, 1999).

Eurasian watermilfoil has slender stems whorled by submersed feathery leaves and tiny flowers produced above the water surface. The flowers are located in the axils of the floral bracts, and are either four-petaled or without petals. The leaves are threadlike, typically uniform in diameter, and aggregated into a submersed terminal spike. The stem thickens below the inflorescence and doubles its width further down, often curving to lie parallel with the water surface. The fruits are four-jointed nut-like bodies. Without flowers or fruits, Eurasian watermilfoil is nearly impossible to distinguish from Northern watermilfoil. Eurasian milfoil is a variable species, often making it difficult to identify without chemical or DNA analysis. Because it is an extremely invasive plant, it is important to distinguish Eurasian milfoil from native milfoils. Eurasian watermilfoil has 9-21 pairs of leaflets per leaf; while Northern milfoil typically has 7-11 pairs of leaflets (see Figure 6.3). Coontail is often mistaken for the milfoils, but does not have individual leaflets (Wisconsin Department of Natural Resources, 2003). Table 6.1 characterizes *Myriophyllum spicatum L.*, Eurasian milfoil.

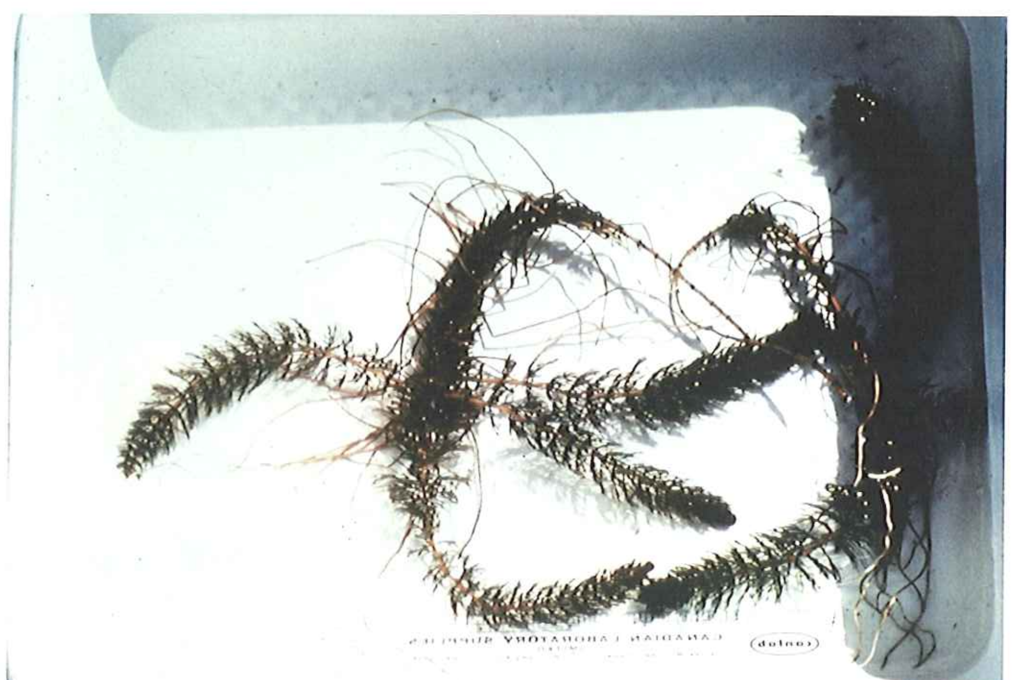


Figure 6.1 *Myriophyllum spicatum L.*, Eurasian milfoil

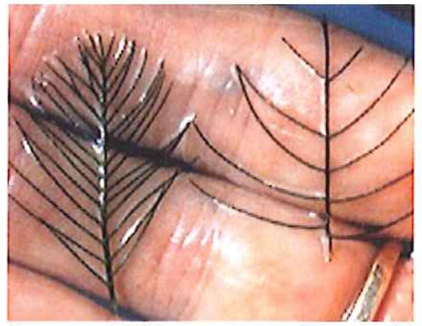


Figure 6.3 Eurasian watermilfoil *Myriophyllum spicatum* (left – 15 leaflet pairs) and Northern milfoil *Myriophyllum sibiricum* (right – 5 leaflet pairs) distinction

Eurasian watermilfoil reproduces primarily by "auto fragmentation" of the stems and propagating root crowns, thus it does not rely on seed for reproduction. This reproduction allows the plant fragments to be dispersed and carried by water currents and wind or inadvertently picked up by boaters. Seed production has been documented, but is considered a minor reproductive mechanism under typical growth conditions. "Milfoil reproduces extremely rapidly and can infest an entire lake within two years of introduction to the system" (Washington State Department of Ecology, 2003). Milfoil is most commonly transported via boats, motors, trailers, bilges, live wells, waterfowl, or bait buckets, and if moist can stay alive for weeks.

Eurasian milfoil is very invasive and can provide only a single habitat by replacing the native plant species and in turn threatening the integrity of aquatic communities. It also inhibits the aesthetic and recreational uses like swimming, boating, and fishing. Severely infested waters display a dense yellow-green matt of vegetation and give off the appearance that the water is "infested" or "dead". The decomposition of the plant mass at the end of the season results in nitrogen and phosphorus loading, and "the cycling of nutrients from sediments to the water column by Eurasian watermilfoil may lead to deteriorating water quality and algae blooms of infested lakes" (Wisconsin Department of Natural Resources, 2003).

Eurasian watermilfoil was believed to have been introduced to the eastern United States around the 1940s, but it may have arrived as early as the late 1800s. The first known herbarium milfoil specimen in Washington was collected from Lake Meridian near Seattle in 1965 (Washington State Department of Ecology, 2003).

Property	*Description*
Leaf	Two types. Submersed leaves: 2-4 cm long, feather-like, arranged in whorls of 4 around the stem. Leaves are often square at the tip and typically have greater than 14 leaflet pairs per leaf. On mature plants, the leaflets are closely crowded along the midrib. Emergent leaves: tiny (1-3 mm long), smooth edged to toothed, located on the flower spikes with one leaf beneath each flower, leaves shorter than flowers.
Stem	Long, often abundantly branched stems form a reddish or olive-green surface mat in summer.
Flower	Tiny. On reddish emergent spikes 4-8 cm long. Female flowers lack petals, 4 petals on male flowers, 8 anthers.
Fruit	Up to 3 mm in diameter, divided into 4 chambers, with 1 seed per chamber.
Root	Many, fibrous, from the plant base. Roots often develop from plant fragments.
Propagation	Plant fragments; rhizomes. Sprouting from seed is rare.
Importance of Plant	This invasive plant spreads rapidly, crowding out native species, clogging waterways, and blocking sunlight and oxygen from underlying waters.
Distribution	Native to Eurasia and northern Africa, but is a widespread weed in North America. Found in many lakes and rivers throughout Washington.
Habitat	Lakes, rivers, and ponds. Tolerates a wide range of water conditions.
May be confused with	Northern milfoil *(Myriophyllum sibiricum),* which has fewer than 14 leaflet pairs per leaf, generally has stouter stems, and produces winter buds. When lacking flower stalks, Eurasian milfoil is also easily confused with most other milfoils.

Table 6.1 Eurasian milfoil identification (Washington State Department of Ecology, 2001a).

CHARACTERIZATION

Due to the concerns about Liberty Lake's health and quality of water, numerous aquatic macrophyte studies and distribution/abundance surveys have occurred. Many of these studies have taken place through the State of Washington Water Research Center at Washington State University and date back as far as the mid 1970s. The bulk of these studies and surveys concentrated on the macrophyte community and their relationship(s) between eutrophication, nutrient enrichment and cycling, phytoplankton productivity, and the depth of light penetration. However, in 1997, following the restoration work, lake residents perceived that the macrophyte beds seemed to be expanding and becoming more dense and close to the surface. While this is an effect frequently noticed in lakes following water clarity improvement, there was a concern that this increased growth might become a nuisance to lake users. Michael Kennedy Consulting Engineers, therefore, implemented the summer of 1987 study in order to assess the seasonal growth of macrophytes to make comparisons to conditions observed in previous years.

Since 1995 with the introduction of Eurasian watermilfoil, the surveys have taken on a new role. Currently the purpose of these surveys is to characterize and quantify the aquatic plant community to be able to distinguish temporal changes in the distribution and abundance of Eurasian watermilfoil and other aquatic plants. The surveys provide baseline data that can be used to evaluate control treatments (or no treatments).

After the initial discovery of milfoil in 1995, a comprehensive diving survey was conducted by Clearwater Scuba, L.L.C.. "The purpose of this survey was to determine the presence or absence of Eurasian watermilfoil and to characterize the nature and extent of the aquatic macrophyte community in Liberty Lake" (Moore, 1995). A year later in 1996, the Liberty Lake Sewer and Water District commissioners considered various options to deal with this serious threat to lake health, and successfully applied for a grant from the Washington Department of Ecology to provide financial assistance in their actions. Effective March 1, 1996, the LLSWD was awarded an early infestation grant of $12,000 for an early intervention project. This grant yielded another comprehensive diving survey to be conducted in the summer of 1996. The results of the survey and control actions are reported in the document *Liberty Lake Early Intervention Milfoil Control Project: Summer 1996*, Moore (1996).

Since the initial comprehensive surveys in 1995 and 1996, additional Scuba surveys and surface observations by Clearwater Scuba, L.L.C. and the Liberty Lake Sewer and Water District have occurred each subsequent year to distinguish temporal changes in the distribution and abundance of Eurasian watermilfoil. *Milfoil Control Activities at Liberty Lake, Summary and Recommendations, 1999 and 2000* describe in depth details of substantial milfoil control activities in Liberty Lake for the summers of 1999 and 2000. Beginning in 2002, Eurasian watermilfoil distribution surveys became geographically referenced using a Trimble GeoExplorer3 GPS. The point features and their attributes are transferred to ArcView geographic information system and mapped. Each point feature represents a single plant or a cluster of plants within a 10-meter radius (large beds are noted). Figure 6.4 and Figure 6.5 display the location and distribution of Eurasian watermilfoil in 2002 and 2003 respectively.

Figure 6.4 2002 Eurasian watermilfoil distribution

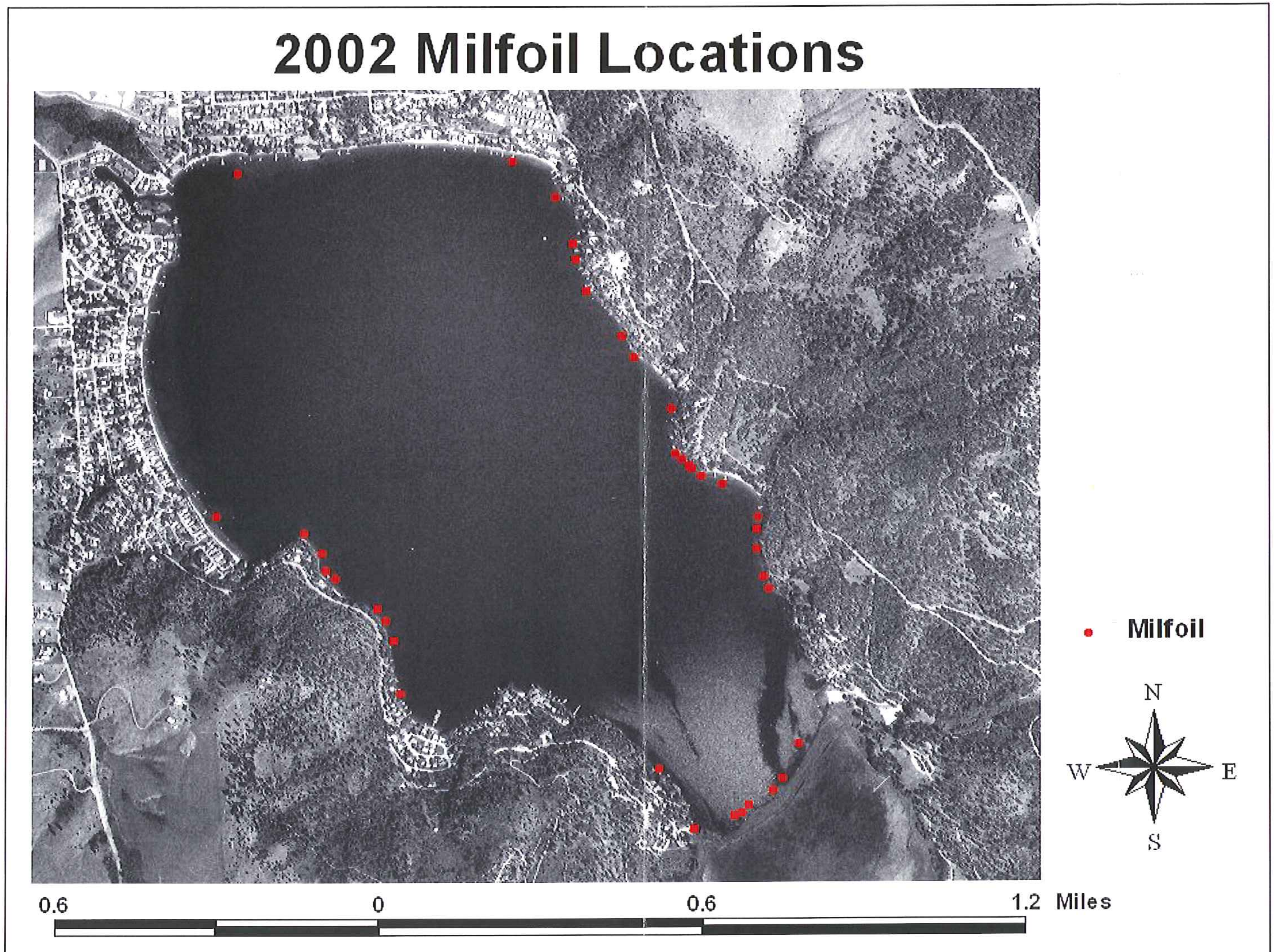
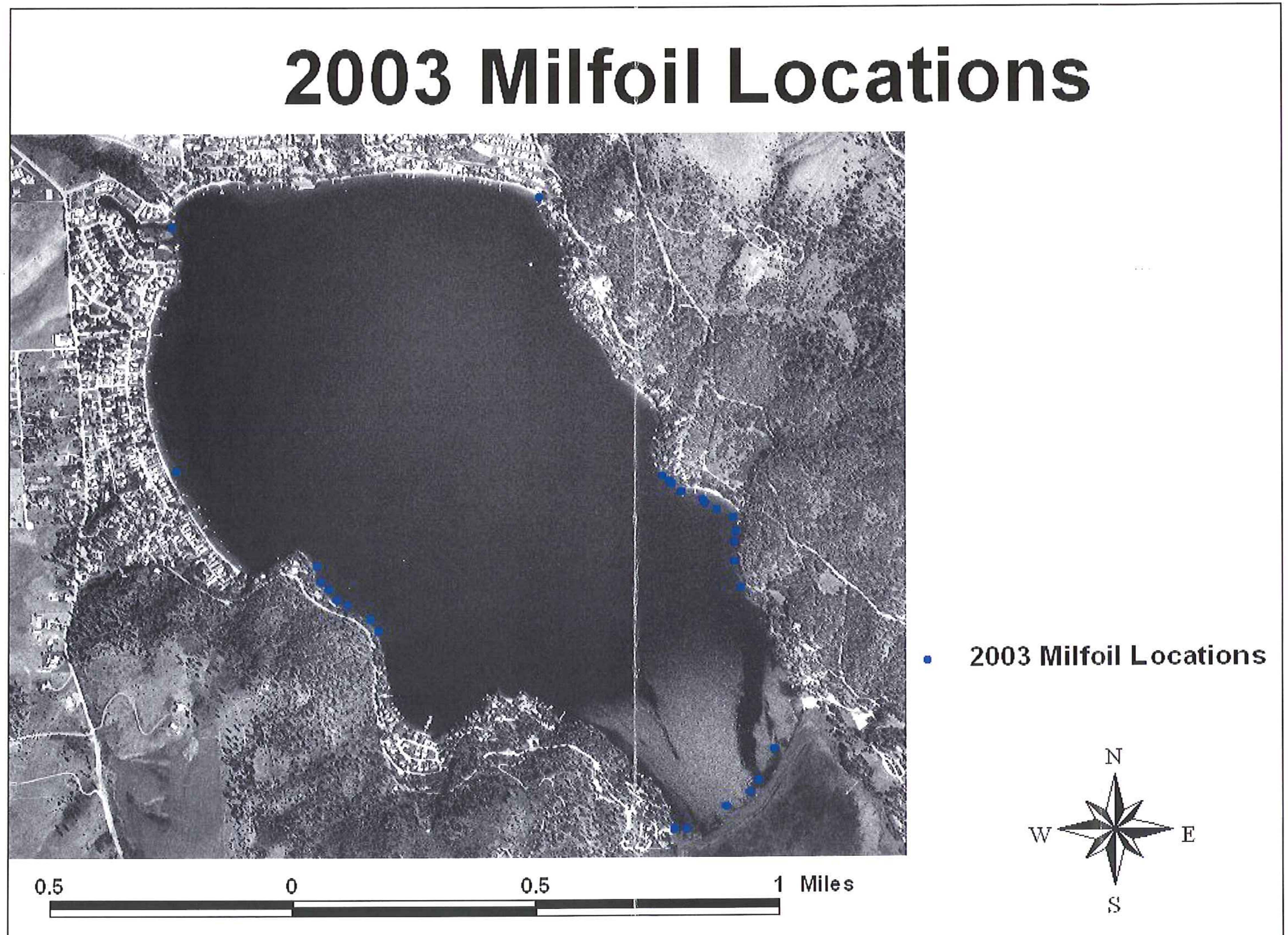


Figure 6.5 2003 Eurasian watermilfoil distribution



In 2003, late spring water transparency problems created complications in Eurasian watermilfoil surveys. With less than 1 meter of clarity, it was difficult to conduct intensive Scuba and boat shoreline surveys. Comprehensive surveys were critical to clarify what new fragmentation and expansion occurred because of the rapid growth and population expansion observable in 2002. This clarification was imperative for the determination of the necessity and localities for a 2003 aquatic 2,4-D treatment. Eurasian watermilfoil Scuba and boat shoreline surveys in 2003 were only as effective as visibility permitted. The aquatic 2,4-D treatment conducted in 2003 was primarily based on the 2002 results but also incorporated the current years surveys.

Other Macrophytes

The 1995 survey noted extensive and relatively dense macrophyte beds located throughout most of the suitable shallow water habitats. The location and species composition of many of these beds, particularly in the south end, is thought to have changed little over the past 15 years. However, macrophyte beds have expanded in many areas where they were previously not present, particularly into deeper waters. Based on data collected from Liberty Lake for the years 1975-1983, the plant coverage and distribution is shown in Figures 6.6 through 6.11 (after Kennedy, 1979 and McKarns, 1985). It is of interest to the LLSWD as part of this plan to update the macrophyte distributions and densities throughout the lake and produce a comprehensive map.

Although plant densities and distributions were not a part of the 1995 survey, the macrophyte beds do appear to be generally denser than in previous years. The macrophyte community represented in 1995 is composed principally of large-leafed pondweed (*Potamogeton amplifolius*), coontail (*Ceratophyllum demersum*), common elodea (*Elodea Canadensis*), nitella (*Nitella spp.*), and fern-leaf pondweed (*Potamogeton robbinsii*).

On July 13, 1998, the Washington State Department of Ecology conducted a macrophyte survey as part of a *Statewide Lake Monitoring Program--Lakes-Specific Study*. The results of the survey conclude that there is a nice plant community with few plants in water less than 1.5m deep; deeper water plants approaching surface to 3m deep are common elodea (*Elodea Canadensis*), chara (*Chara spp.*), and small pondweed (*Potamogeton pusillus*). Details of this survey are contained in Appendix C.

DISUSSION

Past work on macrophytes at Liberty Lake (Funk *et. al.*, 1975; Moore, 1981) has shown that they play an important role in translocation of phosphorus from sediments to the water, especially due to senescence and decay. However, the density of the macrophyte beds is a positive factor in relation to the potential for milfoil invasion. Even though milfoil is very competitive, it does need some initial substrate to become established. At this point, the very dense and well-established macrophyte beds should provide little opportunity for milfoil fragments to root and grow. The most likely places for milfoil to become established are in the portions of the lake, especially along the shoreline, where there are sufficient sediments and relatively sparse macrophyte beds.

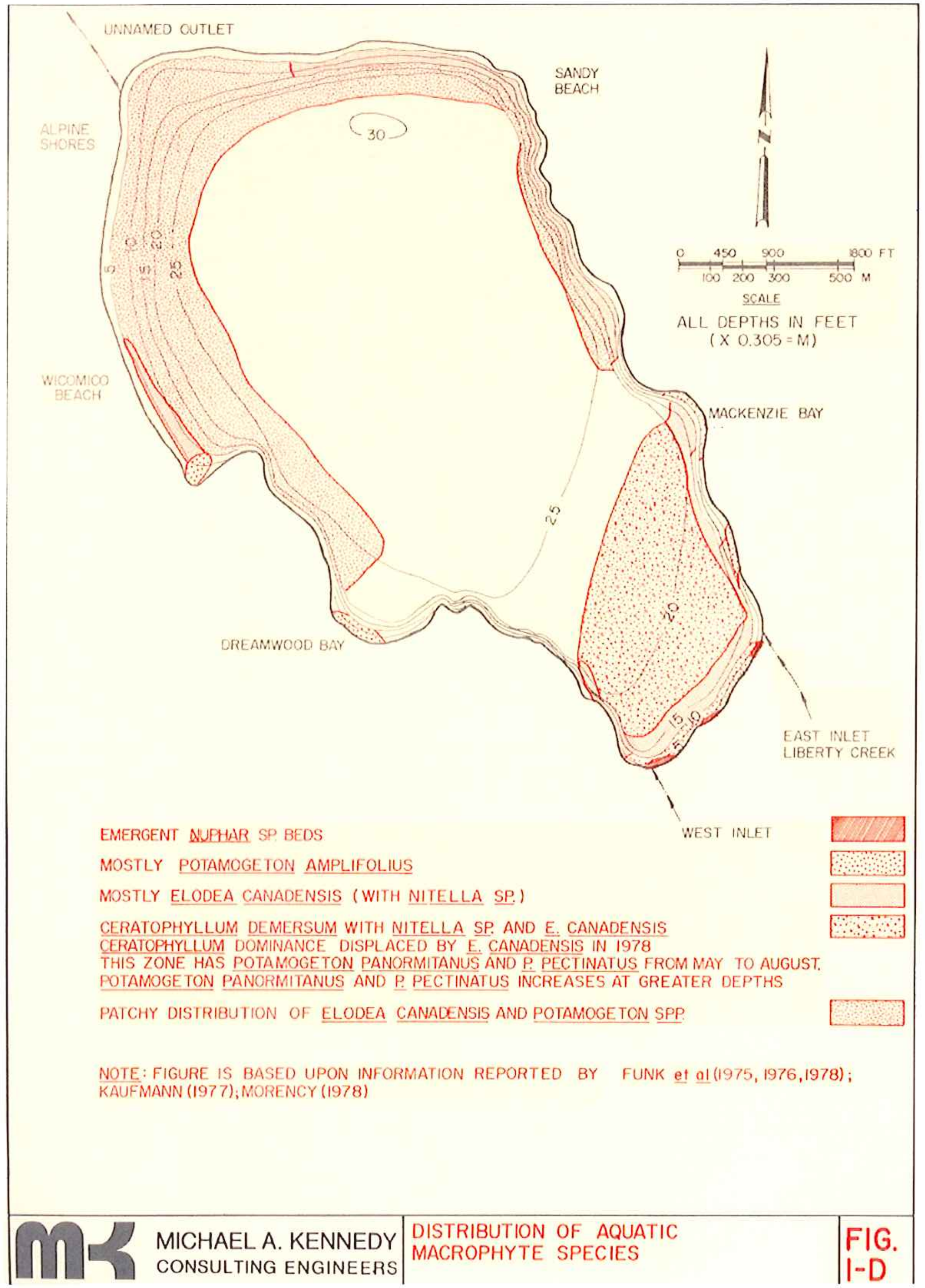


Figure 6.6 Liberty Lake macrophyte distribution map (Kennedy, 1979).

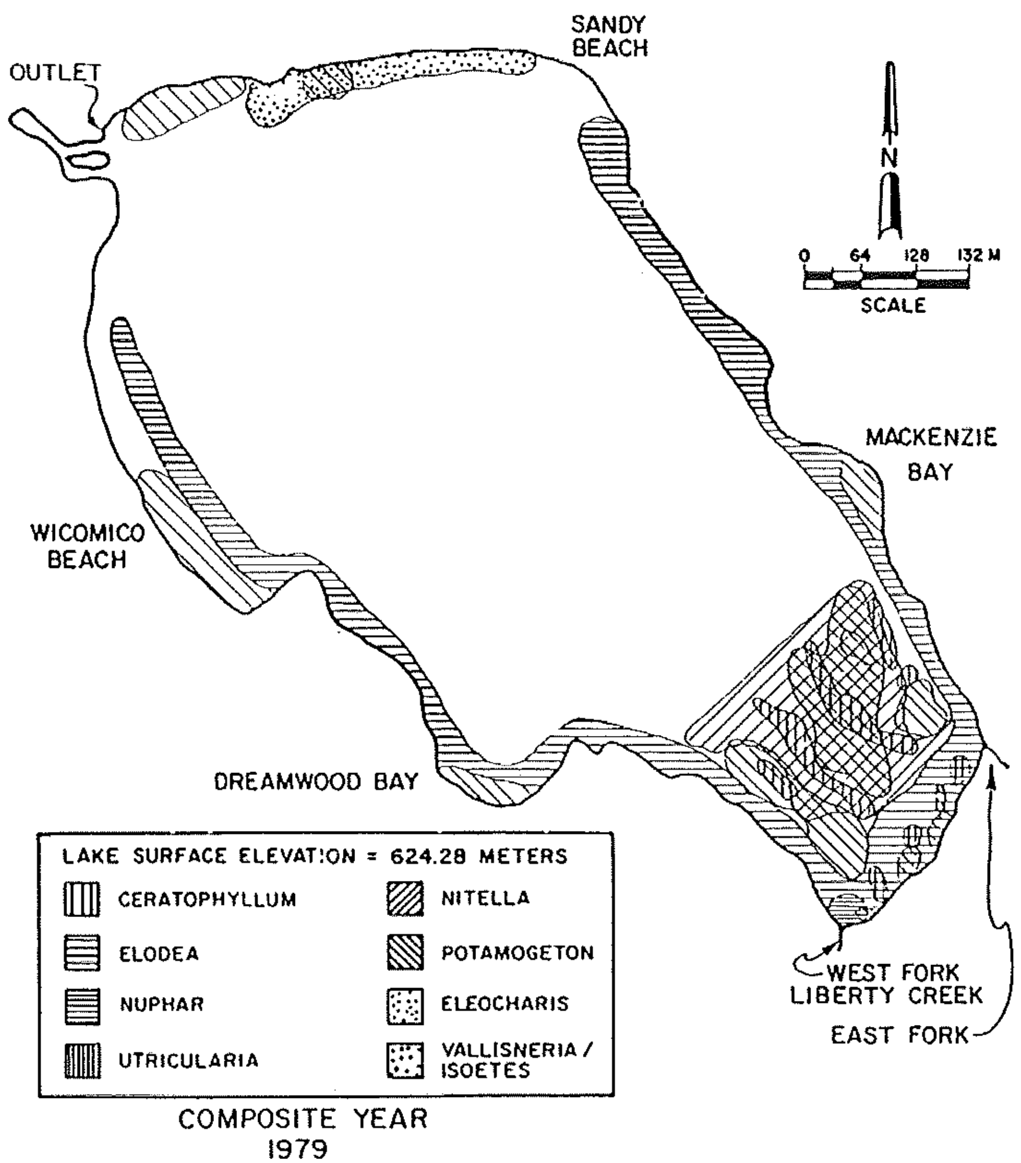


Figure 6.7 1979 Liberty Lake macrophyte distribution map (McKarns, 1985).

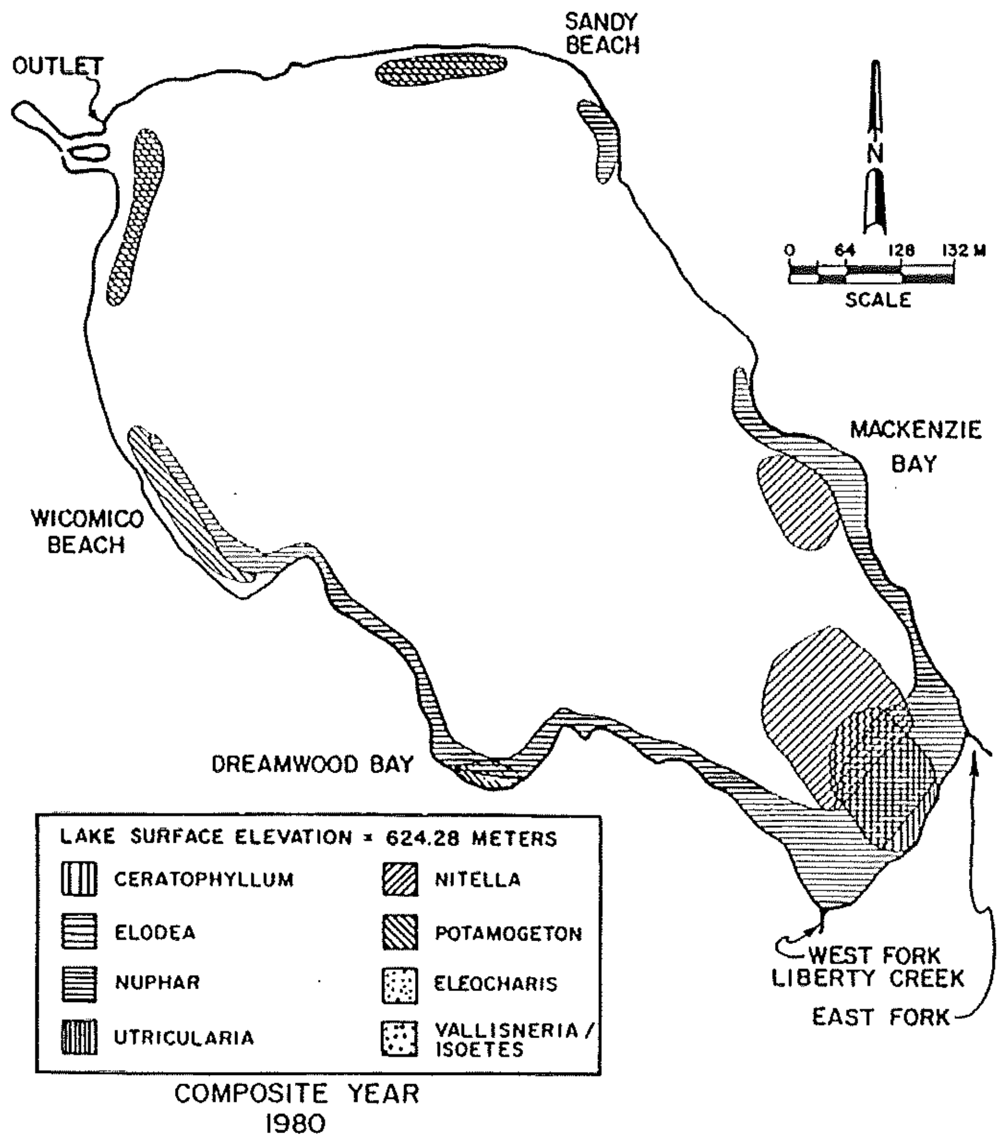


Figure 6.8 1980 Liberty Lake macrophyte distribution map (McKarns, 1985).

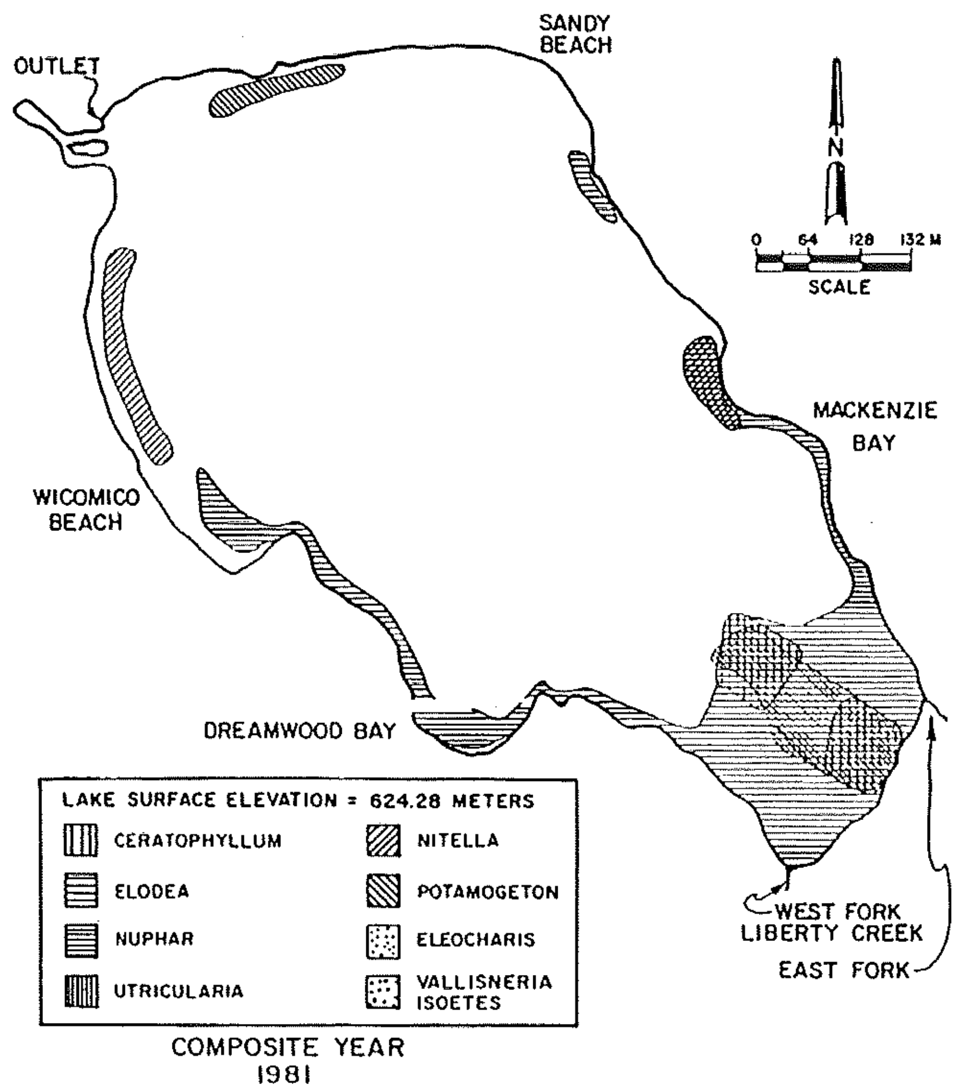


Figure 6.9 1981 Liberty Lake macrophyte distribution map (McKarns, 1985).

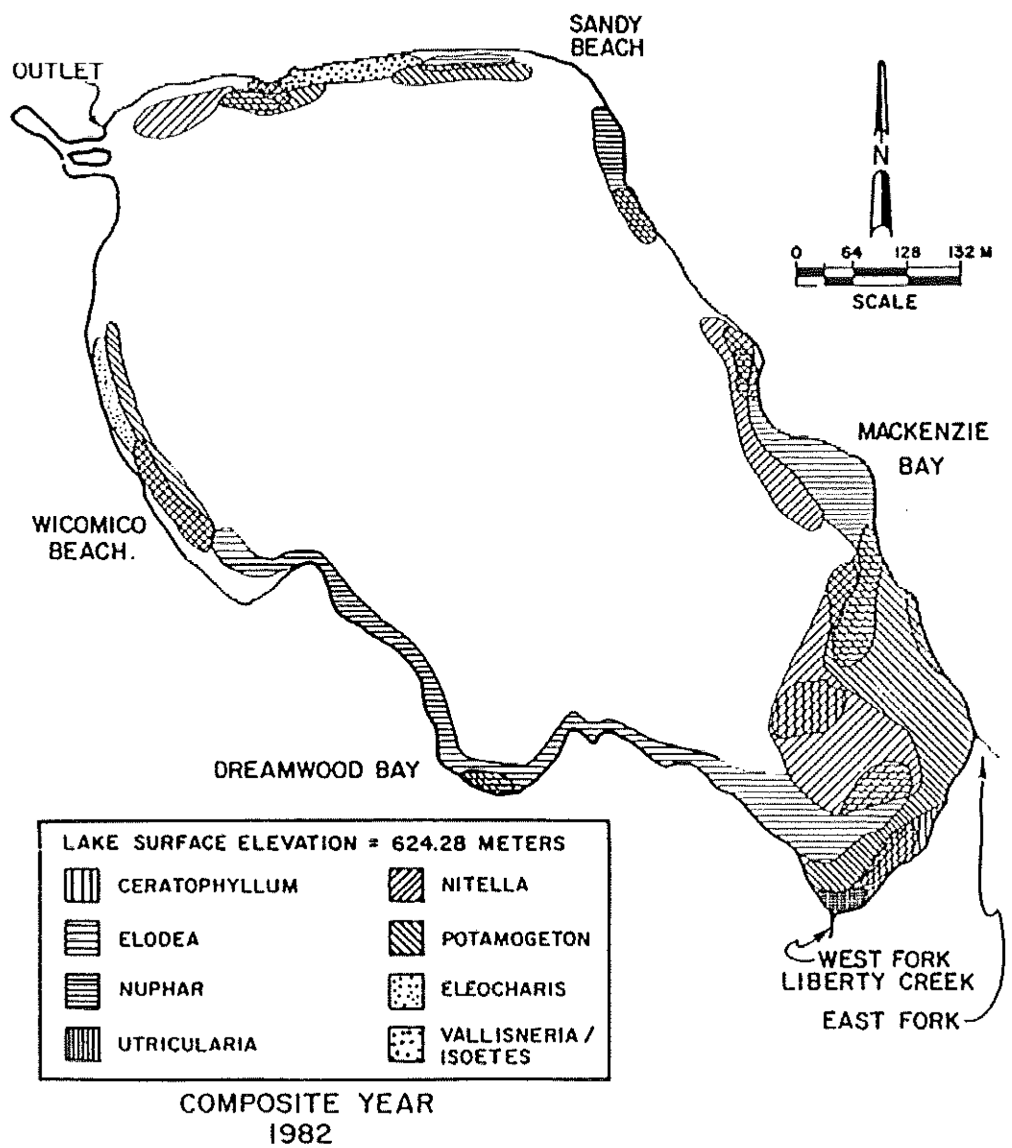


Figure 6.10 1982 Liberty Lake macrophyte distribution map (McKarns, 1985).

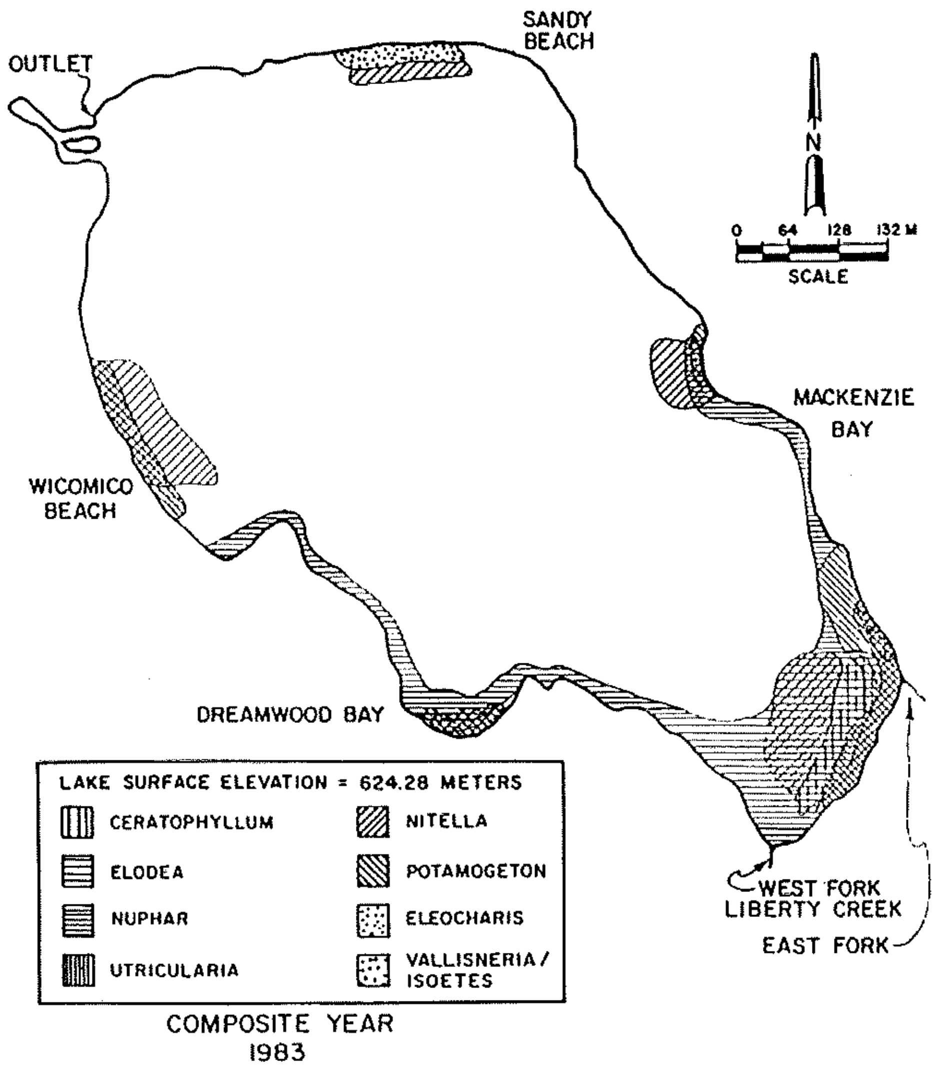


Figure 6.11 1983 Liberty Lake macrophyte distribution map (McKarns, 1985).

7.1 AQUATIC PLANT CONTROL ALTERNATIVES

This section outlines common methods used to control aquatic weeds. Much of the information in this section is quoted directly from the Department of Ecology's website (http://www.ecy.wa.gov/programs/wq/plants/management/index.html).

Additional information is derived from the Spring Lake Integrated Aquatic Vegetation Management Plan, King County Department of Natural Resources and Parks. Information therein is gathered from the field experience of the King County Noxious Weed Control Program, in particular from Drew Kerr, Aquatic Noxious Weed Specialist and WSDA licensed aquatic herbicide applicator. Recommendations therein were also derived from the 2001 draft version of the King County Regional Milfoil Plan.

Control/eradication methods discussed herein include the No Action Alternative, Environmental Manipulation (Water Level Control, Nutrient Reduction), Mechanical Controls (Rotovation, Harvesting, Cutting, and Diver Dredging), Manual Controls (Hand Pulling, Cutting, Raking, and Bottom Barriers-Screens), Biological Controls (Grass Carp and Watermilfoil Weevil), and Chemical Controls (Aquatic Herbicides).

7.2 NO ACTION ALTERNATIVE

One option for managing aquatic weeds in Liberty Lake is to let aquatic weeds continue to grow without intervention. This "no action" alternative would acknowledge the presence of the aquatic weeds but would not outline any management plan or enact any planned control efforts. Effectively, a no action determination would preclude any integrated treatment and/or control effort, placing the choice and responsibility of aquatic weed control with lakefront property owners.

Application for Liberty Lake

The milfoil infestation in Liberty Lake is currently moderate in density; if control measures are not continued, it is likely to increase each growing season in the future until the entire shoreline and littoral zone of the lake is dominated by milfoil. Based on annual survey results by the LLSWD and Clearwater Scuba, the infestations of milfoil have cycled based on treatment areas, and during some years, experienced rapid growth and population expansion. If there is no control effort, it is likely that weed infestations will continue to grow, making Liberty Lake a prime source of milfoil fragments for other nearby lakes with public access and boat launch facilities. Even if some of the residents chose to control the aquatic weeds near their properties, pockets of milfoil would remain. The surviving plants would fragment each autumn, spreading to other areas of the lake, including those that were treated by residents. Consequently, a once thriving recreational lake would become unfavorable for the community and its inhabitants. The LLSWD and the community do not support the No Action alternative for Liberty Lake.

7.3 ENVIRONMENTAL MANIPULATION

WATER LEVEL CONTROL

Lowering the water level of a lake or reservoir could have a dramatic impact on some aquatic weed problems. Water level drawdown can be used where there is a water control structure that allows the managers of lakes or reservoirs to drop the water level in the waterbody for extended periods of time. Water level drawdown often occurs regularly in reservoirs for power generation, flood control, or irrigation; a side benefit being the control of some aquatic plant species. However, regular drawdown can also make it difficult to establish native aquatic plants for fish (esp. spawning areas), wildlife, and waterfowl habitat in some reservoirs.

Application for Liberty Lake

The geological importance of Liberty Lake is that the lake has no natural outlet, but simply a fabricated outlet structure and channel with infiltration basins. The only outlet or disposal for flows from the lake and runoff is through infiltration of permeable rock and soil into the Spokane-Rathdrum Prairie Aquifer. With the construction of this outlet, an adjudicated lake elevation (2049.51) was established in 1951. The decision was designed to maintain adequate lake storage levels to control flooding and runoff, while preserving aesthetic beauty and recreational use. Drawdown is not a viable control strategy for Liberty Lake. On a typical year, the outlet gates become dry at an elevation of 2047.6 and water could not be released below this level. Not only would drawdown be difficult to achieve, it would violate the court adjudication of 1951. Even if the adjudication of 1951 were amended, drawdown would also cause significant damage to the ecosystem, particularly in the 155-acre wetlands at the south end of the lake. The amount of drawdown required to impact milfoil would damage native plants and animals in both the lake and the adjacent wetland and have many negative implications for residents living around the lake.

NUTRIENT REDUCTION ALTERNATIVE

At lakes in watersheds with identifiable sources of excess nutrients, a program to reduce nutrients entering the lake could possibly be an effective method of controlling aquatic vegetation. Sources of excessive nutrients might include failing septic tanks, other accidental or planned wastewater effluent, or runoff from agricultural lands. If nutrient reduction were enacted as the primary method of weed control, extensive research would be necessary to determine the current nutrient budget for the lake and surrounding watershed, whether nutrient reduction would result in milfoil reduction, and to identify and mitigate the natural and human-mediated nutrient sources.

Application for Liberty Lake

Since the 1960s, nuisance water quality conditions occurring in Liberty Lake initiated scientific studies to verify and refine nutrient sources from sediment, recycling, and the interaction of aquatic plants and algae blooms. In 1973, the residents took initiative to petition, vote, and elect three commissioners to represent a special purpose sewer district.

In 1975, the newly created Liberty Lake Sewer and Water District requested and received approval for grant funding under the Clean Lakes Program for a lake restoration project. The State of Washington Water Research Center (SWWRC) and the Civil Engineering Hydraulics Section at WSU carried out the joint study from 1974 to 1976. The study included in-lake chemical and physical testing, hydrology measurements, and analyses of nutrients in precipitation and watershed runoff. This study pinpointed atmospheric contributions, surface runoff, marsh drainage, and recycling of nutrients from sediments as sources of enrichment to the lake (Copp, 1976; Funk *et. al.,* 1976). Development of an integrated restoration plan was undertaken by Wright and Funk in 1974. This plan was based largely on the results of the ongoing research as well as previous studies. It delineated the need for watershed protection, reduction of marsh runoff, sewering to reduce nutrient flow from populated areas, and dredging to remove a large portion of nutrient rich sediments that had accumulated over the numerous years of settlement. These activities were followed by an alum treatment to remove suspended particulate matter and nutrients released from dredging activities. Entranco Engineers developed a facilities plan in 1976 that outlined the engineering activities needed to upgrade and enlarge the sewage collection system and build a new treatment plant. This firm later became Kennedy Engineers, and in 1979, they upgraded the facility plan and began design of the new wastewater treatment facility. The wastewater treatment facility was completed in 1982.

To further verify and refine nutrient sources from sediment, recycling, and the interaction of aquatic plants and algae blooms at Liberty Lake, the U .S. Environmental Protection Agency supported an extensive investigation during 1979 through 1981. Study results were reported in seven progress reports to the USEPA as well as project reports (e.g., Funk *et. al.,* 1979-82), in proceedings (Funk *et. al.,* 1982), and in journal articles (e.g., Gibbons and Funk, 1982; Mawson *et. al.,*1983).

Since 1973, the Liberty Lake Sewer and Water District has taken many measures to protect and maintain the aesthetic beauty that has brought many residents to the area. Protective measures are in place to reduce and prevent point and nonpoint source pollution, and are maintained and strengthened when possible including diversion of runoff, reduction of lawn fertilization, and prevention of disruption of the watershed.

The Liberty Lake Sewer and Water District's StormwaterManagement Plan and resolutions are intended to provide guidance and criteria for establishing and maintaining water quality within the Liberty Lake Sewer and Water District's boundaries and the lake's watershed. In addition, the Plan sets forth the guidelines for monitoring quality and reduction of source problems and provides a framework for mitigation of these elements through specific courses of action (Century West Engineering, 1998).

The primary goals of the Plan are to:

- Reduce point and non-point source pollution loads being discharged to receiving waters in order to protect or restore beneficial uses and meet water quality standards.
- Reduce the damages caused by flooding and inadequate flood hazard management.

- Reduce flushing of the marsh waters into the lake to protect beneficial uses and meet water quality standards.
- Educate residents, landowners, developers, and contractors about accepted stormwater management best practices and how they can affect the water quality within the lake.
- Preserve the natural watershed to reduce flooding impacts and meet water quality standards.

The protective measures taken by the Liberty Lake Sewer and Water District to date have essentially countered increased water quality problems since restoration. All studies to date indicate that the lake has remained in a healthy mesotrophic state and no large-scale algal bloom has occurred in the past thirty years. Liberty Lake, since restoration, has shown good resiliency. It is, however, a soft-water lake with limited buffering capacity. Heavy nutrient in-flow from any source combined with bottom oxygen depletion and subsequent release of nutrients could result in a return of heavy algal blooms.

Wild fowl, chiefly gulls and Canada goose, appear to increase levels of phosphorus and nitrogen, especially at the southeastern area of the lake where large numbers roost at night (Noyes, 1981). Shoreline clean up of leaves and debris in the fall has been instituted by the Liberty Lake Sewer and Water District to reduce contributions from the immediate watershed. In 1998, estimation was made by WSU that about 3000 40 lb bags of leaves and about 3 tons of wet macrophytes were removed from around the lake. Laboratory digestion and analysis indicated that about 56.4 kg (124 lbs) of phosphorus was prevented from being carried or leached into the lake by precipitation (Funk, 1999). Other studies have suggested that leaf removal has been shown to decrease the overall total phosphorus in urban runoff by 56 percent (Swenson and Cooper, 1999). Protection and prevention strategies are also being promoted in watershed studies, environmental education programs, aquatic plant and landscape workshops with emphasis on Eurasian milfoil and proper landscape techniques, and newsletter/news article dissemination of information that explains the relationship between watershed and lakes, water quality, and the activities of human beings (Funk, 1999).

Given the numerous studies conducted, and the protective measures already in place for algae control, nutrient reduction for aquatic weeds alone is not an appropriate method for Liberty Lake. Protective measures coexist with an already established nutrient reduction program, and if used alone, nutrient reduction is not likely to be an effective control on milfoil. Milfoil has the ability to live in various environmental conditions; it can withstand a broad range of aquatic environments, from oligotrophic to eutrophic waters, and it grows in water depths from as shallow as 0.5 meters to as deep as 8 meters. It also can grow in substrates ranging from poor, sandy sediment to highly organic soils and can survive in wide ranges of salinity, pH, and temperature conditions (Aiken *et. al.*, 1979; Nichols and Shaw, 1986; as cited in Creed and Sheldon, 1995).

Macrophytes were also used as an indicator for healthy nutrient levels in Liberty Lake. Morency (1979) found an inverse (opposite) relationship between macrophyte productivity and inorganic nutrient concentrations. Macrophyte and phytoplankton productivity were also inversely related, possibly due to increased competition for limited

nutrients. Thus, reduced inorganic nutrient input may reduce phytoplankton productivity, increase light penetration, and stimulate macrophyte productivity. Nutrient supply is also dependent on the importance of sediment nutrient release in supplying phytoplankton and macrophyte growth (Bronmark and Hansson, 1998). The removal of macrophytes as part of lake restoration could reduce nutrient competition, thereby enhancing phytoplankton productivity (Hartman, 2001).

In conjunction with the established nutrient reduction program at Liberty Lake, recent water quality data (Tables 7.1 - 7.3) collected for the LLSWD by Washington State University (Moore, *et. al.*2002), do not show phosphorus and nitrogen levels to be inordinately high. Additionally, in 1993, the Department of Ecology presented Total Maximum Daily Loads (TMDL) for Liberty Lake. The TMDL's presented load allocations for total phosphorus (TP) and total nitrogen (TN) to be 529 kg/yr (4.45 kg/d) and 4281 kg/yr (11.7 kg/d) respectively. These load allocations were set based on estimated loads achieved after implementation of various restoration activities to the lake that achieved levels of aesthetic enjoyment acceptable to the lake user community.

Historic water quality problems and lake characteristics suggest a need to reduce the external nutrient loading into Liberty Lake. Water quality improvements would likely result if each watershed resident reduced or eliminated sources of nutrient input to the lake (i.e. proper fertilizer use, maintain stormwater swales, limit shoreline development, and perform proper land use practices). However, this would not be likely to be an effective primary method of controlling aquatic weeds. Nutrients in the sediments would be more likely to have an impact, since milfoil and other targeted aquatic weed species obtain more than 85% of their nutrients from the sediment (King County Department of Natural Resources and Parks, 2003).

Nutrient reduction as the primary method of weed control would be beyond the scope of any project that could be undertaken at Liberty Lake. The nutrient reduction program and protective measures already established will continue in order to reduce and prevent point and nonpoint source pollution.

Date	*4/5/02*	*4/25/02*	*5/7/02*	*5/24/02*	*6/4/02*	*6/19/02*	*7/12/02*	*7/23/02*	*8/6/02*	*8/22/02*	*9/5/02*	*9/19/02*	*10/1/02*	*10/18/02*	*11/1/02*
NW-top	0.031	0.032	0.018	0.014	0.021	0.045	0.016	0.042	0.089	0.020	0.030	0.049	0.026	0.104	0.026
NW-mid	0.029	0.027	0.016	0.021	0.031	0.017	0.019	0.042	0.074	0.027	0.022	0.032	0.030	0.068	0.034
NW-bot	0.026	0.052	0.017	0.022	0.027	0.015	0.046	0.047	0.100	0.025	0.025	0.039	0.030	0.085	0.072
SE-top	0.023	0.024	0.016	0.017	0.027	0.017	0.019	0.058	0.116	0.022	0.026	0.033	0.030	0.073	0.030
SE-mid	0.031	0.022	0.020	0.018	0.026	0.015	0.018	0.042	0.077	0.026	0.023	0.048	0.031	0.059	1.369
SE-bot	0.030	0.023	0.027	0.021	0.027	0.013	0.019	0.047	0.088	0.052	0.029	0.061	0.041	0.082	0.066

Table 7.1 2002 Total Phosphorus values (mg/l) for Liberty Lake

Date	*4/5/02*	*4/25/02*	*5/24/02*	*6/4/02*	*6/19/02*	*7/12/02*	*7/23/02*	*8/6/02*	*8/22/02*
NW-top	0.07	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
NW-mid	0.13	0.04	0.06	NA	NA	0.05	0.04	NA	NA
NW-bot	0.3	0.07	0.03	0.11	NA	0.03	0.09	NA	0.02
SE-top	0.23	0.06	0.14	0.15	NA	0.03	NA	NA	NA
SE-mid	0.44	0.07	0.16	0.19	NA	0.07	0.06	0.1	NA
SE-bot	0.28	0.07	0.12	0.2	0.1	1.93	0.09	0.16	NA

Table 7.2 2002 Total Inorganic Nitrogen values (mg/l) for Liberty Lake. NA indicates no data available

Date	*4/5/02*	*4/25/02*	*5/7/02*	*5/24/02*	*6/4/02*	*6/19/02*	*7/12/02*	*7/23/02*	*8/6/02*	*8/22/2002*
NW-top	0.05	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01
NW-mid	0.04	0.01	0.02	0.01	<DL	<DL	0.02	0.01	<DL	<DL
NW-bot	0.06	0.03	0.02	0.01	0.01	<DL	0.01	0.01	<DL	0.01
SE-top	0.04	0.01	<DL	0.01	0.01	<DL	0.01	<DL	<DL	<DL
SE-mid	0.03	0.01	<DL	0.01	0.01	<DL	0.01	0.01	0.01	<DL
SE-bot	0.04	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	<DL

Table 7.3 2002 Nitrate+Nitrite (mg/l) values for Liberty Lake

7.4 MECHANICAL CONTROLS

ROTOVATION, HARVESTING, AND CUTTING

Rotovation
Rotovators use underwater rototiller-like blades to uproot Eurasian watermilfoil plants. The rotating blades churn seven to nine inches deep into the lake or river bottom to dislodge plant root crowns that are generally buoyant. The plants and roots may then be removed from the water using a weed rake attachment to the rototiller head or by harvester or manual collection.

Harvesting
Mechanical harvesters are large machines that both cut and collect aquatic plants. Cut plants are removed from the water by a conveyor belt system and stored on the harvester until disposal. A barge may be stationed near the harvesting site for temporary plant storage or the harvester carries the cut weeds to shore. The shore station equipment is usually a shore conveyor that mates to the harvester and lifts the cut plants into a dump truck. Harvested weeds are disposed of in landfills, used as compost, or in reclaiming spent gravel pits or similar sites.

Cutting
Mechanical weed cutters cut aquatic plants several feet below the water's surface. Unlike harvesting, cut plants are not collected while the machinery operates.

Application for Liberty Lake
None of these options is suitable for the level of infestation at Liberty Lake. They are not eradication tools, but rather are used to manage and control heavy, widespread infestations of aquatic weeds. These processes create plant fragments, and should not be used in systems where milfoil is not already widespread. In a moderate infestation such as Liberty Lake, these methods would probably serve to spread and expand the infestation. According to Ecology, "There is little or no reduction in plant density with mechanical harvesting." Since the overall goal is to eliminate milfoil from the system, these are not compatible control strategies. Harvesting and cutting do not remove root systems, and rotovation would cause disturbance to the highly organic lake sediments. All are scenarios that are not favorable for Liberty Lake.

DIVER DREDGING

Diver dredging (suction dredging) is a method whereby SCUBA divers use hoses attached to small dredges (often dredges used by miners for mining gold from streams) to suck plant material from the sediment. The purpose of diver dredging is to remove all parts of the plant including the roots. A good operator can accurately remove target plants, like Eurasian watermilfoil, while leaving native species untouched.

The suction hose pumps the plant material and the sediments to the surface where they are deposited into a screened basket. The water and sediment are returned back to the

water column (if the permit allows this), and the plant material is retained. The turbid water is generally discharged to an area curtained off from the rest of the lake by a silt curtain. The plants are disposed of on shore. Removal rates vary from approximately 0.25 acres per day to one acre per day depending on plant density, sediment type, size of team, and diver efficiency. Diver dredging is more effective in areas where softer sediment allows easy removal of the entire plants, although water turbidity is increased with softer sediments. Harder sediment may require the use of a knife or tool to help loosen sediment from around the roots. In very hard sediments, milfoil plants tend to break off leaving the roots behind and defeating the purpose of diver dredging.

Diver dredging has been used in British Columbia, Washington, and Idaho to remove early infestations of Eurasian watermilfoil. In a large-scale operation in western Washington, two years of diver dredging reduced the population of milfoil by 80 percent (Silver Lake, Everett). Diver dredging is less effective on plants where seeds, turions, or tubers remain in the sediments to sprout the next growing season. For that reason, Eurasian watermilfoil is generally the target plant for removal during diver dredging operations.

Advantages

- Diver dredging can be a very selective technique for removing pioneer colonies of Eurasian watermilfoil.
- Divers can remove plants around docks and in other difficult to reach areas.
- Diver dredging can be used in situations where herbicide use is not an option for aquatic plant management.

Disadvantages

- Diver dredging is very expensive.
- Dredging stirs up large amounts of sediment. This may lead to the release of nutrients or long-buried toxic materials into the water column.
- Only the tops of plants growing in rocky or hard sediments may be removed, leaving a viable root crown behind to initiate growth.
- In some states, acquisition of permits can take years.

Permits

Diver dredging requires a *Hydraulic Project Approval* from the Department of Fish and Wildlife. City, county, or local government permits may also be required. Verification of requirements is recommended before proceeding with a diver-dredging project. In addition, diver dredging may require a Section 404 permit from the U.S. Army Corps of Engineers.

Costs

Depending on the density of the plants, specific equipment used, number of divers, and disposal requirements, costs can range from a minimum of $1,500 to $2,000 per day.

Other Considerations

Might be good spot control method in subsequent years (coordinated with diver surveys).

Application for Liberty Lake
Diver dredging could be used after herbicide applications to remove plants that were missed or unaffected by the herbicide. The soft sediments in Liberty Lake should make this method effective. However, this would cause disturbance to the highly organic lake sediments, a scenario that is not favorable for Liberty Lake. Diver dredging greatly disturbs sediments and can affect nutrient concentrations and algal production in a lake (see Disadvantages above). If other techniques for removal are suitable, this should not be considered.

7.5 MANUAL CONTROLS

HAND-PULLING, CUTTING, AND RAKING

Hand-pulling
Hand-pulling aquatic plants is similar to pulling weeds out of a garden. It involves removing entire plants (leaves, stems, and roots) from the area of concern and disposing of them in an area away from the shoreline. In water less than three feet deep no specialized equipment is required, although a spade, trowel, or long knife may be needed if the sediment is packed or heavy. In deeper water, hand pulling is best accomplished by divers with SCUBA equipment and mesh bags for the collection of plant fragments. Some sites may not be suitable for hand pulling, such as areas where deep flocculent sediments may cause the person who is hand pulling to sink deeply into the sediment.

Cutting
Cutting differs from hand pulling in that plants are cut and the roots are not removed. Cutting is performed by standing on a dock or on shore and throwing a cutting tool out into the water. A non-mechanical aquatic weed cutter is commercially available. Two single-sided, razor sharp stainless steel blades forming a "V" shape are connected to a handle, which is tied to a long rope. The cutter can be thrown about 20 – 30 feet into the water. As the cutter is pulled through the water, it cuts a 48-inch wide swath. Cut plants rise to the surface where they can be removed. Washington State requires that cut plants be removed from the water. The stainless steel blades that form the V are extremely sharp and great care must be taken with this implement. It should be stored in a secure area where children do not have access.

A battery-operated cutting tool called a Swordfish is also commercially available. It works similarly to an underwater lawn mower.

Raking
A sturdy rake makes a useful tool for removing aquatic plants. Attaching a rope to the rake allows removal of a greater area of weeds. Raking literally tears plants from the sediment, breaking some plants off and removing some roots as well. Specially designed aquatic plant rakes are available. Rakes can be equipped with floats to allow easier plant and fragment collection. The operator should pull towards the shore because a substantial amount of plant material can be collected in a short distance.

Clean-up

All of the manual control methods create plant fragments. It is important to remove all fragments from the water to prevent them from re-rooting or drifting onshore. Plants and fragments can be composted or added directly to a garden.

Advantages

- Manual methods are easy to use around docks and swimming areas.
- The equipment is inexpensive.
- These methods are environmentally safe.
- Manual methods do not require expensive permits, and can be performed on aquatic noxious weeds with a *Hydraulic Project Approval* obtained by reading and following the pamphlet *Aquatic Plants and Fish* (publication #APF-1-98) available from the Washington Department of Fish & Wildlife.

Disadvantages

- As plants re-grow or fragments re-colonize the cleared area, the treatment may need to be repeated several times each summer.
- Because these methods are labor intensive, they may not be practical for large areas or for thick weed beds.
- Even with the best containment efforts, it is difficult to collect all plant fragments, leading to re-colonization.
- Some plants, like water lilies that have massive rhizomes, are difficult to remove by hand pulling.
- Pulling weeds and raking stirs up the sediment and makes it difficult to see remaining plants. Sediment re-suspension can also increase nutrient levels in lake water.
- Hand pulling and raking impacts bottom-dwelling animals.
- The V-shaped cutting tool is extremely sharp and can be dangerous to use.

Diver Harvesting

- Hand-pulling allows the flexibility to remove undesirable aquatic plants while leaving desirable plants.
- Appropriate in conditions of low milfoil density.
- Can provide precise location and control of individual plants.
- Potential rapid mobilization and response.
- High risk of fragmentation-appropriate care must be given

Milfoil Diver Requirements

- Special training required.
- Experienced in milfoil identification.
- Highly competent divers only, especially in buoyancy control and navigation skills.
- Motivated- requires patience and meticulous attention to root removal and fragment control.

Diver services

- Especially useful for accurate detection and mapping in moderate to low visibility conditions.
- Useful for treatment assessment and follow-up.

(after Moore, 2003)

Permits

Permits are required for many types of manual projects in lakes and streams. The Washington State Department of Fish and Wildlife requires a *Hydraulic Project Approval* for all activities taking place at or below the ordinary high water mark, including hand pulling, raking, and cutting of aquatic plants. *Hydraulic Project Approval* applications are available through the Department regional offices or through the internet at: http://www.wdfw.wa.gov/hab/hpapage.htm. There is no cost associated with this permit.

Because of the importance of controlling aquatic noxious weeds, the Washington Department of Fish and Wildlife (WDFW) has created a pamphlet titled "Aquatic Plants and Fish." The pamphlet primarily addresses problems associated with aquatic noxious weeds and is designed to streamline permitting and provide guidance.

The Aquatic Plants and Fish pamphlet deals only with physical and mechanical methods of controlling and removing plants. It does not address aquatic plant control using grass carp, herbicides or water column dye.

The purposes of the pamphlet are:

- to serve as the *Hydraulic Project Approval (HPA)*, thus expediting the approval process for controlling invasive aquatic noxious weeds, especially early infestations.
- to expedite the HPA process for limited aquatic beneficial plant control, using small-scale projects only (such as around docks and in swimming areas).
- to provide guidance in selecting control methods for early and more advanced infestations of aquatic noxious weeds

The Washington State Department of Fish and Wildlife requires a copy of the Aquatic Plants and Fish pamphlet (APF-1-98) to be on site when handpulling or mechanically harvesting weeds. Aquatic Plants and Fish pamphlets are available through the Department regional offices or through the internet at http://www.wdfw.wa.gov/hab/aquaplnt/aquaplnt.pdf.

Costs

Hand-pulling costs up to $130 for the average waterfront lot for a hired commercial puller. A commercial grade weed cutter costs about $130 with accessories. A commercial rake costs about $95 to $125. A homemade weed rake costs about $85 (asphalt rake is about $75 and the rope costs 35-75 cents per foot).

Other Considerations
Manual methods must include regular scheduled surveys to determine the extent of the remaining weeds and/or the appearance of new plants after eradication has been attained

Application for Liberty Lake
The currently infested areas in Liberty Lake are too large to use manual techniques as the sole source of control for Eurasian watermilfoil. These methods would fit best as a supplement to other control methods such as herbicide applications. As with diver dredging, the hand pulling method could be used after herbicide applications to remove plants that were missed or unaffected by the herbicide. Hand harvesting is the most applicable manual method for the supplemental control of milfoil in Liberty Lake. Additionally, the soft sediments in Liberty Lake should make this method effective. However, caution should be used when using manual methods as they have the potential for missing Eurasian watermilfoil plants, (especially after stirring up sediments) and for fragmentation, exacerbating the existing Eurasian watermilfoil problem. Manual methods will also be vital in combating new infestations of Eurasian watermilfoil that may appear, or may contain the infestation at the current level. The Liberty Lake Sewer and Water District and the community favor the use of the combination of a chemical control agent, 2,4-D herbicide, and hand-harvesting.

BOTTOM BARRIERS - SCREENS

A bottom barrier or benthic screen covers the sediment like a blanket, compressing aquatic plants while reducing or blocking light. Materials such as burlap, plastics, perforated black Mylar, and woven synthetics can all be used as bottom barriers. Some people report success using pond liner materials. There is also a commercial bottom barrier fabric called Texel, a heavy, felt-like polyester material, which is specifically designed for aquatic plant control. An ideal bottom barrier should be durable, heavier than water, reduce or block light, prevent plants from growing into and under the fabric, be easy to install and maintain, and should readily allow gases produced by rotting weeds to escape without "ballooning" the fabric upwards. Even the most porous materials, such as window screen, will billow due to gas buildup. Therefore, it is very important to anchor the bottom barrier securely to the bottom. Unsecured barriers can create navigation hazards and are dangerous to swimmers. Anchors must be effective in keeping the material down and must be regularly checked. Natural materials such as rocks or sandbags are preferred as anchors.

The duration of weed control depends on the rate that weeds can grow through or on top of the bottom barrier, the rate that new sediment is deposited on the barrier, and the durability and longevity of the material. For example, burlap may rot within two years; plants can grow through window screening material, and can grow on top of felt-like Texel fabric. Regular maintenance is essential and can extend the life of most bottom barriers. Bottom barriers will control most aquatic plants; however, freely floating species such as the bladderworts or coontail will not be controlled by bottom barriers. Plants like Eurasian watermilfoil will send out lateral surface shoots and may canopy over the area that has been screened giving less than adequate control. In addition to

controlling nuisance weeds around docks and in swimming beaches, bottom screening has become an important tool to help eradicate and contain early infestations of noxious weeds such as Eurasian watermilfoil.

Pioneering colonies that are too extensive to be hand pulled can sometimes be covered with bottom screening material. For these projects, it is suggested using burlap with rocks or burlap sandbags for anchors. By the time the material decomposes, the milfoil patches will be dead as long as all plants were completely covered. When using this technique for Eurasian watermilfoil eradication projects, divers should recheck the barrier within a few weeks to make sure that all milfoil plants remain covered and that no new fragments have taken root nearby.

Bottom barriers can be installed by the homeowner or by a commercial plant control specialist. Installation is easier in winter or early spring when plants have died back. In summer, cutting or hand pulling the plants first will facilitate bottom barrier installation. Research has shown that much more gas is produced under bottom barriers that are installed over the top of aquatic plants. The less plant material that is present before installing the barrier, the more successful the screen will be in staying in place. Bottom barriers may also be attached to frames rather than placed directly onto the sediment. The frames may then be moved for control of a larger area. See Appendix D for instructions on constructing and installing bottom barriers (http://www.ecy.wa.gov/pubs/wqfa9401.pdf).

Advantages

- Installation of a bottom barrier creates an immediate open area of water.
- Bottom barriers are easily installed around docks and in swimming areas.
- Properly installed bottom barriers can control up to 100 percent of aquatic plants.
- Screen materials are readily available and can be installed by homeowners or by divers.

Disadvantages

- Because bottom barriers reduce habitat by covering the sediment, they are suitable only for localized control.
- Cost and maintenance of bottom barriers confine them to very small-scale use.
- For safety and performance reasons, bottom barriers must be regularly inspected and maintained.
- Harvesters, rotovators, fishing gear, propeller backwash, or boat anchors may damage or dislodge bottom barriers.
- Improperly anchored bottom barriers may create safety hazards for boaters and swimmers.
- Poorly maintained anchors used to pin bottom barriers to the sediment may injure swimmers.
- Some bottom barriers are difficult to anchor on deep muck sediments.
- Bottom barriers interfere with fish spawning and bottom-dwelling animals.
- Without regular maintenance, aquatic plants may quickly colonize the bottom.

Permits
Bottom screening in Washington requires a *Hydraulic Project Approval*, obtained free from the Washington Department of Fish and Wildlife. In certain instances, a shoreline permit may also be required.

Costs
Barrier materials cost $0.22 to $1.25 per square foot. The cost of some commercial barriers includes an installation fee. Commercial installation costs vary depending on sediment characteristics and type of bottom screen selected. It costs up to about $750 to have 1,000 square feet of bottom screen installed. Maintenance costs for a waterfront lot are about $120 each year.

Application for Liberty Lake
The Eurasian watermilfoil infestation at Liberty Lake is too advanced to consider this method for large-scale eradication without becoming cost prohibitive. However, the extent of the infestation encompasses much of the lake's perimeter and offers some good specific localities for barrier installation. Most of the lakeshore residences have only small infestations and bottom barriers could be applicable as long as they would not reduce habitat and native vegetation by covering the sediment.

Bottom barriers at Liberty Lake would be appropriate on stretches of shoreline that are free from native vegetation and habitat (i.e. Wicomico Beach area where sandy bottoms are prevalent). Barriers could also be effective in preventing re-infestation after initial control, or in areas that have dense milfoil and have shown resistance to the herbicide. The public boat launch is a suitable location for a bottom barrier to limit the spread of milfoil to other waterbodies and reduce the transfer of other aquatic macrophytes. Since there is a swimming beach at Liberty Lake, the Liberty Lake County Park could also be an appropriate place to install a bottom barrier to enhance the recreational potential of the lake if infestation became too severe.

7.6 BIOLOGICAL CONTROLS

Many problematic aquatic plants in the western United States are non-indigenous species. Plants like Eurasian watermilfoil, Brazilian elodea, and purple loosestrife have been introduced to North America from other continents. Here they grow extremely aggressively, forming monocultures that exclude native aquatic plants and degrade fish and wildlife habitat. Yet, often these same species are not aggressive or invasive in their native range. This may be in part because their populations are kept under control by insects, diseases, or other factors not found in areas new to them.

The biological control of aquatic plants focuses on the selection and introduction of other organisms that have an impact on the growth or reproduction of a target plant, usually from their native ranges. Theoretically, by stocking an infested waterbody or wetland with these organisms, the target plant can be controlled and native plants can recover.

CLASSIC BIOLOGICAL CONTROL

Classic biological control uses control agents that are host specific. These organisms attack only the species targeted for control. Generally, these bio-control agents are found in the native range of the nuisance aquatic plants and, like the targeted plant, these bio-control agents are also non-indigenous species. With classic biological control, an exotic species is introduced to control another exotic species. However, extensive research must be conducted before release to ensure that biological control agents are host specific and will not harm the environment in other ways.

Search for a classical biological control agent typically starts in the region of the world that is home to the nuisance aquatic plant. Researchers collect and rear insects and/or pathogens that appear to have an impact on the growth or reproduction of the target species. Those insects/pathogens that appear to be generalists (feeding or affecting other aquatic plant species) are rejected as biological control agents. Insects that affect the target species (or very closely related species) exclusively are considered for release. Once collected, these insects are reared and tested for host specificity and other parameters. Only extensively researched, host-specific organisms are cleared by the United States for release. It generally takes a number of years of study and specific testing before a biological control agent is approved. The cost for researchers to locate, culture, and test bio-control agents is high. Once approved for use, insects can sell for $1.00 or more per insect. Sometimes it is possible to establish nurseries where weed specialists can collect insects for reestablishment elsewhere.

Even with an approved host-specific bio-control agent, control can be difficult to achieve. Some biological control organisms are very successful in controlling exotic species and others are of little value. A number of factors come into play. It is sometimes difficult to establish reproducing populations of a bio-control agent. The ease of collection of the bio-control and placement on the target species can also have a role in the effectiveness. Climate or other factors may prevent its establishment, with some species not proving capable of over-wintering in their new setting. Sometimes the bio-control insects become prey for native or non-native predator species, and sometimes the impact of the insect on the target plant is not enough to control the growth and reproduction of the target species. People who work in this field say that the more biological control species you can put to work on a problem plant, the better your chance for success will be in controlling the targeted species.

There are some good examples where numerous biological control agents have had little effect on a targeted species, and other examples where one bio-control agent was responsible for the complete control of a problem species. However, even when biological control works, a classic biological control agent generally does not totally eliminate all target plants. A predator-prey cycle establishes where increasing predator populations will reduce the targeted species. In response to decreased food supply (the target plant is the sole food source for the predator), the predator species will decline. The target plant species rebounds due to the decline of the predator species. The cycle continues with the predator populations building in response to an increased food supply.

Although a successful biological control agent rarely eradicates a problem species, it can reduce populations substantially, allowing native species to return. Used in an integrated approach with other control techniques, biological agents can stress target plants making them more susceptible to other control methods.

BIOLOGICAL CONTROL AGENTS

Grass Carp (*Cteno pharynogodon*)

The following information and citations are taken from the Washington State Department of Ecology's website on Aquatic Plant Management (http://www.ecy.wa.gov/programs/wq/plants/management/aqua024.html).

Another type of biological control uses **general agents** such as grass carp (*Cteno pharynogodon)* to manage problem plants. Unlike classical bio-control agents, these fish are not host specific and will not target specific species. Although grass carp do have food preferences, under some circumstances, they can eliminate all submersed vegetation in a waterbody. Like classic biological control agents, grass carp are exotic species and originate from Asia. In Washington, all grass carp must be certified sterile before they can be imported into the state. There are many waterbodies in Washington (mostly smaller sites) where grass carp are being used to control the growth of aquatic plants with mixed results (Bonar *et. al.*, 1996).

The grass carp (*Cteno pharynogodon)*, also known as the white amur, is a vegetarian fish native to the Amur River in Asia. Because this fish feeds on aquatic plants, it can be used as a biological tool to control nuisance aquatic plant growth. Legalized in 1990 for plant management, triploid (sterile) grass carp may be permitted for introduction into Washington waters. Permits are most readily obtained if the lake or pond is privately owned, has no inlet or outlet, and is fairly small. The usual objective of using grass carp to control aquatic plant growth is to end up with a lake that has about 20 to 40 percent plant cover, not a lake devoid of plants. In practice, grass carp often fail to control the plants, or in cases of overstocking, all the submersed plants are often eliminated from the waterbody.

The Washington Department of Fish and Wildlife determines the appropriate stocking rate for each waterbody when they issue the grass carp-stocking permit. Stocking rates for Washington lakes generally range from 9 to 25 eight- to eleven-inch fish per vegetated acre. This number will depend on the amount and type of plants in the lake as well as spring and summer water temperatures. To prevent stocked grass carp from migrating out of the lake and into streams and rivers, all inlets and outlets to the pond or

lake must be screened. For this reason, residents on waterbodies that support a salmon or steelhead run are rarely allowed to stock grass carp into these systems.

Once grass carp are stocked in a lake, it may take from two to five years for them to control nuisance plants. Survival rates of the fish will vary depending on factors like presence of otters, birds of prey, or fish disease. A lake will probably need restocking about every ten years.

Success with grass carp in Washington has been varied. Sometimes the same stocking rate results in no control, control, or even complete elimination of all underwater plants. It has become the consensus among researchers and aquatic plant managers around the country that grass carp are an all or nothing control option. They should be stocked only in waterbodies where complete elimination of all submersed plant species can be tolerated.

Grass carp exhibit definite food preferences and some aquatic plant species will be consumed more readily than others will. Generally, in Washington, grass carp do not consume emergent wetland vegetation or water lilies even when the waterbody is heavily stocked or over stocked. A heavy stocking rate of triploid grass carp may result in the loss of most submersed species, whereas the emergent or floating vegetation remains at pre-stocking levels.

Bonar et. al. 1995 performed experiments to evaluate the importance of 20 Pacific Northwest aquatic plant species as food items for grass carp. Grass carp did not remove plants in a preferred species-by-species sequence in multi-species plant communities. Instead, they grazed simultaneously on palatable plants of similar preference before gradually switching to less preferred groups of plants. The relative preference of many plants was dependent upon what other plants were associated with them. The relative preference rank for the 20 aquatic plants tested was as follows in Table 7.4.

Potamogeton crispus (curly leaf pondweed)
P. pectinatus (sago pondweed)
P. zosteriformes (flat-stemmed pondweed)
Chara spp.(muskgrasses)
Elodea canadensis (American waterweed)
Potamogeton spp. (thin-leaved pondweeds)
Egeria densa (Brazilian elodea) (large fish only)
P. praelongus (white-stemmed pondweed)
Vallisneria Americana (water celery)
***Myriophyllum spicatum* (Eurasian watermilfoil)**
Ceratophyllum demersum (coontail)
Utricularia vulgaris (bladderwort)
Polygonium amphibium (water smartweed)
P. natans (floating leaved pondweed)
P. amplifolius (big leaf pondweed)
Brasenia schreberi (watershield)
Juncus spp.(rush)
Egeria densa (Brazilian elodea) (fingerling fish only)
Nyphaea spp. (fragrant waterlily)
Typha spp. (cattail)
Nuphar spp. (spatterdock)

Table 7.4 Relative preference rank of Pacific Northwest aquatic plant species as food items for grass carp. Eruasian watermilfoil (*Myriophyllum spicatum)* is rated 10 on the list (Bonar, et. al., 1995).

Grass carp stocked into Washington lakes must be certified disease free and sterile. Sterile fish, called triploids because they have an extra chromosome, are created when the fish eggs are subjected to a temperature or pressure shock. Fish are verified sterile by collecting and testing a blood sample. Triploid fish have slightly larger blood cells and can be differentiated from diploid (fertile) fish by this characteristic. Grass carp imported into Washington must be tested to ensure that they are sterile. Because Washington does not allow fertile fish within the state, all grass carp are imported into Washington from out of state locations. Most grass carp farms are located in the southern United States where warmer weather allows for fast fish growth rates. Large shipments are transported in special trucks and small shipments arrive via air.

Grass Carp Facts:

- Are only distantly related to the undesirable European carp, and share few of its habits.
- Generally live for at least ten years and possibly much longer in Washington State waters.
- Will grow rapidly and reach at least ten pounds. They have been known to reach 40 pounds in the southern United States.
- Feed only on plants at the age they are stocked into Washington waters.
- Will not eat fish eggs, young fish or invertebrates, although baby grass carp are omnivorous.

- Feed from the top of the plant down so that mud is not stirred up. However, in ponds and lakes where grass carp have eliminated all submersed vegetation the water becomes turbid. Hungry fish will eat organic material out of the sediments.
- Have definite taste preferences. Plants like Eurasian milfoil and coontail are **not** preferred. American waterweed and thin leaved pondweeds are preferred. Water lilies are rarely consumed in Washington waters.
- Are dormant during the winter. Intensive feeding starts when water temperatures reach 68°F.
- Prefer flowing water to still waters (original habitat is fluvial).
- Are difficult to recapture once released.
- May not feed in swimming areas, docks, boating areas, or other sites where there is heavy human activity.

Advantages

- Grass carp are inexpensive compared to some other control methods and offer long-term control, but fish may need to be restocked at intervals.
- Grass carp offer a biological alternative to aquatic plant control.

Disadvantages

- Depending on plant densities and types, it may take several years to achieve plant control using grass carp and in many cases, control may not occur.
- If the waterbody is overstocked, all submersed aquatic plants may be eliminated. Removing excess fish is difficult and expensive.
- The type of plants grass carp prefer may also be those most important for habitat and for waterfowl food.
- If not enough fish are stocked, less-favored plants, such as Eurasian milfoil, may take over the lake.
- Stocking grass carp may lead to algae blooms.
- All inlets and outlets to the lake or pond must be screened to prevent grass carp from escaping into streams, rivers, or other lakes.

Permits

Stocking grass carp requires a fish-stocking permit from the Washington Department of Fish and Wildlife. Also, if inlets or outlets need to be screened, an *Hydraulic Project Approval* application must be completed for the screening project.

Costs

In quantities of 10,000 or more, 8 to 12 inch sterile grass carp can be purchased for about $5.00 each for truck delivery. The cost of small air freighted orders will vary and is estimated at $8 to $10 per fish.

Other Considerations

- Would not achieve immediate results – takes time and is not guaranteed to work.
- Community may have concerns with introduced species.
- Potential damage to the native plant community of the lake, which could result in the establishment of other aggressive plant species as pioneers.

- Concerns from anglers about grass carp.
- Initial investment very expensive.
- Introduction of grass carp has generally been discouraged by State agencies, especially in systems like Liberty Lake.

Application for Liberty Lake

Grass carp are not suitable for aquatic plant control in Liberty Lake. The infestation of milfoil has not reached a level where a bio-control such as grass carp would be necessary. Their preferred food species include the dominant submersed aquatic species in Liberty Lake, which might be grazed before the milfoil. They could remove all the beneficial plants that support a healthy fish population. Without cover, and the invertebrates associated with beneficial native aquatic vegetation, the system would be degraded and some species (invertebrates, fish, etc.) may be eradicated. In addition, if grass carp eliminated all beneficial submersed vegetation, the removal could reduce nutrient competition, thereby enhancing phytoplankton productivity. If other techniques are suitable, this should not be considered.

Watermilfoil Weevil (*Euhrychiopsis lecontei)*

Size: 2-3 mm, equivalent to a grain of rice

The following information and citations on the watermilfoil weevil are taken from the Washington State Department of Ecology's website on Aquatic Plant Management (http://www.ecy.wa.gov/programs/wq/plants/management/weevil.html).

During the past decade, a third type of control agent has emerged. In this case, a native insect that feeds and reproduces on northern milfoil (*Myriophyllum sibiricum*), which is native to North America, was found to utilize the non-native Eurasian watermilfoil (*Myriophyllum spicatum*). Vermont government scientists first noticed that Eurasian watermilfoil had declined in some lakes and brought this to the attention of researchers. It was discovered that a native watermilfoil weevil (*Euhrychiopsis lecontei)* feeding on Eurasian watermilfoil caused the stems to collapse. Because native milfoil has thicker stems than Eurasian watermilfoil, the mining activity of the larvae does not cause it the same kind of damage. A number of declines of Eurasian watermilfoil have been documented around the United States and researchers believe that weevils may be implicated in many of these declines.

Several researchers around the United States (Vermont, Minnesota, Wisconsin, Ohio, & Washington) have been working to determine the suitability of this insect as a bio-control agent. The University of Washington is conducting research into the suitability of the milfoil weevil for the biological control of milfoil in Washington lakes and rivers. Surveys have shown that in Washington the weevil is found more often in eastern Washington lakes and it seems to prefer waters that are more alkaline. However, it is also present in cooler, wetter western Washington.

The milfoil weevil has been associated with declines of Eurasian watermilfoil in the United States (e.g. Illinois, Minnesota, Vermont, and Wisconsin). Researchers in Vermont found that the milfoil weevil could negatively affect Eurasian watermilfoil by suppressing the plants growth and reducing its buoyancy (Creed and Sheldon 1995). In 1989, state biologists reported that Eurasian watermilfoil in Brownington Pond, Vermont had declined from approximately 10 hectares (in 1986) to less than 0.5 hectares. Researchers from Middlebury College, Vermont hypothesized that the milfoil weevil, which was present in Brownington Pond, played a role in reducing Eurasian watermilfoil (Creed and Sheldon 1995). During 1990 through 1992, researchers monitored the populations of Eurasian watermilfoil and the milfoil weevil in Brownington Pond. They found that by 1991 Eurasian watermilfoil cover had increased to approximately 2.5 hectares (approximately 55-65 g/m_2) and then decreased to about 1 hectare (<15 g/m_2) in 1992. Weevil abundance began increasing in 1990 and peaked in June of 1992, where 3 – 4 weevils (adults and larvae) per stem were detected (Creed and Sheldon 1995). These results supported the hypothesis that the milfoil weevil played a role in reducing Eurasian watermilfoil in Brownington Pond.

Another documented example where a crash of Eurasian watermilfoil has been attributed to the milfoil weevil is in Cenaiko Lake, Minnesota. Researchers from the University of Minnesota reported a decline in the density of Eurasian watermilfoil from 123 g/m_2 in July of 1996 to 14 g/m_2 in September of 1996. Eurasian watermilfoil remained below 5 g/m_2 in 1997, then increased to 44 g/m_2 in June and July of 1998 and declined again to 12 g/m_2 in September of 1998 (Newman and Biesboer, in press). In contrast, researchers found that weevil abundance in Cenaiko Lake was 1.6 weevils (adults and larvae) per stem in July of 1996. Weevil abundance, however, decreased with declining densities of Eurasian watermilfoil in 1996 and by September 1997 weevils were undetectable. In September of 1998 weevil abundance had increased to >2 weevils per stem (Newman and Biesboer, in press). Based on observations made by researchers in Vermont, Ohio and Wisconsin it seems that having 2 weevils (or more) per stem is adequate to control Eurasian watermilfoil. However, as indicated by the study conducted in Cenaiko Lake, Minnesota, an abundance of 1.5 weevils per stem may be sufficient in some cases (Newman and Biesboer, in press).

In Washington State, the milfoil weevil is present primarily in eastern Washington and occurs on both Eurasian and northern watermilfoil, the latter plant being native to the state (Tamayo *et. al.*1999). During the summer of 1999, researchers from the University of Washington determined the abundance of the milfoil weevil in 11 lakes in Washington. They found, that weevil abundance ranged from undetectable levels to 0.3

weevils (adults and larvae) per stem. Fan Lake, Pend Oreille County had the greatest density per stem of 0.6 weevils (adults, larvae and eggs per stem). The weevils were present on northern watermilfoil. These abundance results are well below the recommendations made by other researchers in Minnesota, Ohio, Vermont, and Wisconsin of having at least 1.5 – 2.0 weevils per stem in order to control Eurasian watermilfoil.

To date, there have not been any documented declines of Eurasian watermilfoil in Washington State that can be attributed to the milfoil weevil. Creed speculated that declines of Eurasian watermilfoil in Lake Osoyoos and the Okanogan River might have been caused by the milfoil weevil. In Minnesota, Cenaiko Lake is the only lake in that state that has had a Eurasian watermilfoil crash due to the weevil; other weevil lakes are yet to show declines in Eurasian watermilfoil.

Researchers in Minnesota have suggested that sunfish predation may be limiting weevil densities in some lakes (Sutter and Newman, 1997). The latter may be true for Washington State, as sunfish populations are present in many lakes of the state, including those with weevils. In addition, other environmental factors that may be keeping weevil populations in check in Washington, but have yet to be studied, include over-wintering survival and habitat quality and quantity (Jester *et. al.* 1997; Tamayo *et. al*, in press).

Although the milfoil weevil shows potential as a biological control for Eurasian watermilfoil, more work is needed to determine which factors limit weevil densities and what lakes are suitable candidates for weevil treatments in order to implement a cost and control effective program.

Advantages

- Milfoil weevils offer a biological alternative to aquatic plant control.
- They may be cheaper than other control strategies.
- Bio-controls enable weed control in hard-to-access areas and can become self-supporting in some systems.
- If they are capable of reaching a critical mass, bio-controls can decimate a weed population.

Disadvantages

- There are many uncertainties as to the effectiveness of this bio-control in western Washington waters.
- There have been no documented declines of Eurasian watermilfoil in Washington State that can be attributed to the milfoil weevil.
- Many of our lakes, including Liberty Lake, have introduced sunfish populations that may predate on the milfoil weevils. Two species of sunfish are present in Liberty Lake, bluegill sunfish and pumpkinseed sunfish.
- Bio-controls often do not eradicate the target plant species, and there would be population fluctuations as the milfoil and weevil follow predator-prey cycles.

Permits
The milfoil weevil is native to Washington and is present in a number of lakes and rivers. It is found associated with both native northern milfoil and Eurasian watermilfoil. A few companies are selling milfoil weevils commercially. However, to import these out-of-state weevils into Washington requires a permit from the Washington Department of Agriculture. As of July 31, 2003, no permits have been issued to bring in outside weevils to Washington. However, there have been a few studies using weevils in Washington. In these cases, weevils were collected in Washington and reared on Washington milfoil. The offspring (larvae) were used to augment existing weevil populations or to introduce weevils to the test sites (Kathy Hamel, pers. comm. 2003).

Application for Liberty Lake
Since the milfoil weevil is a new bio-control agent, it has not been intentionally released widely in Washington to control Eurasian watermilfoil. It is uncertain how effective the weevil will be and whether populations per stem can be maintained at levels high enough to eradicate Eurasian watermilfoil. In addition, the infestation of milfoil in Liberty Lake is not heavy enough to warrant bio-control introduction when other methods are still available. The infested areas in Liberty Lake are too scattered and cover too large an area for bio-controls to be effective. Liberty Lake also has two species of introduced sunfish (bluegill sunfish and pumpkinseed sunfish) populations that may predate on the milfoil weevils.

7.7 CHEMICAL CONTROLS

AQUATIC HERBICIDES

Description of Method
The following information and citations were taken from the Washington State Department of Ecology's website on Aquatic Plant Management (http://www.ecy.wa.gov/programs/wq/plants/management/aqua028.html).

Aquatic herbicides are chemicals specifically formulated for use in water to eradicate or control aquatic plants. Herbicides approved for aquatic use by the United States Environmental Protection Agency (EPA) have been reviewed and considered compatible with the aquatic environment when used according to label directions. However, individual states may also impose additional constraints on their use.

Aquatic herbicides are sprayed directly onto floating or emergent aquatic plants, or are applied to the water in a liquid or pellet form. *Systemic* herbicides are capable of killing the entire plant by translocating from foliage or stems and killing the root. *Contact* herbicides cause the parts of the plant in contact with the herbicide to die back, leaving the roots alive and capable of re-growth (chemical mowing). *Non-selective* herbicides will generally affect all plants that they are exposed to, both monocots and dicots. *Selective* herbicides will affect only some plants (usually dicots – broad-leafed plants like Eurasian watermilfoil will be affected by selective herbicides whereas monocots like Brazilian elodea and our native pondweeds may not be affected).

Because of environmental risks from improper application, aquatic herbicide use in Washington State waters is regulated and has certain restrictions. The Washington State Department of Agriculture must license aquatic applicators. In addition, because of a March 2001 court decision (Federal 9th Circuit District Court), coverage under a discharge permit called a National Pollutant Discharge Elimination System (NPDES) permit must be obtained before aquatic herbicides can be applied to some waters of the United States. This ruling, referred to as the Talent Irrigation District decision, has further defined Section 402 of the Clean Water Act. Ecology has developed a general NPDES permit that is available for coverage under the Washington Department of Agriculture for the management of noxious weeds growing in an aquatic situation and a separate general permit for nuisance aquatic weeds (native plants) and algae control. For nuisance weeds (native species also referred to as beneficial vegetation) and algae, applicators and the local sponsor of the project must obtain a NPDES permit from the Washington Department of Ecology before applying herbicides to Washington water bodies. Although there are a number of EPA registered aquatic herbicides, the Department of Ecology currently issues permits for five aquatic herbicides and one algaecide (as of 2003-treatment season) for aquatic weed treatment for lakes, rivers, and streams. Weed control in irrigation canals is covered under another permit. Other herbicides are undergoing review and it is likely that other chemicals may be approved for aquatic use in Washington in the future.

The chemicals that are permitted for use in 2003 are listed below (see Appendix E for applicable herbicide labels).

Washington Department of Ecology Permitted Aquatic Herbicides

- **Glyphosate** - Trade names for aquatic products with glyphosate as the active ingredient include Rodeo®, AquaMaster®, and AquaPro®. This systemic broad-spectrum herbicide is used to control floating-leaved plants like water lilies and shoreline plants like purple loosestrife. It is generally applied as a liquid to the leaves. Glyphosate does not work on underwater plants such as Eurasian watermilfoil. Although glyphosate is a broad spectrum, non-selective herbicide, a good applicator can somewhat selectively remove targeted plants by focusing the spray only on the plants to be removed. Plants can take several weeks to die and a repeat application is often necessary to remove plants that were missed during the first application.

- **Fluridone** – Trade names for fluridone products include Sonar® and Avast!®. Fluridone is a slow-acting non-selective systemic herbicide used to control Eurasian watermilfoil and other underwater plants. It may be applied as a pellet or as a liquid. Fluridone can show good control of submersed plants where there is little water movement and an extended time for the treatment. Its use is most applicable to whole-lake or isolated bay treatments where dilution can be minimized. It is not effective for spot treatments of areas less than five acres. It is slow acting and may take six to twelve weeks before the dying plants fall to the sediment and decompose. When used to manage Eurasian watermilfoil in

Washington, fluridone is applied several times during the spring/summer to maintain a low, but consistent concentration in the water. Although fluridone is considered a broad-spectrum herbicide, when used at very low concentrations, it can be used to selectively remove Eurasian watermilfoil. Some native aquatic plants, especially pondweeds, are minimally affected by low concentrations of fluridone.

- **2,4-D** –There are two formulations of 2,4-D approved for aquatic use. The granular formulation contains the low-volatile butoxy-ethyl ester formulation of 2,4-D (trade names include AquaKleen® and Navigate®). The liquid formulation contains the dimethylamine salt of 2,4-D (Trade name - DMA*4IVM). Both the granular and liquid formulations can be effective for spot treatment of Eurasian watermilfoil and other broad-leaved species. 2,4-D has been shown to be selective to Eurasian watermilfoil when used at the labeled rate, leaving native aquatic species relatively unaffected. For additional information on 2,4-D characteristics and environmental impacts, refer to Compliance Services International, 2000.
    - **Navigate® and AquaKleen®** - (Appendix E) Active ingredient 2,4-D BEE. These granular products contain the low-volatile butoxy-ethyl ester (BEE) formulation of 2,4-D. 2,4-D is a relatively fast acting selective, systemic herbicide. It is applied in a granular formulation and can be effective for spot treatment of Eurasian watermilfoil. When used at a rate of 100 pounds per acre, 2,4-D has shown to be selective to Eurasian watermilfoil, leaving native aquatic species relatively unaffected. Species controlled with Navigate® and AquaKleen® and effectiveness of control are listed in Appendix F.

    - **DMA*4IVM®** - (Appendix E) Dimethylamine Salt of 2,4-D. This is a liquid formulation that is labeled for aquatic weed control. Since 2,4-D DMA (like 2,4-D BEE) is rapidly converted to 2,4-D acid, the two products should be equally effective in controlling Eurasian watermilfoil.

- **Triclopyr (TEA)** – (Appendix E) Trade name Renovate® was registered on April 4, 2003 (EPA Registration number 62719-37-67690). This aquatic herbicide is a selective systemic herbicide used to control submerged, emergent, and floating aquatic plants. Triclopyr functions by disrupting plant growth metabolism by mimicking the plant hormone auxin, causing uncontrolled and disorganized plant growth that ultimately leads to plant death. It has little or no impact on grasses. There are two basic formulations of triclopyr - a triethyamine salt, and a butoxyethyl ester. In soils, both formulations degrade to the parent compound, triclopyr acid. In water, the salt formulation is soluble and degradation occurs primarily through photolysis and hydrolysis and may degrade in several hours. The ester, however, is not water-soluble and can be persistent in aquatic environments. The ester binds to organic particles in the water column and precipitates to the sediment layers. Bound ester molecules will degrade through hydrolysis or photolysis to triclopyr acid, which will move back into the water column and continue to degrade. The rate of degradation is dependent on the

water temperature, pH, and sediment content. The ester can be highly volatile and is best applied at cool temperatures on days with no wind. Renovate® water-soluble triethylamine salt formulation contains three pounds of triclopyr acid equivalent per gallon (http://tncweeds.ucdavis.edu/products/handbook/20.Triclopyr.pdf).

- **Endothall - Dipotassium Salt** – Trade name Aquathol®. Endothall is a fast-acting non-selective contact herbicide that destroys the vegetative part of the plant but generally does not kill the roots. Endothall may be applied in a granular or liquid form. Typically, endothall compounds are used primarily for short-term (one season) control of a variety of aquatic plants. However, there has been some recent research that indicates that when used in low concentrations, endothall can be used to selectively remove exotic weeds; leaving some native species unaffected. Because it is fast acting, endothall can be used to treat smaller areas effectively. Endothall is not effective in controlling Canadian waterweed (*Elodea canadensis*) or Brazilian elodea.

- **Diquat** – Trade name Reward®. Diquat is a fast-acting non-selective contact herbicide that destroys the vegetative part of the plant but does not kill the roots. It is applied as a liquid. Typically, diquat is used primarily for short-term (one season) control of a variety of submersed aquatic plants. It is very fast acting and is suitable for spot treatment. However, turbid water or dense algal blooms can interfere with its effectiveness. Diquat was allowed for use in Washington in 2003 and Ecology will be collecting information about its efficacy against Brazilian elodea in 2003.

Advantages

Aquatic herbicide application can be less expensive than other aquatic plant control methods, especially when used in controlling widespread infestations of state-listed noxious aquatic weeds.

- Aquatic herbicides are easily applied around docks and underwater obstructions.
- Washington has had some success in eradicating Eurasian watermilfoil, a state listed noxious weed, from some smaller lakes (350 acres or less) using fluridone products.
- 2,4-D has been shown to be effective in controlling smaller infestations (not lake-wide) of Eurasian watermilfoil in Washington.

Disadvantages

- Some herbicides have swimming, drinking, fishing, irrigation, and water use restrictions (check the label and general permit).
- Herbicide use may have unwanted impacts to people who use the water and to the environment.
- Non-targeted plants as well as nuisance plants may be controlled or killed by some herbicides.

- Depending on the herbicide used, it may take several days to weeks or several treatments during a growing season before the herbicide controls or kills treated plants.
- Rapid-acting herbicides like endothall and diquat may cause low dissolved oxygen conditions to develop as plants decompose. Low dissolved oxygen can cause fish kills.
- To be most effective, generally herbicides must be applied to rapidly growing plants.
- Some expertise in using herbicides is necessary in order to be successful and to avoid unwanted impacts.
- Many people have strong feelings against using chemicals in water. Find out what lake residents think about chemical use before deciding to treat your water plants with herbicides.
- Some cities or counties may have policies forbidding or discouraging the use of aquatic herbicides. Check before hiring an aquatic herbicide applicator.

Permits
A National Pollutant Discharge Elimination System (NPDES) permit is needed to apply any aquatic pesticide (including herbicides) to waters of the state. Both the noxious aquatic weed and nuisance plant and algae NPDES permits require the development of integrated aquatic vegetation management plans before the third season of treatment. Some herbicide residue monitoring may also be required.

For nuisance weeds and filamentous algae control, apply to your Ecology regional office for a permit in winter before plants become a problem. If you are accepted for coverage under the permit, the permit fee is $300 per year. Talk to your regional permit writer for details.

Costs of Herbicide Treatment
Approximate costs for one-acre herbicide treatment:

- Glyphosate: $250
- Fluridone: $900 to $1,000
- Endothall: $650
- 2,4-D: $300 to $600
- Diquat: $300 to $400
- Triclopyr: $300 to $800

These costs are estimates and will vary from site to site depending on treatment rates and water depths.

Other Considerations
The focus of the discussion below is the active ingredients 2,4-D and triclopyr. The Liberty Lake Sewer and Water District, and with input from Watershed Committee and consultants, have chosen these chemicals as the best herbicide options for the *Integrated Treatment Action Strategy* (see Chapter 9) for Liberty Lake.

2,4-D

Since 2,4-D is a relatively fast acting selective, systemic herbicide it was chosen as the primary option. It can be effective for spot treatment of Eurasian watermilfoil, and when used at a rate of 100 pounds per acre, 2,4-D has shown to be selective to Eurasian watermilfoil, leaving native aquatic species relatively unaffected.

EPA studies yield the parameters LD50 (acute lethal dose to 50% of a test population), NOEL (No Observable Effect Level, which is the highest test dosage causing no adverse responses), and RfD (EPA Reference Dose determined by applying at least a 100-fold uncertainty factor to the NOEL). The EPA defines the RfD as the level that a human could be exposed to daily with reasonable certainty of no adverse effect from any cause, in other words, a "safe" dose. Exposures to bystanders or consumers are deemed safe when the RfD is not exceeded (Felsot, 1998). The LD50 value is useful for comparing one compound with another and for grouping compounds into general hazard classes.

According to Felsot (1998), any pesticide that does not produce adverse effects on aquatic organisms until levels in water reach milligram per liter (i.e., mg/L, equivalent to a part per million, ppm) would be considered of comparatively low hazard. Substances that are biologically active in water at levels one thousand-fold less, (i.e., µg/L, parts per billion, ppb), are considered highly hazardous to aquatic life. Most pesticides falling in the latter category are insecticides rather than herbicides. Also, compounds that have half-lives less than 100 days are considered non-persistent compared to compounds having half-lives approaching one year or longer. The half-life of 2,4-D is about 7 days in water. Since there are multiple factors that modulate the pesticides' hazard, just focusing on the half-life itself is a bit misleading for hazard assessment. It is now known that the longer a residue remains in soil/sediment, the less likely it will be taken up by plants, leach, or runoff (Felsot, 1998). This phenomenon is called residue aging and involves changes in the forces governing interactions of the chemical with the soil matrix over time.

The granular formulation of 2,4-D is typically applied using a bow-mounted centrifugal or blower-type spreader and uniformly spread over the water above the milfoil beds and slightly beyond. The clay particles sink to the bottom or are caught up in the plants. The herbicide slowly releases from the clay over the next day. A few days after the 2,4-D treatment, observers will see the growing tips of milfoil plants twist and look abnormal. These plants will sink to the sediments usually within one to two weeks of treatment. Unless treatment takes place in dense beds of milfoil, it is unlikely for low oxygen conditions to develop. Results of spot treatment may be variable depending on water movement, size of treatment plot, density of milfoil, weather conditions, underwater springs, etc. Granular formulations are generally recommended for spot treatment since liquid applications may have tendencies to drift away from the milfoil beds. When the liquid formulation is used, it is applied using subsurface trailing hoses (http://www.ecy.wa.gov/programs/wq/plants/management/2,4D_strategies.html).

As far as restrictions for aquatic 2,4-D applications; there are no fishing restrictions, and three to five days after treatment the water is generally below the drinking water standards. Although 2,4-D should not damage grass or other monocots, it is not recommended that one use treated water to water lawns during the first three to five days after a treatment. Water within the treatment areas cannot be used for drinking until 2,4-D concentrations have declined to 70 ppb, and water used for irrigation cannot be used until 2,4-D concentrations are 100 ppb or less. There is no swimming restriction for 2,4-D use. Ecology advises that swimmers wait for 24 hours after application before swimming in the treatment area, but that is an advisory only. The choice is up to the individual.

Human and General Mammalian Health

The oral LD50 for 2,4-D (acid) is 764 mg/kg and the dermal LD50 is >2000 mg/kg. This chemical has a low acute toxicity (from an LD50 standpoint, is less toxic than caffeine and slightly more toxic than aspirin). The RfD for 2,4-D (acid) is 0.01 mg/kg/d. Recent, EPA studies continue to find that it is not considered a carcinogen or mutagen, nor does it cause birth defects. It has a relatively short persistence in water, since it tends to bind to organic matter in the sediments. The herbicide 2,4-D generally does not bioaccumulate to a great extent, and the small amounts which do accumulate are rapidly eliminated once exposure ceases (Washington State Department of Ecology, 2001).

The risks to human health from exposure to aquatic 2,4-D applications were evaluated in terms of the most likely forms of contact between humans and the water to which the herbicide was applied. Ecology's Risk Assessment results indicate that 2,4-D should present little or no risk to the public from acute (one time) exposures via dermal contact with the sediment, dermal contact with water (swimming), or ingestion of fish (Washington State Department of Ecology, 2001). Based on the low dermal absorption of the chemical, the dose of 2,4-D received from skin contact with treated water is not considered significant. Dose levels used in studies are often far beyond what an animal or human would experience from an aquatic application. Many experiments have examined the potential for contact by the herbicide applicator, although these concentrations have little relevance to environmental exposure by those not directly involved with the herbicide application. Once the herbicide has entered the water, its concentration will quickly decline because of turbulence associated mixing and dilution, volatilization, and degradation by sunlight and secondarily by microorganisms (Felsot, 1998).

Results of chronic exposure assessments indicate that human health should not be adversely impacted by chronic 2,4-D exposure via ingestion of fish, ingestion of surface water while swimming, incidental ingestion of sediments, dermal contact with sediments, or dermal contact with water (Washington State Department of Ecology, 2001). Pharmacokinetic investigations have demonstrated that 2,4-D is rapidly absorbed from the gastrointestinal tract and is quickly excreted. Animal toxicological investigations carried out at high doses showed a reduction in the ability of the kidneys to excrete the chemical, and resulted in some systemic toxicity. However, the high doses tested may not be relevant to the typical low dose human exposures resulting from labeled use. A review of the scientific and medical literature failed to provide any human case reports of

systemic toxicity or poisoning following overexposure to these herbicide products when used according to label instructions (Washington State Department of Ecology, 2001). The risks to mammalian pets and wildlife should be closely related to these reported human risks, especially since many of the toxicity experiments are carried out on test animals by necessity.

The potential hazard to pregnant women and to the reproductive health of both men and women was evaluated. The results of the 2,4-D developmental or teratology (birth defects) and multigenerational reproduction studies indicate that the chemical is not considered to be a reproductive hazard or cause birth defects (teratogen) when administered below maternally toxic doses (Washington State Department of Ecology, 2001). A review of the histopathological sections of various 2,4-D subchronic and chronic studies provides further support that the chemical does not affect the reproductive organs, except in some higher dose groups beyond the potential level of incidental exposure after an aquatic weed application.

Fish Health

Based on laboratory data reported in the Department of Ecology's Risk Assessment of 2,4-D, 2,4-D DMA has a low acute toxicity to fish (LC50 =100 to 524 mg a.i./L for the rainbow trout and bluegill sunfish respectively). No federally sensitive, threatened or endangered species were tested with 2,4-D DMA. However, it is likely that endangered salmonids would not exhibit higher toxic effects to 2,4-D DMA than those seen in rainbow trout. Since the maximum use rate of 2,4-D DMA would be no higher than the maximum labeled use rate (4.8 mg a.i./L) even the most sensitive fish species within the biota should not suffer adverse impacts from the effects of 2,4-D DMA. In conclusion, 2,4-D DMA will not effect fish or free-swimming invertebrate biota acutely or chronically when applied at typical use rates of 1.36 to 4.8 mg a.i./L (Washington State Department of Ecology, 2001). However, more sensitive species of benthic invertebrates like glass shrimp may be affected by 2,4-D DMA, but 80 and 90% of the benthic species should be safe when exposed to 2,4-D DMA acutely or chronically at rates recommended on the label. Field work indicates that 2,4-D has no significant adverse impacts on fish, free-swimming invertebrates and benthic invertebrates, but well designed field studies are in short supply.

According to the Department of Ecology's Risk Assessment of 2,4-D, in the United States, 2,4-D BEE is the most common herbicide used to control aquatic weeds. 2,4-D BEE, has a high laboratory acute toxicity to fish (LC50 = 0.3 to 5.6 mg a.i./L for rainbow trout fry and fathead minnow fingerlings, respectively). Formal risk assessment indicates that short-term exposure to 2,4-D BEE should cause adverse impact to fish since the risk quotient is above the acute level of concern of 0.01 (RQ = 0.1 ppm/0.3 ppm = 0.33). However, the low solubility of 2,4-D BEE and its rapid hydrolysis to 2,4-D acid means fish are more likely to be exposed to the much less toxic 2,4-D acid. 2,4-D acid has a toxicity similar to 2,4-D DMA to fish (LC50 = 20 mg to 358 mg a.i./L for the common carp and rainbow trout, respectively). In contrast, formal risk assessment with 2,4-D acid indicates that short-term exposure to 2,4-D BEE should not cause adverse impact to fish since the risk quotient is below the federal level of concern of 0.01 (RQ = 0.1 ppm/20

ppm = 0.005). To conclude, 2,4-D BEE will have no significant impact on the animal biota acutely or chronically when using applied rates recommended on the label (Washington State Department of Ecology, 2001). Although laboratory data indicates that 2,4-D BEE may be toxic to fish, free-swimming invertebrates and benthic invertebrates, data indicates that its toxic potential is not realized under typical concentrations and conditions found in the field. This lack of field toxicity is likely due to the low solubility of 2,4-D BEE and its rapid hydrolysis to the practically non-toxic 2,4-D acid within a few hours to a day following the application.

TRICLOPYR

Triclopyr is our second option for the *Integrated Treatment Action Strategy* for Liberty Lake. Over the years of using 2,4-D as the primary herbicide option, we will have a sense as to whether the 2,4-D has eliminated a significant amount of the Eurasian watermilfoil, or whether it has seemed to become less effective. If we determine that the treatments have become less effective, we may a shift from AquaKleen®, DMA*4IVM®, or Navigate® 2,4-D to triclopyr if we find that the plants have become less susceptible to the herbicide. Another applicable reason to switch to triclopyr may be initiated through the discontinuation of 2,4-D statewide (i.e. a lawsuit that may prevent the use of 2,4-D in Washington waters). In any event, triclopyr is considered as an alternative chemical control for Liberty Lake.

Like 2,4-D, triclopyr is a selective systemic herbicide used to control submerged, emergent, and floating aquatic plants. There are two basic formulations of triclopyr – a triethyamine salt, and a butoxyethyl ester. Triclopyr is the pyridine analogue of 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) and differs from 2,4,5-T only by the presence of a nitrogen (N) atom in the ring structure. At ambient temperatures, triclopyr is a fluffy solid and is readily soluble in water. In aqueous solutions, the hydrogen atom of the carboxylic acid group (**COOH**) may be associated (e.g., **COOH**) or dissociated (e.g., **-COO- + H+**) depending on the pH of the solution. The dissociation constant, or pKa, for the carboxylic acid group is approximately 3. Thus, at a pH of 3, 50% of the acid is associated and 50% is disassociated. As the acidity of the solution decreases (i.e., the pH of the solution increases) the proportion of triclopyr that is ionized or dissociated increases. The pH of most biological fluids ranges from approximately 5 to 9. Thus, within this range of pH, most of the triclopyr acid has a net negative charge (**-COO**) (http://www.fs.fed.us/r4/boise/mgmt/weeds/Documents/Pest_links_files/triclopyr.pdf).

Fate in humans and animals

Data from animal studies indicate that triclopyr is rapidly eliminated via the urine as the unchanged parent compound. At higher oral doses, some triclopyr may be eliminated through the feces as the absorption capacity of the intestine is exceeded. Reported half-lives for elimination of triclopyr from mammals are 14 hours (dog) and <24 hours (monkeys). A human elimination half-life of approximately 5 hours has been suggested. Minor metabolites of triclopyr may include trichloropyridinal. (http://ace.ace.orst.edu/info/extoxnet/pips/triclopy.htm).

Effects on aquatic organisms

The parent compound and amine salt are practically nontoxic to fish. Triclopyr has a LC50 (96-hour) of 117 mg/L in rainbow trout and 148 mg/L in bluegill sunfish. The compound is practically nontoxic to the aquatic invertebrate Daphnia magna, a waterflea, with a reported LC50 for the amine salt of 1170 mg/L. The ester formulation has reported 96-hour LC50 values of 0.74 mg/L and 0.87 mg/L in the rainbow trout and bluegill sunfish, respectively. The compound has little if any potential to accumulate in aquatic organisms. The bioconcentration factor for triclopyr in whole bluegill sunfish is only 1.08 (http://ace.ace.orst.edu/info/extoxnet/pips/triclopy.htm).

Effects on aquatic Plants

Triclopyr and other pyridinecarboxylic acid herbicides mimic indole auxin plant growth hormones and cause uncontrolled growth in plants. These herbicides behave similarly to the chlorophenoxy acid herbicides such as 2,4-D and 2,4,5-T. At sufficiently high levels of exposure, the abnormal growth is so severe that vital functions cannot be maintained and the plant dies. As with dermal absorption in mammals, there are significant differences between the uptake of triclopyr acid and triclopyr BEE, with the ester penetrating much more rapidly than the salt. Variations in species sensitivity to triclopyr BBE appear to be related directly to the rate of metabolic ester hydrolysis by the plant (http://www.fs.fed.us/r4/boise/mgmt/weeds/Documents/Pest_links_files/triclopyr.pdf).

The only available information regarding the toxicity of triclopyr to aquatic algae is the study by Peterson *et. al.* (1994). Assaying toxicity as an inhibition of carbon fixation, these investigators noted no or relatively little inhibition at concentrations of triclopyr acid of 2.6 mg/L. One study has been encountered on the effect of triclopyr on aquatic macrophytes. This laboratory study was designed to determine the efficacy of triclopyr for the control of eurasian watermilfoil, an aquatic macrophyte and involved levels of 0.25-2.5 mg a.e./L over time periods of 2-48 hours. Very little effect at any concentration was seen for exposure periods <6 hours. At 0.25 mg/L, effective control was associated with exposure periods of 24 (partially effective) to 72 (very effective) hours. These results are substantially below exposure levels associated with toxicity in fish or aquatic invertebrates. This species is adversely affected if water concentrations remain above 0.25 mg/L for more than 24 hours (http://www.fs.fed.us/r4/boise/mgmt/weeds/Documents/Pest_links_files/triclopyr.pdf).

NPDES PERMIT REQUIREMENTS

The following information is taken from the Washington State Department of Ecology's website on Aquatic Noxious Weed Control NPDES General Permit (http://www.ecy.wa.gov/programs/wq/pesticides/final_pesticide_permits/noxious/noxious_index.html).

Aquatic Nuisance Plant and Algae Control National Pollutant Discharge Elimination System Waste Discharge General Permit. Permit No.: WAG – 994000

State of Washington
Department of Ecology

Issuance Date: June 13, 2002
Effective Date: July 5, 2002
Expiration Date: July 5, 2007

Because of environmental risks from improper application, aquatic herbicide use in Washington State waters is regulated and has certain restrictions. Based on a 9th Circuit court decision, the Washington Department of Ecology determined that National Pollutant Discharge Elimination System (NPDES) permits are required for the application of pesticides to Washington waters of the state. The Noxious Weed NPDES permit requires monitoring of aquatic herbicides applied to manage the growth of state-listed noxious weeds or quarantine list plants growing in aquatic situations.

This permit states that the permittee or its designee may choose to participate in a Group Monitoring Plan or follow the monitoring schedule as set out in the permit. Monitoring is required beginning in the 2003 treatment season and thereafter. Ecology issued a statewide Noxious Weed NPDES permit to the Washington Department of Agriculture and they, in turn, provide coverage to cooperators for noxious weed herbicide applications in state waters.

This general permit covers aquatic nuisance plant and algae control activities that discharge herbicides or algaecides directly or indirectly into surface waters of the state of Washington. It also covers indirect algae control through addition of aluminum sulfate to control phosphorus.

2,4-Dichrophenoxyacetic acid, dimethylamine salt (DMA*4IVM®)and 2,4 - Dichrophenoxyacetic acid, butoxyethyl ester (Navigate® and AquaKleen® - BEE)

- 2,4-D shall not be applied within a four hundred (400) foot radius of the outlet stream if there is an outflow.
- The local habitat and/or fish biologist from the Washington State Department of Fish and Wildlife shall be notified at least fourteen days before 2,4-D is applied to salmonid-bearing waters. 2,4-D shall not be applied to a waterbody when, in the written opinion of the habitat and/or fish biologist, juvenile salmonids would be adversely impacted. This notification requirement will remain in effect until such time that the Washington Department of Fish and Wildlife develops site-specific

timing windows for herbicide application. When and if Fish and Wildlife has approved site-specific timing windows, they may be used in lieu of the notification requirement.

Residential and Business Notification – Direct Applications (Appendix G)

- The applicator shall complete copies of the Herbicide Application - Residential and Business Notice form provided by Ecology. These forms shall be sent to all residences and businesses within one-quarter (¼) mile in each direction along the shoreline of the areas to be treated. No later than the day following distribution of the Herbicide Application - Residential and Business Notice, a copy and the date of distribution of the notice shall be mailed or faxed or e-mailed to the Ecology regional office contact.
- Notification shall take place ten (10) to twenty-one (21) days prior to initial treatment.
- If the Herbicide Application - Residential and Business Notice explains the application schedule for the whole season, and there is no significant deviation from that plan, no further Herbicide Application - Residential and Business Notice will be required for the rest of the season (unless a resident or business specifically requests further notification).
- Notice may be done by mail to residences or businesses, by newsletter, or by handbills given directly to the residences or businesses. If handbills are used, the applicator shall secure the notices to the residences or businesses doorknob in a fashion that will hold them in place but will not damage property. If the residence or business is gated or guarded by watchdogs, the applicator may secure the notice in clear view on the outside of the gateway or may attach the notice to the outside of the residence in a fashion that will hold it in place but will not damage property.
- A copy of the notice and a list of locations or addresses where they were sent or delivered shall be kept by the applicator for five (5) years and be hand delivered or mailed to the department immediately upon request.

Posting Requirements for Direct Aquatic Applications (Appendix H)
The applicator shall post all signs prior to the application of any pesticide(s), but no more than twenty-four (24) hours prior to application. The applicator shall use good faith and reasonable effort to ensure that posted signs remain in place until the end of the period of water use restrictions. The applicator shall be responsible for removal of all signs before the following treatment of the waterbody or before the end of the treatment season, whichever comes first. When the EPA label restricts human consumption of fish, any posted signs or other forms of notification shall explicitly state that restriction. Warning signs shall be posted in English and the language commonly spoken by the community who use the area.

Posting Shoreline Private Property Areas:

- Signs shall be a minimum of eight and one-half (8½) by eleven (11) inches in size and be made of a durable weather-resistant material. Lettering shall be in bold

black type with the word "WARNING" (or "CAUTION") at least one- (1) inch high and all other words at least a one-quarter- (¼) inch high.

a) Signboard color for the first seasonal treatment of a waterbody shall be white, for the next treatment, the signboard color shall be yellow, and the following treatment the signboard color shall be orange.
b) Signs must face both the water and the shore and be placed on each private property within ten (10) feet of the shoreline adjacent to the treatment areas. Where a private property shoreline is greater than one hundred-fifty (150) feet, the applicator shall post one sign for every one hundred (100) feet of shoreline. Signs shall be posted so they are secure from the normal effects of weather and water currents, but cause no damage to private or public property.

When using pesticides with swimming and/or fish consumption restrictions or precautions, the applicator shall extend the zone of shoreline posting to include all property within four hundred (400) feet of the treatment area(s).

<u>Posting Shoreline Public Access Areas</u>:

- Public access areas include swim beaches, docks, and boat launches at resorts; privately owned community access areas; and public access areas. Signs shall be a minimum of two (2) feet by three (3) feet in size and be made of a durable weather-resistant material. Lettering shall be in bold black type with the word "WARNING" (or "CAUTION") at least two (2) inches high and all other words at least a one-half- (½) inch high. The colors used for the signboard shall be white, yellow, or orange.
    a) Signs must face both the water and the shore and be placed within twenty-five (25) feet of the shoreline. Where the public access has a shoreline length greater than one hundred-fifty (150) feet, the applicator shall post one sign for every one hundred (100) feet of shoreline. The applicator shall place signs so they are clearly readable by people using the access areas. Signs shall be posted so they are secure from the normal effects of weather and water currents, but cause no damage to private or public property.
    b) An eight and one-half- (8½) by-eleven (11) inch weather resistant map detailing the treatment areas for each herbicide used shall be attached to the sign. The map shall identify the location(s) of the pesticide(s) used and mark the reader's location at the public access site.
    c) These public notice signs shall be posted at all of the waterbody's public access areas within one-quarter (¼) mile of the treatment area and all of the waterbody's public boat launches within one and one-half (1½) miles of the treatment area. NOTE: When using pesticides with swimming and/or fish consumption restrictions or precautions, the applicator's map shall include a four hundred- (400) foot buffer strip around the treatment area(s).

Posting on the Water:

- Durable weather-resistant signs are to be attached to a buoy so they are readable from two opposing directions. The applicator shall position signs so they are completely out of the water. The signs must be at least eight and one-half- (8½) by-eleven (11) inches in size. Lettering shall be in bold black type and the word "WARNING" (or "CAUTION") shall be at least one- (1) inch high and all other words shall be at least a one-quarter- (¼) inch high. The colors used for the signboard shall be white (first application), yellow (second application), or orange (subsequent applications).
    - a) When the pesticide to be used does not have swimming and/or fish consumption restrictions or precautions, posting buoys on the water is not necessary. When the waterbody is less than one acre and/or less than two hundred (200) feet from the treatment area to the opposite shore, posting by buoys is not necessary. When the entire shoreline is restricted by one treatment, no buoys shall be required.
    - b) When the pesticide has a swimming or fish restriction, the applicator shall use buoys or similar devices to mark treatment area boundaries on the water. The applicator shall space buoys so there is one at each approximate corner of the treatment area and at one hundred- (100) foot intervals around the treatment area. Treatment areas of one hundred- (100) foot diameter or less shall be marked with one buoy in the center of the treatment or at one hundred- (100) foot intervals around the treatment area. The applicator shall place buoys so they form a minimum fifty- (50) foot buffer strip around the treatment area(s).

Monitoring Requirements

Monitoring plans, which include sampling for the applied herbicide, shall be included in the Aquatic Weed Management Plan (AWMP) for all whole lake herbicide applications, herbicide applications near drinking and stock watering water withdrawal sites, where native vegetation or threatened or endangered species are likely to be affected, and applications to sites where the total area of treatment exceeds ten acres. The monitoring at a minimum shall include sampling and analysis for the pesticide of use according to the following schedule:

Category	Timing	Units	Sample Point	Sample Type
Receiving water within application site	2,4-D - 5 days after initial application	mg/l	Within boundaries of the treatment site	One area composite
Receiving water outside the application site	Within 24 hours after completion of the application	mg/l	100 feet from boundary of the application site	One area composite of the perimeter

Table 7.5 NPDES Sampling schedule

The AWMP shall include a post application evaluation of the site(s). The timing of this evaluation shall be appropriate for the herbicide or algaecide used at the site. This evaluation shall include an estimate of the effectiveness of the application (qualitative or quantitative), any dead or dying organisms, algae conditions, and may include any other environmental data which may be available (dissolved oxygen, pH, Secchi disk, turbidity, etc.).

Four water right holders within WRIA 57 use Liberty Lake as a source of water (see figure 2.1). These water rights have old priority dates and are active according to the *Water Rights Application Tracking System*. The *Water Rights Application Tracking System* indicates that the primary purpose(s) for withdrawal from the lake is for General Domestic use and Irrigation (shown in Figure 2.1). The list of individuals will be contacted prior to herbicide treatments and agreements will be made to stop use of the water until the herbicide concentrations have dropped to below the irrigation or drinking water standard. In addition, sampling will be conducted at these locations as part of the NPDES permit to verify that the water is safe to use.

Application for Chemical Controls in Liberty Lake

Aquatic herbicides can provide an effective method for control and eventual eradication of noxious weeds. 2,4-D is a selective herbicide and milfoil is particularly susceptible at a labeled rate of about 100 pounds per acre (granular product). Regrowth can be controlled for as little as six weeks to as long as one year. The use of a formulation of 2,4-D should provide excellent primary control of the Eurasian watermilfoil while allowing for the more-appropriate spot treatments in scattered infestation areas. For localized reductions around docks and short stretches of shoreline, the LLSWD recommends hand pulling. These methods can improve swimming safety and fishing conditions in limited areas. Follow-up is essential to ensure the success of eradication. Used alone, 2,4-D is not an eradication tool. Some plants survive the treatment and regrow, so these plants must be removed by other means. In this case, the LLSWD recommends hand pulling, or depending on the initial treatments success, a secondary 2,4-D treatment.

However, there are factors to consider when choosing this chemical treatment. The most important of which is the possibility of over application. This would be detrimental to fish and wildlife and possibly to water quality. Based on laboratory data reported in the Department of Ecology's Risk Assessment of 2,4-D, 2,4-D DMA has a low acute toxicity to fish. Since the maximum use rate should be no higher than the maximum labeled use rate (4.8 mg a.i./L), even the most sensitive fish species within the biota should not suffer adverse impacts from the effects of 2,4-D DMA. In conclusion, neither formulation of the herbicide (2,4-D BEE or 2,4-D DMA) will effect fish or free-swimming invertebrate biota acutely or chronically when applied at typical use rates of 1.36 to 4.8 mg a.i./L (Washington State Department of Ecology, 2001).

There is also some concern that the granular formulations of 2,4-D BEE found in Navigate® and AquaKleen® may settle by gravity into Liberty Lake's high organic and flocculent sediments, which could inhibit the release of the 2,4-D to the water column. If this was the case, we may not achieve the predicted level of control of Eurasian watermilfoil because the concentrations released to the water column may not be high

enough to kill the plants. This phenomenon is called residue aging and involves changes in the forces governing interactions of the chemical with the soil matrix over time. Since the liquid formulation 2,4-D DMA is now available for use in Washington State, this may provide better control than the granular formulation in certain instances. There may also come a time when the need to switch from granular to liquid 2,4-D may be apparent. The need may be instituted through a cost benefit and/or herbicide effectiveness. The liquid formulation of 2,4-D is less expensive and concentrations tend to stay high and persistent after a treatment. The higher concentrations become a drawback when irrigation or drinking water withdrawals occur on a lake. Using the liquid formulation of 2,4-D, it may be possible to get an effective treatment of milfoil at lower treatment rates, cutting down overall treatment costs; an alternative to the use of granular 2,4-D. The Liberty Lake Sewer and Water District and community will consider this alternative as part of the action strategy for controlling milfoil at Liberty Lake.

One of the main reasons to eradicate milfoil is to maintain the health of the native aquatic plant community for all of the species that utilize them in their life cycles, as well as to maintain the viability of the lake for human recreational uses. The nature of the control methods to be implemented will minimize impacts to native aquatic vegetation. According to the Washington State Department of Natural Resources search of the Natural Heritage Information System, there are no records for rare plants or high quality native ecosystems in the vicinity of this project area. In the event that rare plants or high quality ecosystems are discovered in Liberty Lake, a mitigation plan will be adopted and implemented to protect these plants from the treatments used to control Eurasian watermilfoil.

An experienced herbicide applicator can selectively target individual weed species and minimize collateral damage to other species. This is especially true when infestations are small so that large areas with a diverse plant distribution do not have to be treated. Since the Eurasian watermilfoil infestations at Liberty Lake are still confined largely to the shoreline, it should be relatively simple for the control applicator to avoid collateral damage and preserve the native plant community. This is particularly important when considering the 155-acre seasonal marsh at the south end of Liberty Lake. Preservation of the sensitive marsh ecosystem is important, and all efforts will be taken to protect this area from the activities used to control Eurasian watermilfoil.

The control of the Eurasian watermilfoil will be conducted by methods designed to preserve (and eventually enhance or conserve) the native plant communities. Most of the native submersed macrophyte species are monocots (i.e. *Potamogeton* spp.) that should be relatively unaffected by the 2,4-D application. Removing the noxious invaders will halt the degradation of the system and allow the dynamic natural equilibrium to be maintained. A herbicide selective to Eurasian watermilfoil will be used for its control, and will not require a whole-lake treatment that would expose all the submersed plants to the herbicide. Follow-up control methods will focus specifically on the target species and should leave beneficial plants intact.

Since 1998, aquatic 2,4-D (Navigate® and AquaKleen® granular 2,4-D) herbicide treatments have occurred on Liberty Lake with variable success. Since the treatments began, hand harvesting has declined while the herbicide helped limit the spread of milfoil, and in some locations, eradicate it completely. Figure 7.1 illustrates the decline in the need for hand harvesting since herbicide treatments began. Notice the increase of hand harvesting in 2002 when no herbicide was applied.

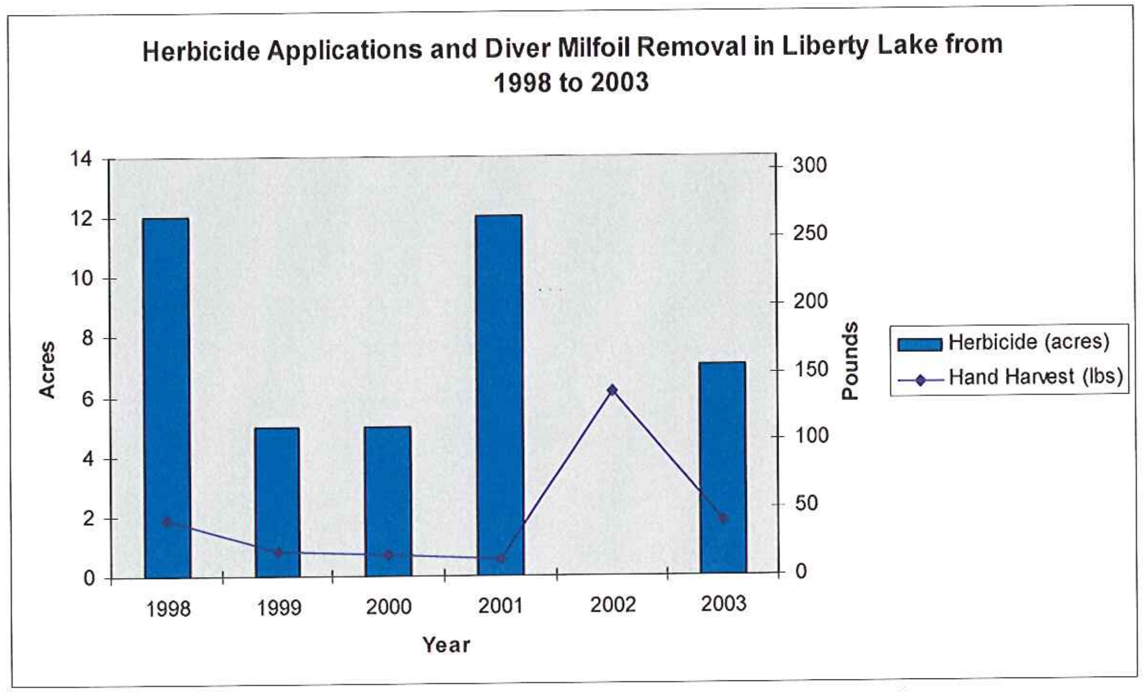


Figure 7.1 Herbicide applications (acres) and diver milfoil removal (pounds) in Liberty Lake from 1995 to 2003 (after Moore, 2003)

We have had great decimation of Eurasian watermilfoil plants using AquaKleen® granular 2,4-D applied at the labeled use rate. Most of these treatments inherently have had variable overall success due to the plant's capacity for rapid vegetative spread. When treatments first began in 1998, a herbicide treatment (AquaKleen® granular 2,4-D) was initiated treating nearly 12 acres in the northern and southern sections of the lake. The following three subsequent years involved a cyclic treatment pattern between the northern and southern sections of the lake. In 1999, 5 acres were treated in the north. In 2000, another 5 acres were treated, this time in the south. Continuing the pattern, in 2001, treatment was conducted on 12 acres in the north. After four consecutive years of this north-south pattern of treatment, a 2,4-D treatment was not conducted in 2002. This particular year yielded slow growth patterns in the early summer, but as summer progressed, high water transparency allowed rapid growth and population expansion. In July 2003, a AquaKleen® Granular 2,4-D treatment occurred on Liberty Lake treating nearly 7.5 acres of milfoil infested areas around the lake's southern parameter, again continuing the pattern.

In certain sections of the lake, the effectiveness of the treatments and hand harvesting regimes have resulted in significant population reduction of Eurasian watermilfoil. This is observable in Dreamwood Bay, areas around the public boat launch, and in areas near Sandy Beach. However, should the milfoil become widespread in Liberty Lake, more drastic measures may need to be implemented. A consideration of permitted products and active ingredients to be used could include Glyphosate, Fluridone, Endothall, and Diquat (see the listing of Washington Department of Ecology Permitted Aquatic Herbicides for details). These systemic and contact herbicides are non-selective and used to control a variety of submersed aquatic plants. Although the Liberty Lake Sewer and Water District and community favor the use of 2,4-D as the primary herbicide, other alternatives must be researched and considered. In addition, it may be necessary to amend the aquatic weed management plan as new technologies become available. Given this scenario, a placeholder will be placed here to accommodate such a change.

Long-term success for control and eventual eradication of Eurasian watermilfoil will require long-term community commitment and involvement as well as educational and communication efforts. The Liberty Lake Sewer and Water District is willing to fund the follow-up activities necessary to ensure continued milfoil management and control. Monitoring and management of the plant community will allow the beneficial uses such as fishing, boating, and swimming to exist.

8.1 PUBLIC INVOLVEMENT

From the very beginning, the Liberty Lake community has demonstrated their commitment to protecting the lake. This section provides an overview of the past, present, and future community involvement at Liberty Lake.

Community History
Native Americans inhabited Liberty Lake when the first settlers arrived in the Spokane Valley. As early as 1815, one of these camps was located on the banks of Liberty Lake. Liberty Lake is steeped in Native American lore, and the Native Americans were very superstitious. When the ice would freeze, it would make terrible roaring sound, sometimes cracking the ice clear across the lake. The Native Americans swore there were devils in the lake, and soon left the immediate vicinity. Another story told was the one about the Native American chief who was drowned in the lake, and the tribe never recovered his body. As this made them fearful of the lake, they all left. The Native Americans would come down from the top of the hills back to the lake and pick huckleberries, but did not come down to the water. Over the years, many Native Americans made arrowheads, rock meal bowls, and mallets were found around the lake indicating that at one time there was quite a tribe at the lake (Brereton and Foedish, 1951).

The name Liberty was adopted from a young man whose original name was Etienne Eduard Laliberte. He later changed his name to Steve Liberty, and in 1871, homesteaded on the west side of Liberty Lake, just one year before Spokane's first settlers arrived. His wife's name was Christine, and they were the parents of nine children. He cut and supplied lumber for part of the construction of the Northern Pacific Railroad, and sold supplies to the army of Fort Sherman. Steve Liberty and his family lived at Liberty Lake until 1889 when he sold his homestead. He died in the Sacred Heart Hospital in 1911, and is buried in Farimont cemetery in Spokane (Brereton and Foedish, 1951).

Steve Liberty

By the late 1800s and early 1900s, Liberty Lake became a popular recreation and resort community for many Spokane area residents. Boating businesses, hotels, resorts, restaurants, dance pavilions, and a railroad depot made Liberty Lake one of the most popular recreational areas in the vicinity. In fact, one of the biggest known crowds that were at the lake was on the 4th of July, 1924, when 14,000 people came out to enjoy the celebration (Brereton and Foedish, 1951).

This irreplaceable resource had once been a beautiful clean, clear lake heavily used by area anglers, boaters, swimmers, and picnickers. However, the natural eutrophication process of the lake was being sped up by human's activities, and the water was starting to lose its clarity. In the 1960s, residents noted that nuisance water quality conditions were occurring earlier in the summer and fall and were becoming more aesthetically displeasing and noticeable each year. By late 1968, tons of decaying aquatic weeds and dried algal mats were being removed from the lake. This prompted the residents to become concerned about the lake's health and quality of water, and they turned to the Property Owner's Association to help remedy the problem. The association educated itself about lakes and water quality problems, and then requested assistance from Spokane County to protect the lake by constructing a sewer system around the entire lake. When help was not forthcoming, the Property Owner's Association determined a sewer district was needed, and spearheaded a petition drive to form a sewer district to accomplish lake restoration. In 1973, the people voted to form a special purpose sewer district and elected three commissioners to be their representatives. The district was formed by the residents of Liberty Lake with assistance from the Liberty Lake Property Owner's Association for the express purpose of restoring Liberty Lake, and the district has worked non-stop since 1973 to attain that goal (Kaun, 1986).

Liberty Lake today is still a popular recreational lake for the greater community and residents. As of the 2000 census, 4,660 people reside in the Liberty Lake Census Data Place (CDP). Based on Spokane County information and the 2003 LLSWD accounts, 207 single-family resident homes and 1 multi-family mobile home villa park are located along Liberty Lake's shoreline (waterfront). 616 resident homes and 7 multi-family complexes are within the watershed. Spokane County parcel data shows 1057 parcels to be within the watershed and 292 parcels along Liberty Lake's shoreline.

Today's Liberty Lake community melds the strength of history with the addition of new perspectives and interests. As properties change hands, and the last available lots begin to develop new homes, new families on the lake join existing residents and together they form a common relationship. These unified residents all share a love of this unique ecosystem, and by working together can maintain the legacy of good stewardship.

Community Commitment
Throughout its history, the Liberty Lake community has demonstrated its commitment to preserving the health and recreational quality of the lake. As mentioned above, residents living around the lake started a lake restoration project and the formation of a sewer and water district. With support from state and federal grants, residents around the lake paid for these efforts.

In the late 1960s, contact was made with the State of Washington Water Research Center (SWWRC) at Washington State University (WSU) and a grass roots sampling and testing program was initiated that included homeowners, graduate students, and the WSU Environmental Engineer Laboratories (Funk *et. al.,* 1968). Since that time, some of these residents have volunteered to assist in distribution of educational materials, annual trash and dock clean up, beach and leaf clean up, monitoring the lake level and precipitation, Secchi transparency, water temperature, algae, and bird observations.

The success of the aquatic weed control efforts at Liberty Lake rely, in the long run, on public education and awareness, monitoring the success of control measures, surveying for aquatic weed species each year, and responding to new growth areas quickly to maintain a low level of infestation. Currently the Liberty Lake Sewer and Water District, Clearwater Scuba, L.L.C, and lake residents perform invasive weed surveys and evaluate success of control efforts at Liberty Lake.

Watershed Advisory Committee, outreach, and educational process

Since its formation in 2001, the Liberty Lake Watershed Advisory Committee has been an active participant in the District's Lake Protection activities. Community participation has been an integral part of the development of the Liberty Lake Aquatic Weed Management Plan. Community education is promoted in aquatic plant and landscape workshops with emphasis on Eurasian milfoil and proper landscape techniques, the potential problems posed by noxious aquatic weeds, newsletter/news article dissemination of information that explains the relationship between lakes, aquatic weeds, and the activities of human beings.

Public education is an important element in the control of aquatic nuisance plants. Signs have been collaboratively developed by DOE and WDFW to bring attention to the Eurasian watermilfoil infestation in lakes and to show anglers and other lake users how to avoid transporting aquatic plants from one lake to another. These signs have been installed at the Washington Department of Fish and Wildlife public boat launch at Liberty Lake. Educational flyers are available at the Sewer District administrative building and have been distributed to residents and concerned citizens. Mailings and newspaper articles are also written to inform residents of the infestation and best management practices that can be applied to limit the spread and future degree of infestation.

Public meeting dates, attendance, and meeting notes are contained in Appendix I entitled, Public Meetings on Eurasian watermilfoil. AWMP work hours, number of people, time spent and work completed are contained in Appendix I, entitled Aquatic Weed Management Plan Hours and Work Completed. E-mails and letters applicable to the AWMP are also included in Appendix I. In addition, an *Affidavit of Publishing Noti*ce regarding public notice of publication is displayed in Appendix N.

The remainder of this section provides a chronological overview of the public information process and involvement from the first discussions through the completion of the Aquatic Weed Management Plan.

Early Discussions:

- In 1996, the LLSWD Commissioners considered various options to deal with the serious threat of Eurasian watermilfoil. That year, the district received a $12,000 Early Infestation Grant from the Washington State Department of Ecology to provide financial assistance in their actions.
- Early discussions arose in acquiring funding for watershed and lake studies. In researching these funding sources, it became apparent that the development of a management plan is required before grants or funding will be awarded. This initiated interest in the development of an Aquatic Weed Management Plan for control of Eurasian watermilfoil in Liberty Lake.
- The LLSWD explored the idea of developing an Aquatic Weed Management Plan for Liberty Lake. In late 2000, Manager Lee Mellish talked with the Department of Ecology about formulation of an AWMP. Consultation also occurred with Sacheen Sewer District.
- In 2001, the Watershed Advisory Committee became active; issues were discussed regarding aquatic plant management.
- From 2001 to 2002, the idea of developing an Integrated Aquatic Weed Management Plan was discussed with the Watershed Advisory Committee. It was explained that this plan would assist in obtaining funding for the management and control of Eurasian watermilfoil. The Watershed Advisory Committee expressed their interest and support in this process.
- On February 21, 2002, the LLSWD Board of Commissioners approved the formulation of an AWMP. It was moved, seconded, and unanimously approved to accept the Department of Ecology Grant for the development of an Integrated Aquatic Weed Management Plan in the amount of $15,000 with a $5,000 District match.
- On October 16, 2002, the Liberty Lake Sewer and Water District was awarded a grant by the Washington State Department of Ecology to develop an Aquatic Weed Management Plan for Liberty Lake (Appendix K).

May 2002

- Sent to 3,500 residents, *LLSWD Newsletter, May 2002*: During the next few weeks, divers will be conducting an aquatic weed survey of the lake to determine the extent of Eurasian watermilfoil infestation. Last year's survey revealed milfoil at the north end of the lake between the public access and Sandy Beach. In addition, a few plants were noted and removed in Dreamwood Bay. This year's survey will concentrate on the area along the north shore of the lake. Treatment with chemicals may be necessary depending on the extent of the milfoil growth.
- May 15th Watershed Advisory Committee public meeting, 10 members attended, discussed the status of the milfoil infestation and the schedule of early summer surveys.

June 2002

- June 18th Watershed Advisory Committee public meeting, 10 members attended, discussed preliminary application process for AWMP, report on early milfoil survey results, and schedule of next survey to be conducted.

- June 20th LLSWD public Board Meeting, 9 attendants, report on Lake Protection activities, early milfoil survey results, and schedule of next survey to be conducted.

July 2002

- July 24th Advisory Committee public meeting, 15 members attended, took boat tour of Liberty Lake, discussed lakeside landscaping practices, conducted milfoil survey, aquatic plant ID, and milfoil ID.

September 2002

- September 10th LLSWD staff meeting, 8 attendants, update report on milfoil survey results, hand harvesting efforts, and conference with Dr. Barry Moore.
- LLSWD draft application for Aquatic Weed Management Plan for Liberty Lake.

October 2002

- Sent to 3,500 residents, *LLSWD, Newsletter October 2002*: This summer Eurasian watermilfoil was found in the southern portion of the lake. Surveys were conducted and mapped with GPS. Dr. Barry Moore, WSU, conducted diving surveys and hand harvested approximately 130 pounds of wet milfoil. Milfoil was not detected at other locations in the lake. Treatment may be necessary next spring for the south end of the lake.
- October 2nd, Watershed Advisory Committee public meeting, 9 members attended, discussed application process for AWMP, report on milfoil hand harvesting results, survey results, and schedule of possible next hand harvest to be conducted.
- Received notification on October 16, 2002 that the Liberty Lake Sewer and Water District was awarded a grant by the Washington State Department of Ecology to develop an Aquatic Weed Management Plan for Liberty Lake (Appendix K).

November 2002

- November 5, LLSWD public Board Meeting, 10 attendants, report on Lake Protection activities and results of last milfoil survey and hand harvesting regimes.
- Updated milfoil information on LLSWD web site, including GIS milfoil location map.
- Sent informational letter to Watershed Advisory group

December 2002

- December 10, LLSWD public Board Meeting, 9 attendants, report on Lake Protection activities and presented GIS milfoil location map.

January 2003

- January 30th *Liberty Lake Splash* newspaper article (see below).

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Milfoil Invasion Explained

By Bijay Adams - Liberty Lake Sewer and Water District

This summer was a prolific season in Liberty Lake for the invasive aquatic plant, Eurasian Watermilfoil. Eurasian Watermilfoil is not native to Washington State. Since its infestation from Europe and Asia in the mid to early 1900s, it has begun to spread and propagate in our waterbodies.

Milfoil was first discovered in Liberty Lake in 1995, where it has been primarily controlled by hand harvesting and aquatic herbicide (2,4-D) treatments. Eurasian milfoil spreads easily because new plants and colonies can start from single fragments. Boats and boat trailers, water currents, wind, fishing gear, and other disturbances are all possible contributors to the spread of milfoil.

When spreading and fragmentation occurs, new growth can rapidly follow. This was observable in Liberty Lake in the summer of 2002, where relatively clear water and abundant sunlight provided excellent growing conditions for the invasive plant. The Liberty Lake Sewer and Water District has conducted numerous surveys of the lake and has marked the locations of the plants and colonies using a Global Positioning System (GPS). These locations are then graphically displayed in a Geographic Information System (GIS) as a map

2002 Milfoil Locations

Updated on November 20, 2002, the map indicates the current locations of Eurasian Watermilfoil. Appropriate treatment will be necessary this coming spring to attempt to control the invasive plant. For any questions or concerns, contact BiJay Adams at 922-5443 ext. 30.

You can also obtain information at: http://www.libertylake.org/Milfoil.htm

Check out additional aquatic plant web sites through the Washington Department of Ecology: http://www.ecy.wa.gov/programs/wq/plants/weeds/aqua004.html http://www.ecy.wa.gov/programs/wq/links/plants.html

- January 8th Watershed Advisory Committee public meeting, 10 members attended, discussed acceptance of the AWMP by Ecology, action strategy for attacking milfoil, proper signage for milfoil at public boat launch, notification of residents of milfoil at their property, the GIS milfoil location map, and the Liberty Lake Splash Newspaper article.

February 2003

- February 4th LLSWD staff meeting, 9 attendants, report on the status of work on the AWMP.

March 2003

- March 26th Watershed Advisory Committee public meeting, 10 members attended, discussed the LLSWD involvement in the Central Valley School

District Kids in the Creek Program; teaching 5th graders the importance of a healthy watershed and lake, focusing on Lake Protection activities such as algae control and milfoil identification.

April 2003

- April 30th Watershed Advisory Committee public meeting, 10 members attended, discussed Kids in the Creek program and the LLSWD involvement. Every day for 1 month (March 21 – April 21), every 5th grade class in the school district (13 schools total); 870 5th graders were taught the importance of a healthy watershed and lake, focusing on Lake Protection activities such as algae control and milfoil identification. Other items discussed in the meeting were the preliminary schedules of the milfoil survey and chemical treatment(s), Newman Lake collaboration, and the status of the AWMP action items.

May 2003

- Sent to 3,500 residents, *LLSWD Newsletter May 2003*: Surveys conducted last fall revealed that Eurasian watermilfoil has spread around the lake. A detailed map showing location of milfoil can be seen on the District web site, www.libertylake.org/Milfoil.htm. Chemical treatment will be conducted by a licensed applicator familiar with aquatic weeds. The chemical is a granular 2,4-D product that will kill the milfoil but will not harm other aquatic plants. The treatment will take one day.
- May 29th LLSWD staff meeting, 7 attendants, reported results of the early milfoil survey and work on the AWMP.

June 2003

- June 4th Watershed Advisory Committee public meeting, 10 members attended, discussed status of AWMP, milfoil locations, and meeting with contracted applicator Terry McNabb-AquaTechnex.
- June 17th LLSWD staff meeting, 7 attendants, report on status of AWMP work, milfoil survey, and preparation for chemical treatment.

August 2003

- August 12th LLSWD staff meeting, 7 attendants, report on status of AWMP work, new survey results of milfoil and treatment, and additional treatment plan and schedule.
- August 26th LLSWD staff meeting, 8 attendants, report on status of milfoil and treatment, new survey results, and additional treatment or hand harvest plan.

September 2003

- September 23rd LLSWD staff meeting, 8 attendants, report on status of milfoil treatment and hand harvests, report on AWMP status and public review process.
- September 24th Watershed Advisory Committee public meeting, 9 members attended, discussed milfoil treatment and hand harvests, new milfoil survey results, status of AWMP, public review process of AWMP.

October 2003

- Public review process of Liberty Lake Aquatic Weed Management Plan.
- Submittal of Draft AWMP to DOE.

November-February 2004

- Revisions of the Draft AWMP and submittal of the Final AWMP to DOE

Continuing Community Education
Public education is an important element in the management strategy for control of aquatic nuisance plants. The Liberty Lake Sewer and Water District will offer organization for ongoing education and is willing to fund these activities. The community is encouraged to advocate for continued education, while being attentive to new developing educational strategies and passing along the information to friends and neighbors.

To ensure that the educational efforts are up to date, the LLSWD will maintain existing and establish new educational contacts through agencies and various consultants such as: the Washington State Department of Ecology (DOE), the North American Lake Management Society (NALMS), Washington State Lake Protection Association (WALPA), U.S. Fish and Wildlife Service, Washington State Department of Fish and Wildlife, Environmental Protection Agency (EPA), Washington State University, Clearwater Scuba L.L.C., AquaTechnex, Spokane County, and informational literature.

Information will be disseminated through Watershed Advisory Committee meetings, watershed mailings and newspaper articles when applicable (past publications are listed in Appendix O), brochures/handouts at the LLSWD Administration Building education center, the LLSWD quarterly newsletter, school and youth organizations, college programs, workshops and seminars, the LLSWD website (www.libertylake.org links are provided in the website for information about the district, on going lake protection activities, algae, Eurasian watermilfoil, lake and stream monitoring, stormwater, data collected, and reference links), educational flyers, and public signage. In addition, Lake books (put together by the Newman Watershed Plan Committee and DOE) are distributed to every Lake property owner. These books have been developed to help property owners understand how our actions affect the water quality of our lakes (Department of Ecology, 1992).

In 2003, as a celebration for 30 years of commitment, the Liberty Lake Sewer and Water District and Lon Gibby Productions, Inc. produced an informational CD on the protection activities taking place at Liberty Lake. This CD is an updated version of the Liberty Lake Legacy video filmed in May 1999 that gave the Liberty Lake story and the Sewer and Water District's efforts to protect the lake and watershed.

The public education program for Liberty Lake consists of the following five elements:

1. **Distribution of educational materials**. The LLSWD will compile published materials and generate literature specifically related to Liberty Lake and will be distributed to residents at the time they are acquired by the district. Information will be distributed via watershed meetings and mailings, newspaper articles, brochures/handouts at the LLSWD Administration Building education center, videos, poster boards and signage, the LLSWD website, and the LLSWD quarterly newsletter.
2. **Annual aquatic plant and landscape workshops**. Workshops each spring will cover native plants as well as noxious aquatic weeds with emphasis on Eurasian

milfoil and proper landscape techniques. Workshops will be instructed by plant experts from the Washington State University Extension program and the Department of Ecology. All residents and lake-users will be invited and encouraged to attend. The residents at Newman Lake and other nearby waterbodies might also be invited to expand the educational effort beyond Liberty Lake. A better-educated community of residents and lake-users will be more likely to identify and report noxious aquatic weeds and adopt proper lakeside landscaping techniques.

3. **Professional meetings and conferences.** Information will also be disseminated and gathered through professional presentations, meetings, and conferences. Examples of these meetings/conferences include the North American Lake Management Society (NALMS), Washington State Lake Protection Association (WALPA), Portland State University Aquatic Weed School, and the Regional Lakes Conference sponsored by the LLSWD.
4. **School and youth organizations.**
    a. *Kids in the Creek*: Kids in the Creek is part of the Central Valley School District Environmental Education Program. Each year the Central Valley School District puts on their annual environmental education program in the Liberty Lake County Park to teach four fields of study: forestry, geology, streams, and a team building rope course. Each of the thirteen elementary schools in the Central Valley School District sends all its fifth graders for one day. The Environment Education Program was started in 1988, and since the beginning, they have taught over ten thousand students. The Kids in the Creek program provides students with a simple method of assessing the long-term health of a stream by viewing and identifying the aquatic insects and observing the world they inhabit. It explains the importance of a healthy watershed and the effect of a vibrant forest canopy and riparian area on the stream and its water quality. It also connects the conditions of the stream being explored to the immediate food chain as well as the entire ecosystem (http://www.cvsd.org/libertylake/env5/default.htm). In 2003, the LLSWD embarked in facilitating the Kids in the Creek session. 870 students were taught the fundamentals of watershed protection, lake protection (with emphasis on Milfoil and algae), and aquifer preservation.
    b. *Boy Scout Troops*: A continuation of the Kids in the Creek Curriculum, instructing the scouts on the importance of a healthy watershed, lake, and aquifer
    c. *Alternative High School Students*: Instructional course on the methods of measuring creek discharge and the importance of a healthy watershed and lake
    d. *Spokane Community College*: Working with watershed classes to demonstrate real-time stream and lake monitoring applications
5. **Signage.** Signs have been developed by the Washington Department of Ecology and the Washington Department of Fish and Wildlife to bring attention to Eurasian watermilfoil and alert boaters about removing all plant fragments from boats and trailers. These signs have been installed at the Fish and Wildlife boat

launch at Liberty Lake. Additional and improved signs will be posted at the boat ramp to inform lake-users of the problems caused by noxious aquatic weeds and how to prevent spreading them from lake to lake. If the signs posted at the boat launch included step-by step directions on how to properly clean boats and trailers, and why it is important, lake-users may be more apt to do the right thing. The boat launch at Liberty Lake does not have any tools to perform this cleaning, which is similar to most other lakes in the area. Any adhering pollutants that are washed off by a diligent boat owner at the launch site will probably end up in the lake since there is no facility to collect the gray water. Ultimately, it may be more appropriate to have a facility (such as a disposal can) to dispose of aquatic weed fragments that are caught by boats and boat trailers. It may also be beneficial to conduct a survey of boater awareness and knowledge via a mailout, handout, or personnel survey. The LLSWD and the Watershed Advisory Committee will research this option, as well as others, in further detail.

It should be understood that activities taking place in the watershed have adverse effects on Liberty Lake, although sometimes the cause and effect relationships are not readily apparent. It is through education of the community that these cause and effect relationships between human behaviors and water quality will be understood. It is our goal to provide residents with the appropriate information on how to reduce the amount of pollutants entering the lake from their property. It is also our desire to work hand in hand with property owners to do whatever is necessary to ensure a healthier lake environment.

9.1 INTEGRATED TREATMENT ACTION STRATEGY

The target species in Liberty Lake is Eurasian watermilfoil (*Myriophyllum spicatum*). As mentioned previously, the Liberty Lake Sewer and Water District and community favor the use of the combination of a chemical control agent (2,4-D herbicide), hand harvesting, and nutrient reduction. Used alone, 2,4-D is not an eradication tool. Some plants survive the treatment and regrow, so these plants must be removed by other means. For that reason, hand pulling will continue in Liberty Lake in order to remove any milfoil plants that are not killed by the treatment, or where infestations are too diffuse for a treatment to be applicable.

Assessment of Control Levels

Some of the following information was taken from the Washington State Department of Ecology's website on developing Integrated Aquatic Vegetation Management Plans (http://www.ecy.wa.gov/programs/wq/plants/management/manual/chapter11.html).

This step of the Plan development involves determining how much control is needed for Eurasian watermilfoil problems. Are there plant zones around the lake that should be left alone, **no control**? Where should a **low level of control** be applied to allow some intermediate level of plant growth? In addition, under what circumstances would a **high level of control** be necessary, such as where a minimal amount of nuisance plants can be tolerated? Identification of plant problems in specific locations are done by assessing the control levels of each of the areas identified on the beneficial use map.

The different levels off control are identified as:

No Control: Areas of the lake that may be best to leave untouched. These include areas that may be too deep or unsuitable for Eurasian watermilfoil to proliferate. These areas might be best to be left alone or subjected to minimal treatments.

Low Level of Control: Low levels of control may be all that is needed to attain our management goals. This usually involves a partial removal of vegetation. Low-level control maximizes enjoyment of a water body while minimizing plant removal. A benefit of low-level control is the low treatment cost per acre because less plant material is being removed or treated. Examples include developing control strategies that consider depths and areas of control for activities such as water skiing, boating, aesthetics, and swimming.

High Level of Control: Certain situations may require aggressive control. High intensity levels of control-may include areas such as beaches, docks, and boat ramps where any infestations of Eurasian watermilfoil may be unacceptable. In addition, areas where native plant beds function as fish spawning, nesting and forage sites for waterfowl and other animals, and areas that are designated for wildlife conservancy may also require intensive control efforts. Lake-wide control efforts affecting 100 percent of aquatic plants are not appropriate.

Although eradication of Eurasian watermilfoil is the end goal, it is important to recognize that control and management may be a more realistic scenario given the characteristics of the highly aggressive aquatic weed and the size of Liberty Lake. Given that scenario, many of the locations in Liberty Lake may receive high levels of control while others may only include low levels of control. Only those that are virtually unaffected by Eurasian watermilfoil will receive no control efforts (i.e. areas that are too deep for milfoil to proliferate).

The levels of control in Liberty Lake were determined by analyzing a combination of the aquatic plant density and distribution maps, the beneficial use map, and bathymetry. The combination of these maps produced the site-specific control map. Consideration was also given to these control areas based on past control efforts and suitable habitat for Eurasian watermilfoil observable in Liberty Lake. Figure 9.1 displays the Milfoil Site Specific Control Areas and Figure 9.2 displays the Liberty Lake Beneficial Uses and Milfoil Site Specific Control Areas.

Figure 9.1 Milfoil Site Specific Control Areas

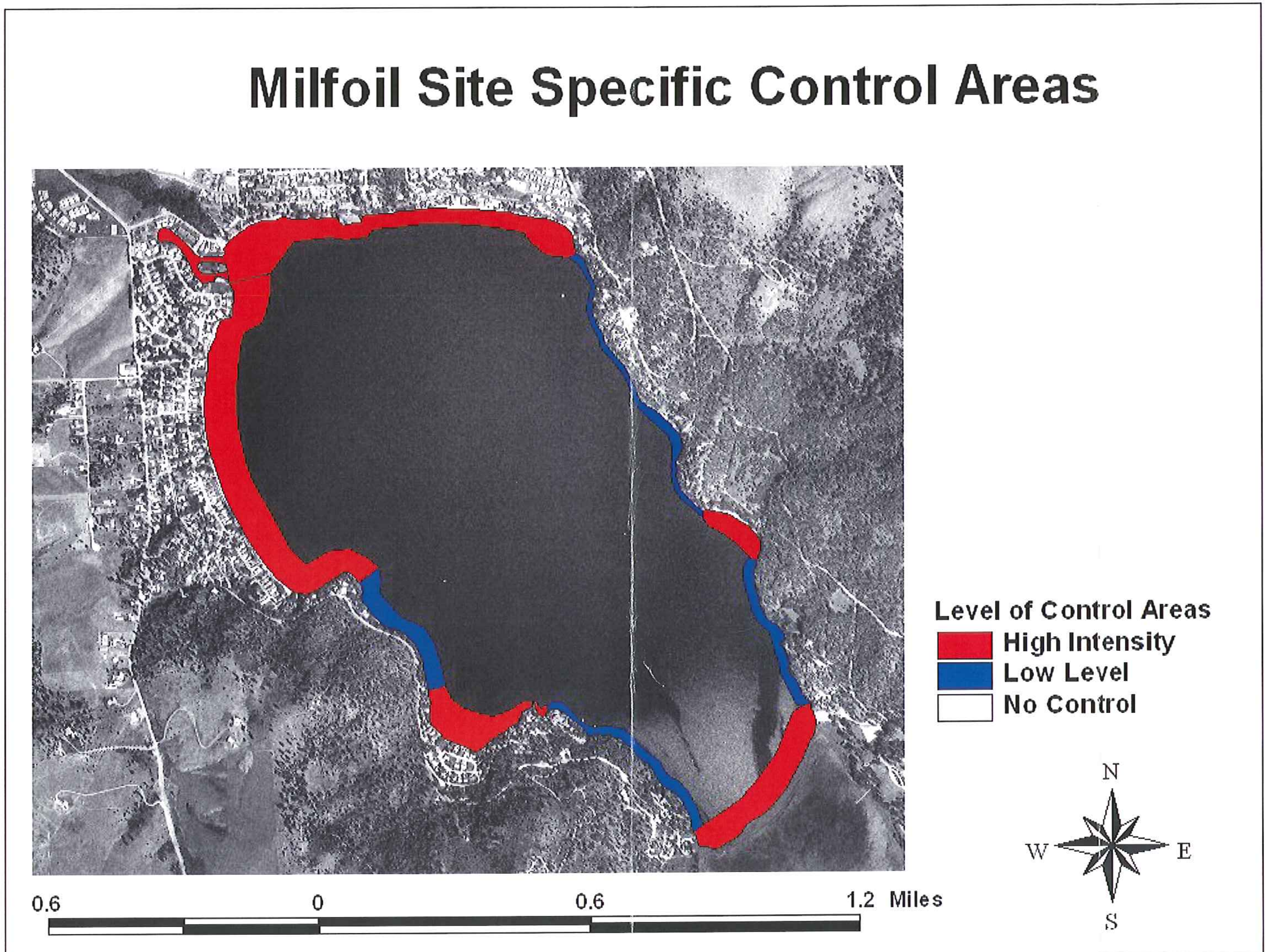
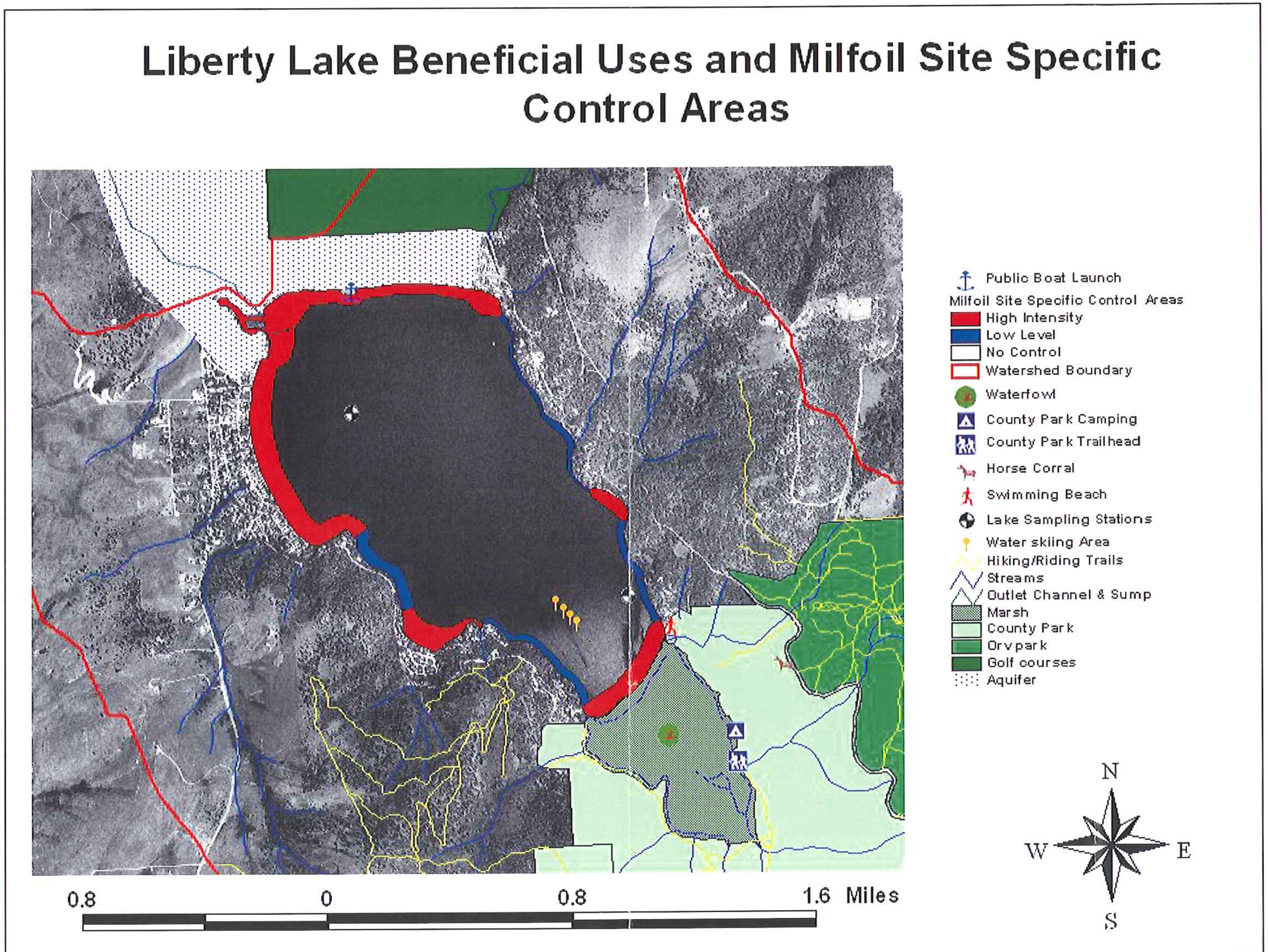


Figure 9.2 Liberty Lake Beneficial Uses and Milfoil Site Specific Control Areas



Strategy for control of Eurasian watermilfoil (*Myriophyllum spicatum*)
Control and management of Eurasian watermilfoil will be accomplished using an aquatic formulation of 2,4-D (DMA*4IVM®, AquaKleen® or Navigate® [Appendix E]) in late June to early July according to the annual survey results. Although the Liberty Lake Sewer and Water District and community favor the use of 2,4-D as the primary herbicide, other alternatives must be researched and considered as new technologies become available. Annual surface and dive surveys will be conducted over the entire lake to check the status of the infestation, and a GPS will be used to mark all the points that need treatment. When a treatment is near, the areas will be marked on the water's surface with buoys and then the application is performed by a licensed applicator via a boat to disperse the herbicide. Of the three available 2,4-D formulations, 2,4-D AquaKleen® is the preferred formulation. The reason for this particular choice is based on our previous experience and knowledge of the product. We (LLSWD and Clearwater Scuba L.L.C) have felt that Liberty Lake has experienced good control and management of Eurasian watermilfoil by the use of this formulation since 1998.

Follow-up applications may occur about three weeks after the initial treatment to pick up missed plants or late emergents. Diver hand-pulling will clean up any remaining milfoil found after herbicide applications have had time to take effect or in areas that are not feasible for a chemical treatment (i.e. areas in which only one or two plants exist). Bottom Barriers may also be laid down in areas that would not reduce habitat and native vegetation by covering the sediment.

Surface and dive surveys after the initial application shall include a post evaluation of the site(s). The timing of this evaluation shall be appropriate for the herbicide used at the site. This evaluation shall include an estimate of the effectiveness of the application (qualitative or quantitative), any dead or dying organisms or plants, algae conditions, and any other environmental data which may be available (dissolved oxygen, pH, Secchi disk, turbidity, etc.). Survey evaluations are essential to determining the success of the effort, and will be used to determine what measures need to be implemented to improve the milfoil control.

Because of the environmental risks from improper application, aquatic herbicide use in Washington State waters is regulated by the National Pollutant Discharge Elimination System (NPDES) permit. All specific protocols of the NPDES permit coverage from Washington Department of Agriculture (WSDA) will be directly followed in Liberty Lake by the licensed applicator and the LLSWD. Particular care will be given when treating the southern portion of the lake that adjoins the 155-acre seasonal marsh. Preservation of the sensitive marsh ecosystem is important, and all efforts will be taken to protect this area from the activities used to control Eurasian watermilfoil. If all specific protocols of the NPDES permit are followed, it should be relatively simple for the control applicator to avoid collateral damage and preserve the plant community of the marsh. Surveys and a post evaluation of the marsh/lake boundary will occur after each herbicide treatment to verify that this area has remained unaffected by the efforts used to control Eurasian milfoil.

As mentioned earlier in the chemical controls section we may a shift from AquaKleen®, DMA*4IVM®, or Navigate® 2,4-D to triclopyr if we find that the plants have become less susceptible to the herbicide. Triclopyr has just been registered and will be sold as Renovate® (see Appendix E for label). It is similar to 2,4-D in its mode of action (systemic), and is also another selective product.

Although eradication of Eurasian watermilfoil is the end goal, we realize that control and management is a more realistic scenario given the characteristics of the highly aggressive aquatic weed and the size of Liberty Lake. Without becoming cost prohibitive, it is apparent that there is no ideal management tool that is 100 percent effective in eradicating Eurasian watermilfoil. Eurasian watermilfoil should be drastically reduced, if not eliminated, by this integrated approach. Herbicide applications, followed by manual methods and nutrient reduction programs, should ensure that proper control of Eurasian watermilfoil would occur.

The LLSWD, the watershed committee, and their consultants understand that the south end of the lake is perhaps the most vulnerable location for the milfoil. Due to the high levels of transient boats, we feel it is necessary to buoy this section off and establish a No Wake Zone. This will aid in reducing the spread of milfoil via motor boats and erosion from the marsh/lake dike by waves. There will also be an increase in the signage at the public boat launch.

Recently it has been identified that animals such as waterfowl can also transport seeds or stem fragments from one location to another. We (the LLSWD and community) will cooperatively work with the Washington State Department of Fish and Wildlife and the three golf courses in the Liberty Lake area to minimize this means of spreading. By working with the area golf courses, we can eliminate any milfoil plants discovered growing in their ponds and reduce the potential for spread back and forth to area lakes. We will continue the nutrient reduction program and community education efforts, including training in milfoil identification and survey methods.

10.1 PLAN ELEMENTS, COSTS, AND FUNDING

This section outlines the tasks and estimated costs of control and management of the listed noxious weed species Eurasian watermilfoil on an annual basis. Control costs have occurred for Liberty Lake since Eurasian watermilfoil was first discovered in 1995. These costs are outlined in Table 10.1. Implementation of the Liberty Lake AWMP will continue each year, at a total estimated cost of $12,320 annually. Table 10.2 outlines the tasks and estimated costs of implementation. Table 10.3 summarizes the LLSWD composite hourly burden rate for assistance in aquatic weed management.

Year	*Description*	*Diver Survey/Hand Harvest/ Post-treatment Monitoring Costs*	*Herbicide Milfoil Treatment Costs*	*Annual Cost*
1995	Milfoil discovered, Comprehensive diving survey conducted	$10,800		***$10,800***
1996	Effective 3/1/96, $12,000 Early Infestation Grant awarded to the LLSWD by DOE, Comprehensive diving survey conducted and 245 lbs (wet weight) hand harvested	$2,500		***$2,500***
1997	Diver survey, 70 lbs (wet weight) hand harvested	$2,240		***$2,240***
1998	Diver survey, herbicide treatment of 12 acres, 42 lbs (wet weight) hand harvested	$4,400	$5,940	***$10,340***
1999	Diver survey, herbicide treatment of 5 acres, 18 lbs (wet weight) hand harvested	$4,200	$2,754	***$6,954***
2000	Diver survey, herbicide treatment of 5 acres, 16 lbs (wet weight) hand harvested	$3,534	$2,295	***$5,829***
2001	Diver survey, herbicide treatment of 12 acres, 12 lbs (wet weight) hand harvested	$3,870	$5,940	***$9,810***
2002	Diver survey, 136 lbs (wet weight) hand harvested	$1,955		***$1,955***
2003	Herbicide treatment of 7.5 acres, 40 lbs (wet weight) hand harvested	-----	-----	-----
Total		***$33,499***	***$16,929***	***$50,428***

Table 10.1 Liberty Lake annual Eurasian watermilfoil control costs from 1995 to 2002

Task Control	*Allocated Annual Cost*
Diver Survey	500
GIS Mapping	1,000
Herbicide Milfoil Treatment	5,000
Post-treatment Monitoring	500
Diver Hand Harvest	2,500
Public Education and Research	1,500
Boat and Maintenance Costs	200
Totals	11,200
10% Contingency	1,120
Total Estimated Cost	***12,320***

Table 10.2 Liberty Lake annual Eurasian watermilfoil control Budget

Position	*Composite Hourly Rate*
LLSWD General Manager - Lake Protection, Permitting, Operations, Personnel, Safety	48.67
Lake Protection Manager -Lake Protection, Water Quality Monitoring, Stormwater Management, Public education and awareness, Web Master	28.54
Chief Operator -Supervisor of Operations for Water Distribution & Sewer Collection Systems	41.90
Operator - Water & Sewer Systems Utility & Stormwater Drainage Inspections, Maintenance Coordinator	33.28
Operator -Water & Sewer Systems, Repair & Maintenance	31.61
Accountant - Residential Billing, New and/or Changed Accounts, Financial Reporting	29.95
Receptionist - Office Assistant, Commercial Billing, Accounts Payable	22.59
Summer Assistant - Laborer	15.02

Table 10.3 Liberty Lake Sewer and Water District composite hourly burden rate

Sources of Funding
There are several likely sources of funding available for project implementation. The Liberty Lake Sewer and Water District is willing to fund, or find funding for the follow-up activities necessary to ensure continued milfoil management and control.

Grants
The Washington State Department of Ecology has an Aquatic Weeds Management Fund (AWMF) to tackle the problem of aquatic weeds on a statewide level. In 1991, the legislature established the Freshwater Aquatic Weeds Account to provide financial and technical support to help control aquatic weeds. Revenue for the Account comes from a $3 increase in annual license fees for boat trailers. Grant projects must address prevention and/or control of freshwater, invasive, non-native aquatic plants. The types of activities funded include planning, education, monitoring, implementation, pilot/demonstration projects, surveillance and mapping projects. Cities, counties, state agencies, tribes, and special purpose districts (does not include lake management districts) are eligible to receive grants. Generally, about $300,000 is available during each annual funding cycle. An additional $100,000 is available on a year-round basis for "early infestation" grants. The purpose of early infestation grants is to provide immediate financial assistance to local or state governments to eradicate or contain an invasion of a non-native aquatic plant. Local sponsors are required to provide 25 percent of the eligible project costs as a match to state funds. However, in-kind services can be used for up to one-half of the local share. Grants of up to 87.5 percent of the eligible project costs can be provided for "early infestation" projects and for pilot projects. In waterbodies with well-established populations of non-native, invasive aquatic plants, the development of an integrated aquatic plant management plan is required before grants can be awarded for implementation (control projects). However, grants are available for the development of integrated aquatic plant management plans. Funds are limited to $30,000 (state share) for planning grants and $75,000 (state share) for other projects. Each public body is limited to $75,000 per annual grant cycle and $75,000 for "early infestation." Early infestation projects are limited to $50,000 per project. Projects dealing with the prevention or management of freshwater invasive submersed plants like Eurasian watermilfoil or Brazilian elodea receive funding priority over projects dealing with nuisance native plants. Projects that implement an approved integrated aquatic plant management plan receive the highest priority. Other factors considered when evaluating projects include the environmental and economic impacts of the problem plants on the ecosystem, the degree that the project will benefit the public, the likelihood of the problem plant to spread to other waterbodies, the long-term interest and commitment to the project by the waterbody residents, and statewide significance of the project (http://www.ecy.wa.gov/programs/wq/plants/grants/focusgrant.html).

Other possible funding sources for lake management activities include:

- **Centennial Clean Water Fund (CCWF)** administered by the Washington State Department of Ecology (WSDOE), eligible projects include lake restoration, public information, education and watershed improvements
- **U.S. Environmental Protection Agency** Environmental education grants are available for workshops, teacher training, signage and other public information projects.
- **U.S. Fish and Wildlife Service** Wetlands for Washington Program grants can be used to restore or enhance wetlands bordering lakes.

- **Washington State Department of Fish and Wildlife and U.S Fish and Wildlife Service** offer grants for public education, habitat improvement and development, or fish production-related projects.
- **Washington State Department of Natural Resources** provides funding for fisheries and wildlife enhancement and protection for forest, soil, water, and wetland protection.
- **The National Fish and Wildlife Foundation** funds projects to conserve and restore fish, wildlife, and native plants through challenge grant programs.
- **Aquatic Plant Management Society** provides special funds for research, control, and management of aquatic plants
- **U.S Department of Agriculture** funds projects for research, economic aspects, evaluation, modeling, and/or decision support system development with direct implications for USDA policies and programs that protect, control, manage, or regulate invasive species.

Implementation and Action Strategy
The implementation of the plan will follow the process outlined below:

1. **Review AWMP and develop specific tasks and timeline.**
2. **Conduct surface and SCUBA surveys and GPS infested areas.** Professional contractors and the Liberty Lake Sewer and Water District will conduct these surveys.
3. **Generate a GIS map of infested areas and determine necessary treatment locations.**
4. **Convene with the Watershed Advisory Committee and the LLSWD Board of Commissioners.**
5. **Implement community education plan.**
6. **Secure necessary permits.** Permit application will be coordinated with the contracted applicator.
7. **Apply herbicide treatment.** Application will be completed as prescribed in the AWMP, unless consultation with Ecology and the applicator leads to defensible changes in the process.
8. **Conduct follow-up surveys**. Professional contractors and the Liberty Lake Sewer and Water District will conduct these surveys.
9. **Apply follow-up herbicide treatment or diver hand harvest if necessary.** Follow-up surveys will determine the extent to which this work is necessary.

REFERENCES

Aiken, S.G., P.R. Newroth, and I. Wile. 1979. The biology of Canadian weeds. 34. Myriophyllum spicatum L. Canadian Journal of Plant Science. 59:201-215. Cited in Sheldon and Creed, 1995.

Bonar, S.A., G.B. Pauley, D. A. Marino, S.L. Thiesfeld, S.A. Vecht, G.L. Thomas, and D.A. Beauchamp. 1995. Chapter 9 - Impacts of Triploid Grass Carp Grazing on the Game Fish Assemblages of Pacific Northwest Lakes. In: The Biology Management and Stocking Rates of Triploid Grass Carp Ctenophyaryngodon idella, and Their Effects on the Plant Community, Fish Assemblage, and Water Quality of Several Pacific Northwest Lakes. Final Report to the Washington Department of Ecology.

Bonar, S.A., B. Bolding, and M. Divens. 1996. Management of Aquatic Plants in Washington State Using Grass Carp: Effects on Aquatic Plants, Water Quality and Public Satisfaction 1990-1995. Washington Department of Fish and Wildlife. Report Number IF96-05.

Brereton, M.A., and E.M. Foedish. 1951. Memories of Liberty Lake. 28pp.

Bronmark, C. and L. Hansson. 1998. The Biology of Lakes and Ponds. Oxford University Press.

Brown, S. 2004. Liberty Lake Real Estate Market Shines. Liberty Lake Splash Press. Volume 6, Issue 6. Liberty Lake, Washington.

Central Valley School District. 2002. Central Valley Environmental Education Program Website: http://www.cvsd.org/libertylake/env5/default.htm.

Century West Engineers. 1998. Liberty Lake Stormwater Management Plan. Funded by the Washington State Department of Ecology Centennial Clean Water Fund. Developed for the Liberty Lake Sewer and Water District. Project No. 30221.007.01.

Compliance Services International. 2000. Supplemental Environmental Impact Statement Assessments of Aquatic Herbicides, 2,4-D. Label Description and History. Volume 3. Section 1.

Copp, H. 1976. Investigation to Determine Extent and Nature of Nonpoint Source Enrichment and Hydrology of Several Recreational Lakes of Eastern Washington. Part 1. Report No. 26, Washington Water Research Center, Washington State University, Pullman, Washington.

Creed, R.P. and S.P. Sheldon. 1995. Weevils and Watermilfoil: Did a North American Herbivore Cause the Decline of an Exotic Weed? Ecological Applications 5(4): 1113-1121.

Daniel S. and D. Freeland. 1999. Notice of Eurasian Milfoil Treatment, Life Cycle and Habitat of Eurasian Milfoil. Kootenai County Noxious Weed Control Office. In Press.

Extension Toxicology Network, 1996. A Pesticide Information Project of Cooperative Extension Offices of Cornell University, Oregon State University, the University of Idaho, and the University of California at Davis and the Institute for Environmental Toxicology, Michigan State University. EXTOXNET website: http://ace.ace.orst.edu/info/extoxnet/pips/triclopy.htm.

Felsot, A.S. 1998. Hazard Assessment of Herbicides Recommended for Use by the King County Noxious Weed Control Program. Prepared for the Utilities and Natural Resources Committee of the Metropolitan King County Council. Available online at: http://dnr.metrokc.gov/wlr/lands/weeds/herbicid.htm.

Funk *et. al.* 1968. Report to the Liberty Lake Property Owner's Association on Water Quality. Annual report for Liberty Lake, Washington. State of Washington Water Research Center, Washington State University, Pullman, Washington.

Funk, W.H., H.L. Gibbons, D.A. Morency, S.K. Bhagat, G.C. Bailey, J.E. Ongerth, D. Martin and P.J. Bennett. 1975. Determination, Extent, and Nature of Nonpoint Source Enrichment of Liberty Lake and Possible Treatment. Washington Water Research Center. Report No. 23. Washington State University, Pullman, Wahsington.

Funk, W.H., H.L. Gibbons, D.A. Morency, P.J. Bennett, R. Marcley, and G.C. Bailey. 1976. Investigation to Determine Extent and Nature of Nonpoint Source Enrichment and Hydrology of Several Recreational Lakes of Eastern Washington. Part II. Report No. 26, Washington Water Research Center, Washington State University, Pullman, Washington.

Funk, W.H. 1979-1982. Progress reports to the USEPA on water quality and productivity of Liberty Lake, Washington (unpublished reports). Department of Civil and Environmental Engineering, Washington State University, Pullman, Washington.

Funk, W.H., H.L. Gibbons, G.C. Bailey, B. Moore, F. Woodwick, S. Mawson, M. Gibbons, R. Nelson, P. Bennett, S. Breithaupt, P. Bulson, G. LeCain, D. Lamb, and J. Hein. 1982. Preliminary Assessment of Multiphase Restoration Efforts at Liberty Lake, Washington. Report No. 43. State of Washington Water Research Center. Washington State University. Pullman, Washington.

Funk, W.H. 1999. Report to the Liberty Lake Sewer and Water District. Annual Report for Liberty Lake, Washington. State of Washington Water Research Center. Washington State University. Pullman, Washington.

Gibbons, M.V. and W.H. Funk. 1982. Seasonal Patterns in the Zooplankton Community of a Eutrophic Lake in Eastern Washington Prior to Multiphased Restoration. Journal of Freshwater Ecology. 1(6): 616-628.

Gibbons, M.V., H.L. Gibbons, Jr., and M.D. Sytsma. 1994. A Citizen's Manual for Developing Integrated Aquatic Vegetation Management Plans. First Edition. Washington State Department of Ecology, Olympia, WA.

Hamel, Kathy. September 2002- February 2003. Personal communication. Aquatic Plant Specialist, Washington State Department of Ecology. Olympia, WA. Cited in Spring Lake Integrated Aquatic Vegetation Management Plan, 2003.

Hartman, G. 2001. The effect of Nutrient Loading and Residential runoff in the Liberty Lake Watershed. Whitman College, Walla Walla, Washington.

Jacono, C.C. and M.M. Richerson. 15 April 2003. Nonindigenous Aquatic Species Website: http://nas.er.usgs.gov/plants/docs/my_spica.html.

Jester, L.L., M.A. Bozek, S.P. Sheldon, and D.R. Helsel. 1997. New Records for Euhrychiopsis lecontei (Coleoptera: Curculionidae) and Their Densities in Wisconsin Lakes. Gr. Lakes Entomol. 30: 169-176.

Kaun, S. 1986. A Report on the Lake Restoration Program to the Members of the Liberty Lake Property Owners Association. Liberty Lake Sewer and Water District. Liberty Lake, Washington.

Kennedy, M.A. Consulting Engineers. 1979. Liberty Lake Restoration Plan. Prepared for Liberty Lake Sewer District. Spokane, Washington.

King County Department of Natural Resources and Parks. 2003. Spring Lake Integrated Aquatic Vegetation Management Plan. Water and Land Resources Division. Seattle, Washington.

Liberty Lake Sewer and Water District. Liberty Lake Sewer and Water District Website: www.libertylake.org.

Mawson, S.J., H.L. Gibbons, W.H. Funk, and K.E. Hartz. 1983. Phosphorus Flux Rates in Lake Sediments. Journal Water Pollution Control Federation 55:1105-1110.

McKarns, T.C. 1985. Translocation of Phosphorus in Elodea Canadensis in Liberty Lake, Washington. M.S. thesis. Washington State University. Pullman, Washington.

Michael Kennedy Consulting Engineers, Funk W.H., and B. Moore. 1986. Extended Post-Restoration Evaluation of Liberty Lake, Washington. Michael Kennedy Consulting Engineers, Spokane, Washington, and Environmental Engineering Section. Washington State University, Pullman, Washington.

Moore, B.C. 1981. Release of Sediment Phosphorus by Elodea Canadensis. M.S. thesis. Washington State University. Pullman, Washington.

Moore, B.C. 1995. Liberty Lake Aquatic Macrophyte Survey: September 1995. A Report to the Liberty Lake Sewer and Water District. Clearwater Company, LLC. Pullman, Washington.

Moore, B.C. 1996. Liberty Lake early Intervention Milfoil Control Project: Summer 1996. A Report to the Liberty Lake Sewer and Water District. Clearwater Company, LLC. Pullman, Washington.

Moore, B.C. 1998. Liberty Lake Milfoil Control Project 1998, Summary and Recommendations. A Report to the Liberty Lake Sewer and Water District. Clearwater Company, LLC. Pullman, Washington.

Moore, B.C. 1999. Milfoil Control Activities at Liberty Lake, Washington. Clearwater Company, LLC. Pullman, Washington.

Moore, B.C. 2000. Milfoil Control Activities at Liberty Lake, Washington. Clearwater Company, LLC. Pullman, Washington.

Moore, B.C. 2001. Milfoil Control Activities at Liberty Lake, Washington. Clearwater Company, LLC. Pullman, Washington.

Moore, B.C., L. Audin, L. Flaherty, E. Martinez, M. Rogers, and B. Southerland. 2001. Water Quality Indicators and Trends 2000 and 2001. A Report to the Liberty Lake Sewer and Water District. Department of Natural Resource Sciences. Washington State University. Pullman, Washington.

Moore, B.C., M. Ewing, K. Hanley, M. Marsh, P. Mosman, L. Newton, N. Porter, A. Roberts, J. Squeochs, and O. Magden. 2001. Analysis of the Liberty Lake Watershed. Department of Natural Resource Sciences. Washington State University. Pullman, Washington.

Moore, B.C., L. Audin, L. Flaherty, E. Martinez, A, Richter, and M. Rogers. 2003. Liberty Lake Water Quality Monitoring 2002. A Status Report to the Liberty Lake Sewer and Water District. Department of Natural Resource Sciences. Washington State University. Pullman, Washington.

Morency, D.A. 1979. Primary Productivity and General Ecology of Aquatic Macrophytes in Liberty Lake, Washington with Implications for Lake Restoration and Management. Unpublished data. M.S. thesis. Washington State University Program in Environmental Science.

Newman, R.M., and D.D. Biesboer. A Decline of Eurasian Watermilfoil in Minnesota Associated with the Milfoil Weevil, Euhrychiopsis lecontei. Journal of Aquatic Plant Management. In Press.

Nichols, S.A., and B.H. Shaw. 1986. Ecological Life Histories of the Three Aquatic Nuisance Plants, Myriophyllum spicatum, Potamogeton crispus, and Elodea canadensis. Hydrobiologia 131:3-21.

Noyes, T.K. 1981. Phosphorus and Nitrogen Loading to Liberty Lake by Waterbirds. Unpublished data. M.S. thesis. Washington State University Program in Environmental Science.

Peterson, HG; Boutin, C; Martin, PA; Freemark, KE; Ruecker, NJ; Moody, MJ. 1994. Aquatic phyto-toxicity of 23 pesticides applied at Expected Environmental Concentrations. Aquat. Toxicol. 28: 275-292.

Phillips, L., M. Divens, and C. Donley. 1999. 1998 Warmwater Fisheries Survey of Liberty Lake. Warmwater Enhancement Program. Washington Department of Fish and Wildlife. Olympia, Washington.

Sutter, T.J., and R.M. Newman. 1997. Is predation by Sunfish (Lepomis spp.) an Important Source of Mortality for the Eurasian Watermilfoil Bio-control Agent Euhrychiopsis lecontei? Journal of Freshwater Ecology. 12:225-234.

Swenson, J.A. and T.H. Cooper. 1999. Phosphorus and the Lakes. CURA Reporter. Vol 29, NO.3. Center for Urban and Regional Affairs. University of Minnesota. MPLS, MN. Pp 9-14.

Tamayo, M., C.W. O'Brien, R.P. Creed, C.E. Grue, and K. Hamel. 1999. Distribution and Classification of Aquatic Weevils (Coleoptera: Curculionidae) in the Genus Euhrychiopsis in Washington State. Entomol. News 110:103-112.

Tamayo, M., C.E. Grue, and K. Hamel. 2000. The Relationship Between Water Quality, Watermilfol Frequency, and Weevil Distribution in the State of Washington. Journal of Aquatic Plant Management. In Press.

United States Forest Service. Noxious Weeds on the Boise and Sawtooth National Forests, Aquatic Resource Risks Website: http://www.fs.fed.us/r4/boise/mgmt/weeds/Documents/Pest_links_files/triclopyr.pdf

University of California, Davis. 2003. Department of Vegetable Crops. The Nature Conservancy Wildland Invasive Species Team Website: http://tncweeds.ucdavis.edu/products/handbook/20.Triclopyr.pdf.

URS Corporation. 2002. Shoreline Assessment for Spokane County Lakes. Prepared for Spokane County Public Works Department, Division of Planning. Spokane, Washington.

Washington State Department of Ecology, Newman Lake Watershed Plan Committee, and Alliance of the Chesapeake Bay, Inc.. 1992. The Lake Book, A Homeowners Guide for Lake Preservation. Ecology Grant No. WFG 89013.

Washington State Department of Ecology. 1993. Total Maximum Daily Load for Liberty Lake, Washington. TMDL number: 57-001. Recommendation for TMDL approval by the United States Environmental Protection Agency. Seattle, Washington.
Washington State Dept. of Fish and Wildlife. 1998. Aquatic Plants and Fish. Publication # APF-1-98.

Washington State Dept. of Fish and Wildlife.1997-2004. Habitat Website. http://www.wdfw.wa.gov/habitat.htm

Washington State Department of Ecology. 2001. Final Supplemental Impact Statement for Freshwater Aquatic Plant Management. Ecology Publication No. 00-10-040.

Washington State Department of Ecology, 2001a. An Aquatic Plant Identification Manual for Washington's Freshwater Plants. 195pp.

Washington State Department of Ecology, 2001b. Herbicide Risk Assessment for the Aquatic Plant Management Final Supplemental Environmental Impact Statement (Appendix C - Volume 3: 2,4-D). Available online at: http://www.ecy.wa.gov/pubs/0010043.pdf.

Washington State Department of Ecology. 2002. Washington State Wetland Rating System for Eastern Washington. Ecology Publication No. 02-06-019.

Washington State Department of Ecology, 2003. General Information about Eurasian Watermilfoil Website: http://www.ecy.wa.gov/programs/wq/plants/weeds/milfoil.html.

Washington State Department of Ecology, 2003. Aquatic Plant Management website. http://www.ecy.wa.gov/programs/wq/plants/management/index.html.

Washington State Department of Ecology, 2003. Aquatic Weeds Management Fund Grants Overview Website: http://www.ecy.wa.gov/programs/wq/plants/grants/focusgrant.html.

Washington State Department of Ecology, 2003. Aquatic Pesticide Permits, Aquatic Noxious Weed Control NPDES General Permit Website: http://www.ecy.wa.gov/programs/wq/pesticides/final_pesticide_permits/noxious/noxious_index.html.

Wisconsin Department of Natural Resources. 2003. Eurasian Water Milfoil Website: http://www.dnr.state.wi.us/org/land/er/invasive/factsheets/milfoil.htm.