2024 Integrated Aquatic Vegetation Management Plan

Green Lake, Seattle, Washington

Prepared for
Seattle Parks and Recreation

Prepared by
Herrera Environmental Consultants, Inc.

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Integrated Aquatic Vegetation Management Plan

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Executive Summary

Green Lake is in the City of Seattle. Green Lake is surrounded by Green Lake Park, which is managed by Seattle Parks and Recreation (SPR). The lake is an important recreational and aesthetic resource for city residents. Green Lake is a shallow, urban lake, with a long history of water quality and aquatic plant management to maintain its many beneficial uses.

Dense growth of invasive aquatic plants interferes with recreational uses in some areas of Green Lake during the summer. Beneficial uses are primarily impacted by the spiked watermilfoil, Egeria (Brazilian elodea), and fragrant waterlily. The cover of invasive plants has rapidly increased over time. There are no native plants to support wildlife and habitat within the lake.

Residents and lake users within the City of Seattle, as well as aquatic plant biologists and plant management experts, came together to develop goals and a proposal for the City's Integrated Aquatic Vegetation Management Plan (IAVMP) for Green Lake.

The aquatic plant management goals are to control aquatic noxious weed species; reduce impacts to beneficial uses, including swimming, crew, and paddlers; and to maintain a healthy environment for fish and other wildlife. Management activities will target the three noxious weeds in the lake in the following order of priority: Spiked watermilfoil, Egeria, and fragrant waterlily. An additional goal is to establish native aquatic plants in Green Lake in order to maintain a healthy environment for fish and other wildlife without impacting recreational uses.

Aquatic plants will be managed by contractors (licensed herbicide applicators) hired by SPR to implement a targeted herbicide application approach in beneficial use areas. This approach is described in detail in this IAVMP. Herbicides to be used include ProcellaCOR for control of Spiked watermilfoil, slow release fluridone for control of Egeria and Spiked watermilfoil, and imazapyr for control of fragrant waterlily. Each of these herbicides is approved for use by the Washington Department of Ecology and has no post-application recreational use restrictions or anticipated impacts to non-target organisms. SPR also will implement a native planting effort after the targeted herbicide application reduces the cover of noxious weeds present.

Successful implementation of this plan will include ongoing communication, monitoring, and management efforts. SPR will work to solicit public input and keep residents and businesses informed of current and future plant management strategies. SPR will monitor the aquatic plant population during and after the targeted herbicide applications and native plantings. Aquatic plants will continue to be managed into the future, with management strategies being adapted based on changing conditions within the lake.

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Introduction

Green Lake is surrounded by Green Lake Park, which is managed by Seattle Parks and Recreation (SPR). Green Lake Park is an important recreational and aesthetic resource for city residents. Green Lake is a shallow, urban lake, with a long history of water quality and aquatic plant management to maintain its many beneficial uses, which include the following:

- Swimming, water polo, and other in-water activities at two life-guarded beaches with large rafts and at additional open water locations
- Boating from the Small Craft Center, which teaches rowing, canoeing, kayaking, and sailing classes and hosts three major rowing regattas each year, a boat rental concession at the Green Lake Boathouse, and private non-motorized boat use from multiple hand-carry boat launch locations
- Fishing at five piers and various shore access points
- Aesthetics and bird watching for the thousands of lakeside path users each day

SPR requested that Herrera Environmental Consultants (Herrera) conduct a quantitative survey of aquatic plants in Green Lake and prepare an Integrated Aquatic Vegetation Management Plan (IAVMP). Herrera conducted the survey in 2022 and continued preparation of the IAVMP thereafter.

Aquatic noxious weeds are nonnative plants that are particularly invasive in shoreline areas or open water. The natural competitors that would typically keep the growth of these species in check in their native ecosystems are not present in western Washington. Without these competitors, noxious weeds grow widely and aggressively. These plants negatively impact ecological processes, recreation, and business activities. The aquatic plant community in Green Lake is entirely comprised of the three noxious weed species: Spiked watermilfoil (milfoil) (*Myriophyllum spicatum*), Egeria (Brazilian elodea) (*Egeria densa*), and fragrant waterlily (*Nymphaea odorata*). Management of these aquatic weeds in Green Lake is an important step in ensuring the continuation of beneficial uses on the lake.

This IAVMP is intended to serve as a resource for SPR and the community of Green Lake users. It includes an evaluation of plant management strategies, a recommended plant management scenario, and plans for future monitoring and adaptive management.

Problem Statement

Dense growth of invasive aquatic plants interferes with recreational uses in some areas of Green Lake during the summer. Beneficial uses are primarily impacted by the Spiked watermilfoil (milfoil), Egeria (Brazilian elodea), and fragrant waterlily. The cover of invasive plants has rapidly increased over time. There are no native plants to support wildlife and habitat within the lake.

Problems created by the presence of nonnative, invasive plants fall into three categories—environmental, recreational, and economic—with significant overlap between categories.

Environmental problems created by dense aquatic weeds include the following:

- Negative impact on fish habitat, by limiting the ability of fish to move around the lake freely in areas of dense vegetation and stunting fish growth
- Increased levels of algae from nutrients released by plant decay
- Less structural diversity resulting from monocultures, reducing habitat complexity for fish and other aquatic life
- Water quality concerns:
  - Low dissolved oxygen under plant canopies
  - High temperature from reduced water circulation

Recreational problems include the following:

- Dense weeds that inhibit swimming and paddle sports (rowing, sailing, and kayaking), increase risk during these activities due to the possibility of entanglement, and discourage water users
  - Weeds cause the most problems during the summer months when the lake water is low. Ridders, skags, and dagger boards get caught in the weeds.
  - This is especially problematic during the two summer regattas but also an issue during the fall regattas and the two to three canoeing/kayaking regattas each year. These events are fundraisers, which support multiple causes, including a scholarship fund.
- Fishing lines that tangle with weeds, leading to filamentous fishing line and lures in the lake
- Health risks of toxic blue-green algae scum that accumulates on dense and decaying plants
- Aesthetic impacts:
  - Plant accumulation and decay
  - Foul aroma
  - Water clarity issues

Economic impacts include the following:

- Reduction of recreational uses and associated reduction in perceived quality of life
- Cost of management efforts

Public Involvement

Green Lake is surrounded by Green Lake Park, a highly used public park in the City of Seattle. In order to involve community members throughout the development of this document, representative lake users and technical experts were included on the IAVMP steering committee. As a result of this outreach, the steering committee included the following members:

- Kevin Bergsrud, Bridget Kelsh, Jason Coffman, Jordan Merrian, Christina Hirsch, and Adam Bailey, with SPR
- Ben Peterson, with King County Noxious Weed Control Program
- Wes Glisson, with Washington Department of Ecology
- Julian Douglas and Justin Spinelli, with Washington Department of Fish and Wildlife
- Tamara Oki, with Green Lake Small Craft Center
- Kim Tennican, with Friends of Green Lake
- Eliza Spear and Rob Zisette, with Herrera

Steering committee meeting presentations summarizing the topics discussed in each meeting are presented in Appendix A.

In addition to the steering committee meetings, the City invited the public to two community meetings (Appendix A). On July 26, 2024, in response to post card invitations to Green Lake residents, community members met to hear about the development of the IAVMP, learn about management options, and express their thoughts on the work done to date. Participation was enthusiastic, and there was clearly a desire to learn more and do more, both individually and collectively, to address aquatic weed problems. As staffing and funding allows, SPR plans to continue to reach out to the community to provide education and solicit input to chosen management strategies.

Plant Management Goals

The aquatic plant management goals are to control regulated noxious weeds and dominant weed species; reduce impacts to beneficial uses, including swimming, crew, and paddlers; and to maintain a healthy environment for fish and other wildlife.

Management priorities include the following:

- Control of aquatic noxious weeds
- Early detection of emerging noxious weed species
- Establishment of native aquatic plants in the lake

Management goals include the following:

- Reduce impacts on boating and fishing:
  - Reduce weed growth to the water surface.
  - Reduce weeds catching on paddles, rudders, and fishing line.
- Provide clear, clean water for swimmers:
  - Reduce weeds at swimming beaches and other near-shore swimming areas.
  - Reduce the accumulation of decomposing noxious weeds on beaches.
- Maintain healthy environment for wildlife:
  - Provide appropriate water temperatures.
  - Provide appropriate dissolved oxygen levels.

Waterbody Characteristics

Watershed and Physical Characteristics

Green Lake is a freshwater lake located entirely within Green Lake Park in the City of Seattle. Green Lake is adjacent to the Green Lake neighborhood to the north and east, the Wallingford neighborhood to the south, Phinney Ridge to the west, and Woodland Park to the southwest. Green Lake was formed by the Vashon glacial ice sheet 50,000 years ago. Green Lake Park was included in the Olmsted Brothers' comprehensive parks plan and given to Washington State in 1905 (SPR 2024).

Green Lake is 259 acres in area; it has a mean depth of 13 feet and maximum depth of 30 feet. Historically, Green Lake drained east through what is now Ravenna Park into Union Bay of Lake Washington, but this drainage ceased in 1911 when the City of Seattle lowered the water level to add green space to the park surrounding the lake. Green Lake now discharges through a single outlet near Meridian Avenue North, which then flows east and south through a storm drain system to Lake Union.

Green Lake is fed by direct precipitation, stormwater drainage, groundwater seepage, and drinking water discharge (Herrera 2015). The watershed in 1,873 acres, including three basins: nearshore basin within the park (103 acres), Woodland Park basin to the south (72 acres), and Densmore basin to the north (1,698 acres) (Figure 1). Most of the drainage from the Densmore basin bypasses the lake and combines with lake outflow in route to Lake Union. Drainage only overflows into Green Lake by jumping a weir during large storm events (e.g., greater than 1 inch of rain). The lake water budget was last calculated for 1994 and estimated the following percentages of inflow: 39 percent direct precipitation, 9 percent stormwater drainage (similar amounts from each basin), 36 percent groundwater, and 16 percent City drinking water. Groundwater inputs include miscellaneous seepage and discharges to the lake from the Woodland Park and Phinney Ridge drains. City drinking water inputs only occur when the Green Lake and Maple Leaf reservoirs are drained for regular cleaning. Inputs may be less now than in 1995.

Figure 1.
Green Lake Watershed.

Produced by Herrera Environmental Consultants (herrerainc.com) | Sources: King County, Aerial (2021)

Date: 11/13/2024 Author: bbagniewski

Water Quality

The King County Lake Stewardship Program and the Friends of Green Lake (FOGL) regularly collect water quality data on Green Lake. The lake was included in the King County Lake Stewardship Program, starting in 2005, and FOGL conducts monitoring via kayak. The water quality sampling station is called Green-1 (formerly called INDEX) and is located in the deepest part of the lake, just southwest of the East Beach (Figure 2). King County also collected water quality data in the northwestern portion of the lake at the Green-2 station (formerly called Station A) until 2009, at which point sampling was discontinued.

Monitoring is conducted every 2 weeks from mid-May to mid-October. Monitoring includes water temperatures and Secchi depth, a measurement of water transparency. Water samples are collected and analyzed for chlorophyll-a (algae biomass), total phosphorus, and total nitrogen. Twice a year, in May and August, monitoring also includes a water column profile to track lake nutrient cycling. Profile samples are additionally analyzed for ammonia, nitrate+nitrite, orthophosphate, and alkalinity (King County 2023). Precipitation and lake level measurements are measured daily, and King County has operated a continuous water level recorder at the lake since 2018.

Temperature, Dissolved Oxygen, and pH

At 1 meter-depth at station Green-1, the temperatures in Green Lake range from 9 degrees Celsius (°C) in the winter to over 25°C in the summer (Figure 3). Temperatures above 23°C can be fatal to salmonids (King County 2024b), while weekly average temperatures over 19°C impair growth of young rainbow trout (EPA 2021). Green Lake is not routinely monitored for dissolved oxygen (DO) or pH, but it has been on occasion historically.

Trophic State

One way to characterize the health of lakes is by using total phosphorus, chlorophyll-a, and Secchi depth (water transparency) data to calculate the Trophic State Index (TSI, Carlson 1977). This index provides a way to rate and compare lakes according to their level of biological activity on a scale from 0 to 100. As the TSI values increase by 10 (10, 20, 30, etc.) they represent a doubling of algal biovolume that can be related to easily measured parameters through linear regression and re-scaling. The TSI scale provides thresholds for three ranges of lake primary productivity (oligotrophic, mesotrophic, and eutrophic) representing low, moderate, and high amounts of algae growth. The indices are based on summer mean values (June through September) of three commonly measured lake parameters: water transparency measured by Secchi depth, and concentrations of total phosphorus (TP) and chlorophyll-a (Chla). TSI values for Green Lake (Station Green-1) are presented in Figure 4.

Secchi depth transparency is a measurement of water clarity produced by lowering a Secchi disk (an 8-inch disk with alternating black and white quadrants) into the water until the observer can no longer see it. This depth of disappearance, called the Secchi depth, is a relative measure of the water's transparency that can be used to look at events in a lake or trends over time, or to make comparisons between lakes. Algae, soil particles, and other materials suspended in the water all affect transparency. The Secchi depth will decrease as these factors increase.

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Figure 2.
Green Lake Sampling Stations.

Produced by Herrera Environmental Consultants (herrerainc.com) | Sources: King County, Aerial (2021)

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Date: 11/13/2024
Author: bBagniewski

Figure 3. Temperature at Station Green-1 in Green Lake.

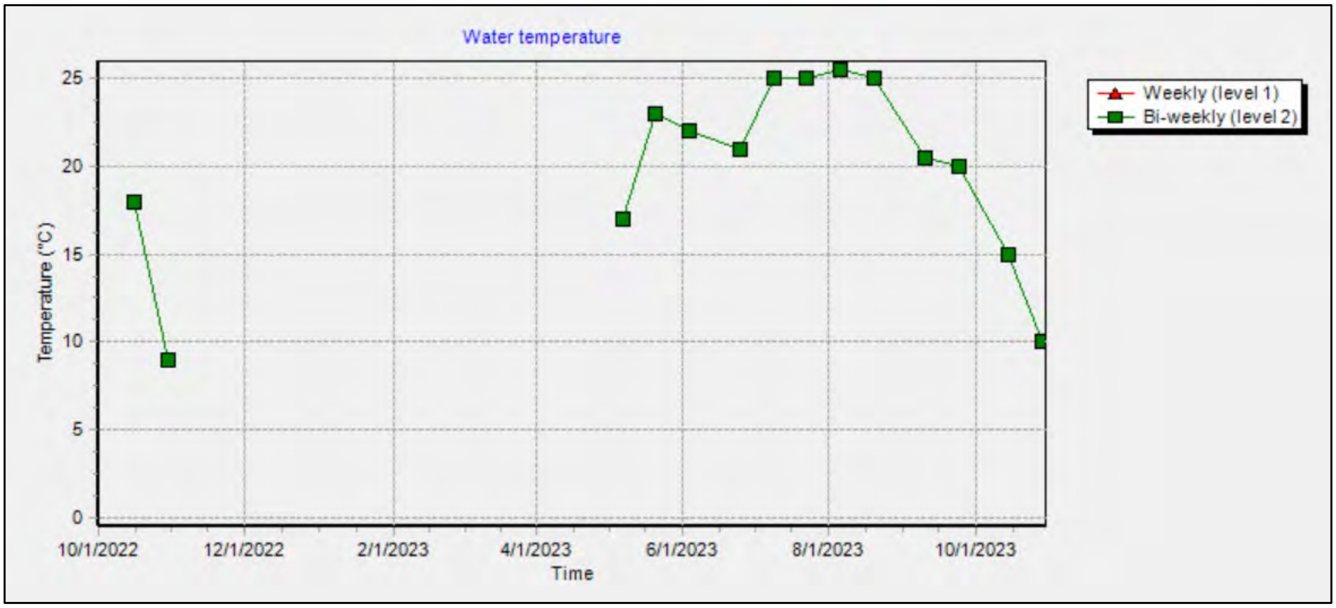
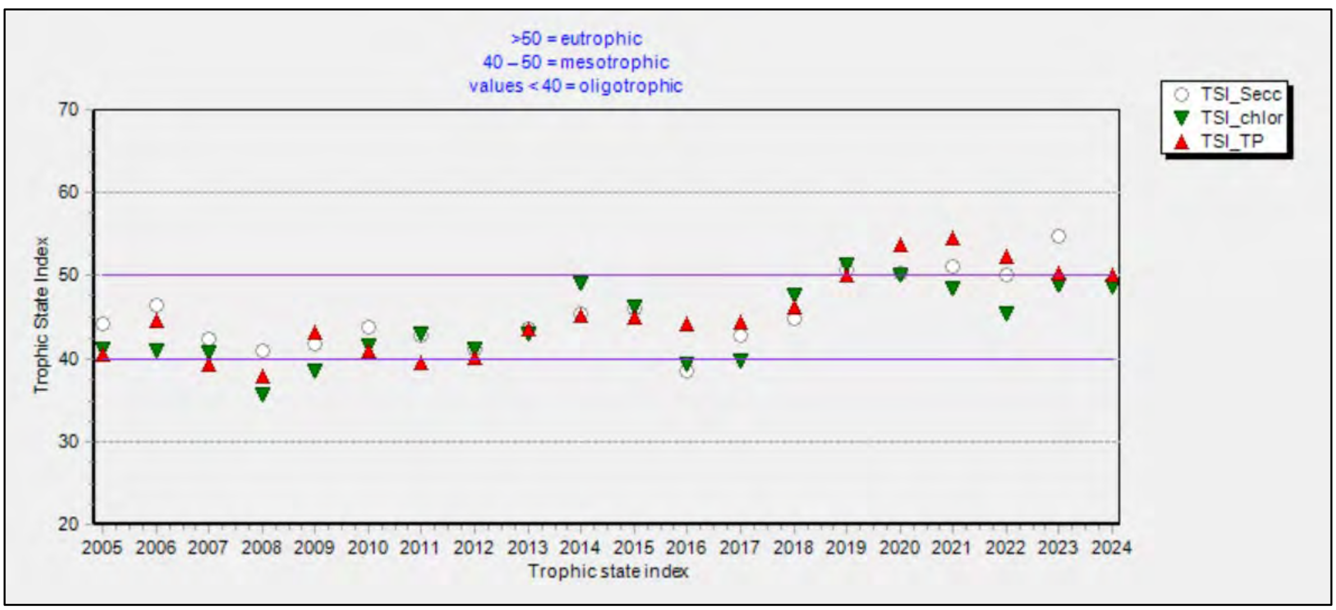


Figure 4. Trophic State Index Values for Green Lake



Nutrients, such as nitrogen, phosphorus, and silica, are necessary for plant and animal growth. However, increasing nutrients availability can increase the growth of aquatic plants, which can cause nuisance blooms that subsequently decay. Decomposition can deplete oxygen to levels incapable of sustaining many aquatic organisms, thus leading to more problems. In the temperate latitudes, **phosphorus** is most often the primary nutrient of concern in freshwater systems. This is because it is usually the nutrient that is in shortest supply, thus limiting algae growth. If excess phosphorus gets into lake water, it can cause nuisance algal blooms or even algal blooms that produce toxins. Additional phosphorus from human activities enters water bodies via pathways, such as discharge of detergents, runoff containing fertilizers, pet waste, car washing and seepage from failing septic systems. Sediment can also be a source of phosphorus, as phosphorus readily binds to soil particles and is washed into the lakes. Through chemical reactions, phosphorus may be later released into the water column from the lake sediments when DO concentrations fall below 0.2 mg/L.

In general, the TSI-TP values for Green Lake in the last decade have fluctuated between mesotrophic and eutrophic thresholds (Figure 4). Mesotrophic lakes have a moderate level of productivity and nutrients, and fairly clear water, while eutrophic lakes have high levels of nutrients and less-clear water. Compared to mesotrophic lakes, eutrophic lakes are more likely to have frequent algal blooms. Figure 5 presents recent seasonal patterns in total phosphorus and chlorophyll near the water surface at Station Green-1 in 2023. Total phosphorus concentrations in 2023 peaked in the summer and decreased in fall, but patterns are highly variable between years.

Chlorophyll is the green pigment in plants that allows them to create energy from light (photosynthesis). Measuring chlorophyll provides an indirect estimate of the amount of algae in the water column. Chlorophyll-a is a measure of the portion of the pigment that is still actively photosynthesizing at the time of sampling. There are several other forms of chlorophyll present in different groups of algae, as well as other assisting pigments and degradation byproducts that may be found in the water, but chlorophyll-a is the most common form present and is used as an indicator of the volume of algae present.

In general, TSI chlorophyll-a values for Green Lake are about the same as TSI total phosphorus values. TSI chlorophyll-a values have gradually increased over time and now tend to fluctuate at and above the eutrophic threshold, indicating a moderate to high potential for nuisance algal blooms. In 2023, seasonal patterns in chlorophyll were less variable than total phosphorus concentrations and tended to peak in late summer and fall (see Figure 5).

The lake was treated with buffered aluminum sulfate (alum) in 1991, 2004, and 2016, to inactivate phosphorus and to reduce its release from the lake sediments and uptake by algae, thereby reducing chlorophyll. TSI values decreased after the 2016 alum treatment (before the summer 2016 monitoring period), then increased for a few years, starting in 2018, and have been relatively stable between mesotrophic and eutrophic states in the past few years (see Figure 4).

Toxic Algae

For many years, Green Lake has suffered from toxic algae blooms that are caused by certain species of a type of algae called cyanobacteria, which occasionally produce toxins at concentrations exceeding state guidelines for human health. King County monitors cyanotoxin concentrations at the east and west swimming beaches and at Duck Island Beach (see Figure 2) weekly from Memorial Day to Labor Day. Microcystin (a liver toxin) is the problem cyanotoxin produced in Green Lake. The Seattle-King County Health Department advises SPR to post warning signs when microcystin concentrations exceed the state guideline of 8 micrograms per liter (µg/L).

Figure 5. Total Phosphorus and Chlorophyll-a at Station Green-1 in Green Lake.

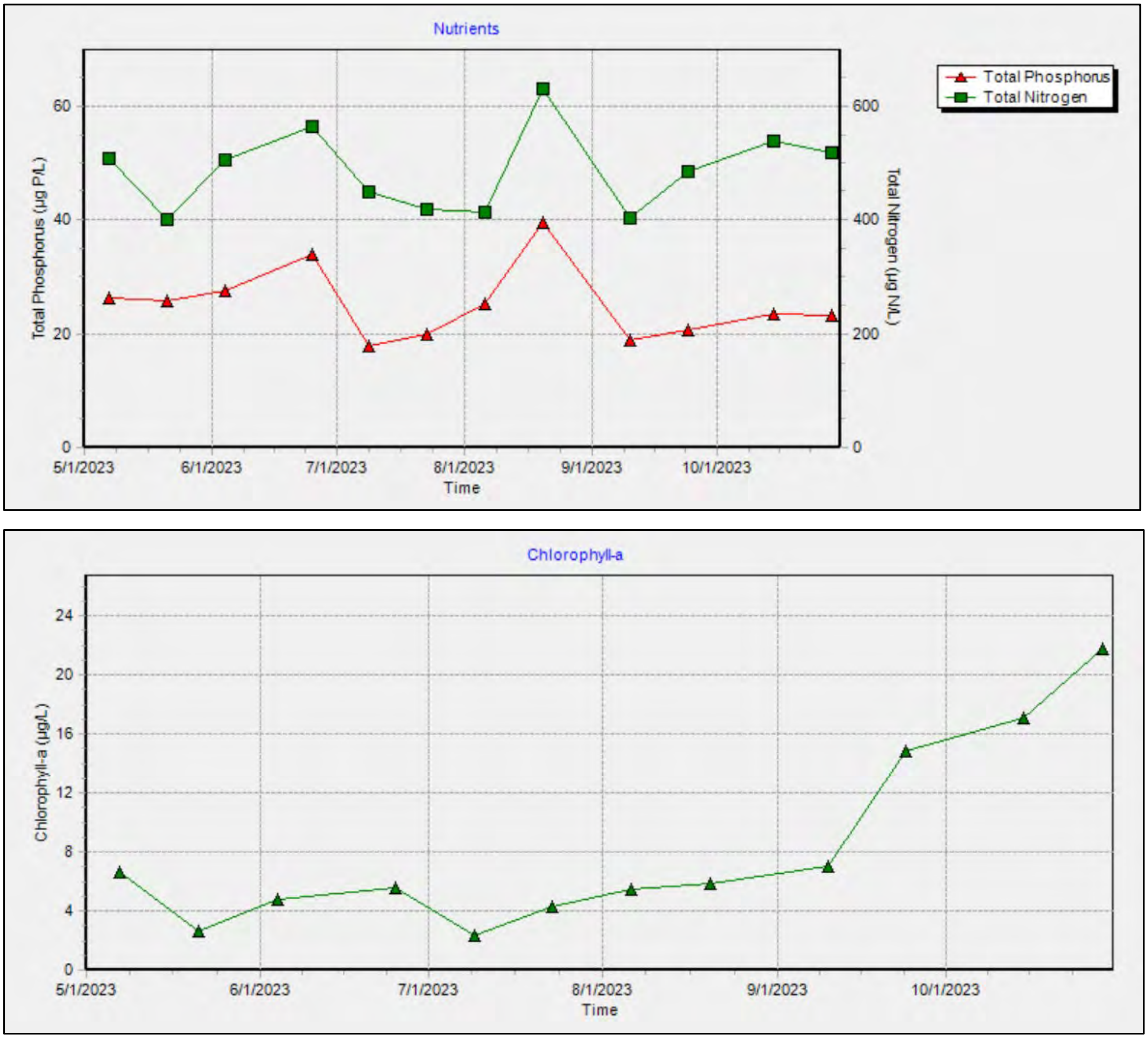
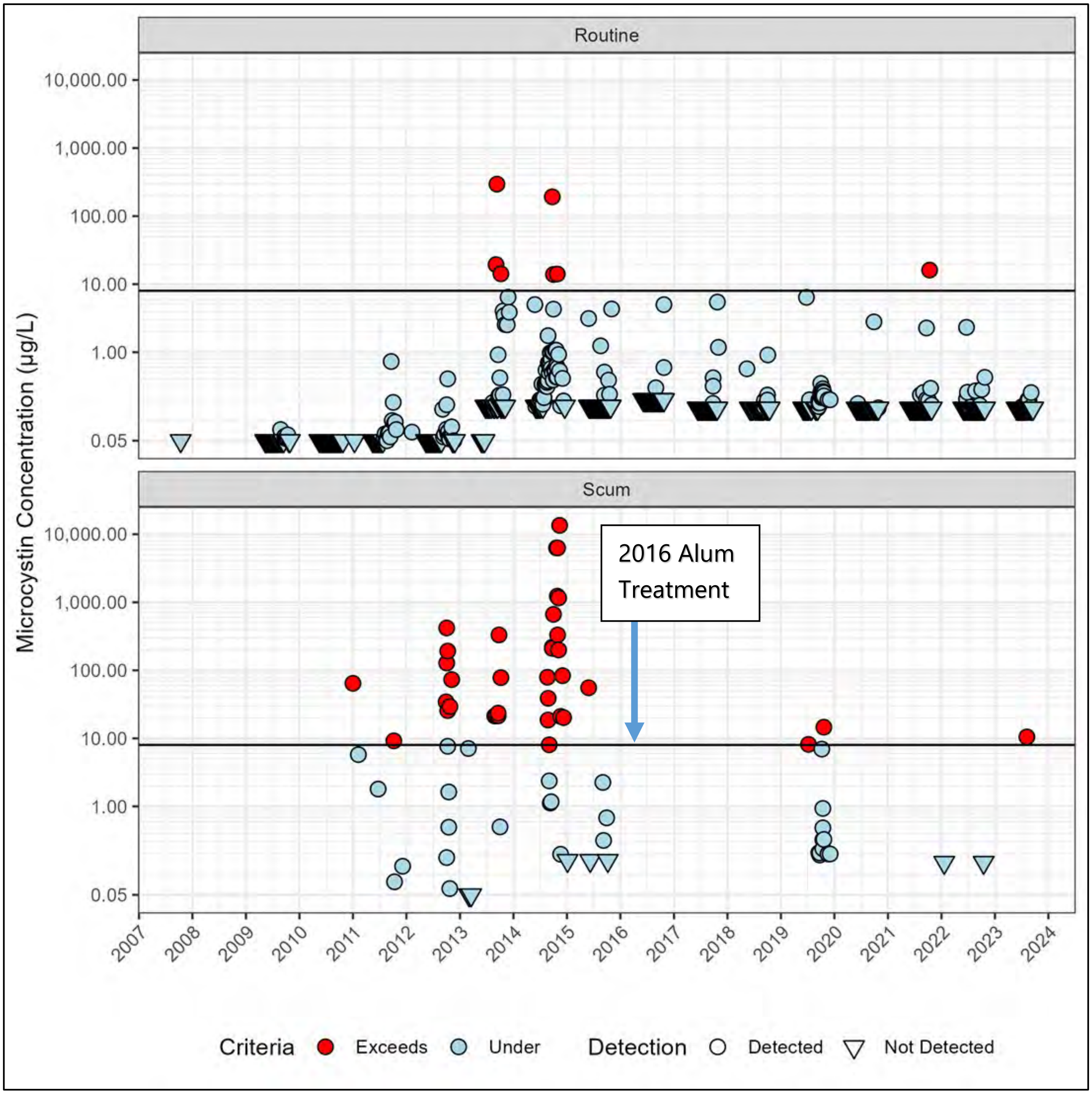


Figure 6 presents microcystin concentrations in samples collected during routine weekly sampling at the two beaches, as well as in occasional algae scum samples that are typically collected where scum accumulates in small embayments on the north shore. The state microcystin guideline is commonly exceeded in scum samples, but not at the beaches where scum rarely accumulates. Microcystin concentrations frequently exceeded guidelines before the 2016 alum treatment (Alum 3), but rarely since then (see Figure 6). In 2023, warning signs were posted on two occasions, recommending no swimming or pet use, due to one sample of a small scum at 10 µg/L in August and one sample of a larger scum area at 14 µg/L in October. These scums readily dissipated, and samples collected 1 week after these samples did not exceed the guideline. The microcystin guideline has not been exceeded in 2024.

The more phosphorus that can be prevented from entering lakes, the less chance that a potentially toxic cyanobacteria bloom will occur. The cyanobacteria generally responsible for making toxins are known to be poor competitors for phosphorus, so the available levels must be high before they will do well in a body of water. In addition to the alum treatments, phosphorus inputs can be minimized through well-designed storm water drainage systems, maintenance of sewer infrastructure, changing homeowner and business behaviors (such as using no phosphorus-rich fertilizers on lawns) and education and incentives (King County 2024b).

Figure 6. Microcystin in Weekly Samples from Green Lake East and West Beaches and Occasional Scum Samples, 2007–2023.



Algae Management

Intense blooms of cyanobacteria have plagued the lake since at least 1916. In late 1990, The City adopted a program to improve the quality of Green Lake. The program included the following actions for controlling sources of phosphorus (Herrera 2015), which is the primary nutrient fueling the cyanobacteria blooms:

- **Alum treatment** is the primary method used for reducing internal phosphorus loading, which has been estimated to account for approximately 60 to 88 percent of the total input of phosphorus to the lake during the summer algae bloom season. Alum treatments reduce internal phosphorus loading, because the aluminum permanently binds with available phosphate ions in the sediments and the alum is applied using a buffer to neutralize the acidic aluminum sulfate while the alum floc settles to the lake bottom. Buffered alum treatments have been applied to the entire lake in 1991, 2004, 2016, using amounts based on measured sediment phosphorus concentrations (each intended to last approximately 10 years).

- **Stormwater diversion** was the primary method for reducing external phosphorus loading to the lake from the Densmore basin, which comprises 91 percent of the lake watershed. The diversion was estimated to reduce stormwater phosphorus loadings to the lake by 86 percent. In addition, in 1991, stormwater treatment devices were constructed to reduce phosphorus inputs to the southwest shore of the lake. Stormwater source control actions were taken to reduce phosphorus inputs from Woodland Park by removing a large, decomposing wood chip pile in 2004 and converting surfaces of two soccer fields from dirt to synthetic turf in 2009.

- **Canada geese management** was conducted from 1987 to 2004, to control phosphorus inputs from a small portion of the population. Various methods included relocation in 1990 to 1995, egg addling (oiling) in the late 1990s to 2003, and euthanasia of small numbers in the early 2000s. The City stopped participating in the lethal goose control program in 2004. Lake monitors did not notice an increase in geese from 2004 to 2015 (Hererra 2015), but recent observations indicate geese numbers have quadrupled over the past 5 years (F. Alvarez, pers. comm.).

- **Dilution** of the lake with drinking water reservoir water was performed intentionally to reduce phosphorus concentrations in 1976 to 1991. High rates ranged from 2 to 6 million gallons per day (mgd), with an average annual equivalent of 1 lake volume. Dilution rates reduced to only 0.5 to 1 mgd in subsequent years, because water was only discharged from the Maple Leaf and Roosevelt reservoirs to the lake when the reservoirs were cleaned or overfilled. In 2013, further reductions occurred to only 0.1 mgd—such that dilution is no longer reducing phosphorus concentrations in the lake.

- **Milfoil harvesting** was conducted by SPR staff in 1992 to 2002. It removed phosphorus in the milfoil from a maximum of harvest of 1,200 tons in 1992, decreasing to 30 tons in 1995, and then ranging from 15 to 30 tons/year until harvesting was terminated in 2002 (following the planting of 177 grass carp to control milfoil in 2001).

- **Public education** has been ongoing since 1990, to inform citizens of management actions and to educate the community about water pollution and phosphorus source control methods through various city-wide programs.

- **Water quality monitoring** has been conducted in May through October each year, since 2005, to track effectiveness of phosphorus controls.

Generally, algae management through phosphorus control does not substantially affect aquatic plant populations in lakes because plant roots penetrate deep into lake sediments where there is a large supply of nutrients unaffected by recent reductions in external phosphorus loadings to the lake. An exception may be for alum treatments that inactivate biologically available phosphorus in the upper 4 inches of sediments, potentially limiting aquatic plant growth. However, the rapid expansion of invasive aquatic plants in Green Lake since the 2004 and 2016 alum treatments, as described below, suggests that—while the alum treatments have effectively reduced algae blooms—they have not substantially deterred plant growth. While aquatic plant growth can be shaded by algae blooms caused by increased phosphorus inputs, this does not appear to have occurred in Green Lake based on the co-occurrence of milfoil covering 85 percent of the lake with thick algae blooms before the first alum treatment in 1991.

Beneficial Uses and Identified Problems

The project area provides numerous beneficial uses to humans and wildlife, including the following (Figure 7):

- **Recreational Use:** Boating, fishing, swimming, and aesthetic and wildlife observation
- **Wildlife Use:** Waterfowl, fish, and other aquatic organisms

Beneficial uses are impacted by excessive aquatic plant growth, including the following three types of problems identified by the Steering Committee:

- **Environmental:**
  - Negative impact of dense plants on fish habitat
  - Impact of invasive noxious weeds on native biodiversity
  - Excessive levels of algae from scum accumulation on dense plants and nutrient release by decaying plants that impair aquatic habitat
  - Water quality degradation (low dissolved oxygen and high temperature) in dense plant growth
- **Recreational:**
  - Inhibited swimming and paddle sports
  - Weeds wound around crew boat rudders
  - Weeds tangled in fishing lines
  - Nonnative weeds promoting habitat for nonnative fish species
  - Health risks of toxic blue-green algae and nuisance of excess filamentous green algae
  - Aesthetical impacts from plant accumulation and decay, foul aroma, and water clarity
  - Restricted shoreline access
- **Economic:**
  - Quality of life
  - Cost to manage/control/eradicate

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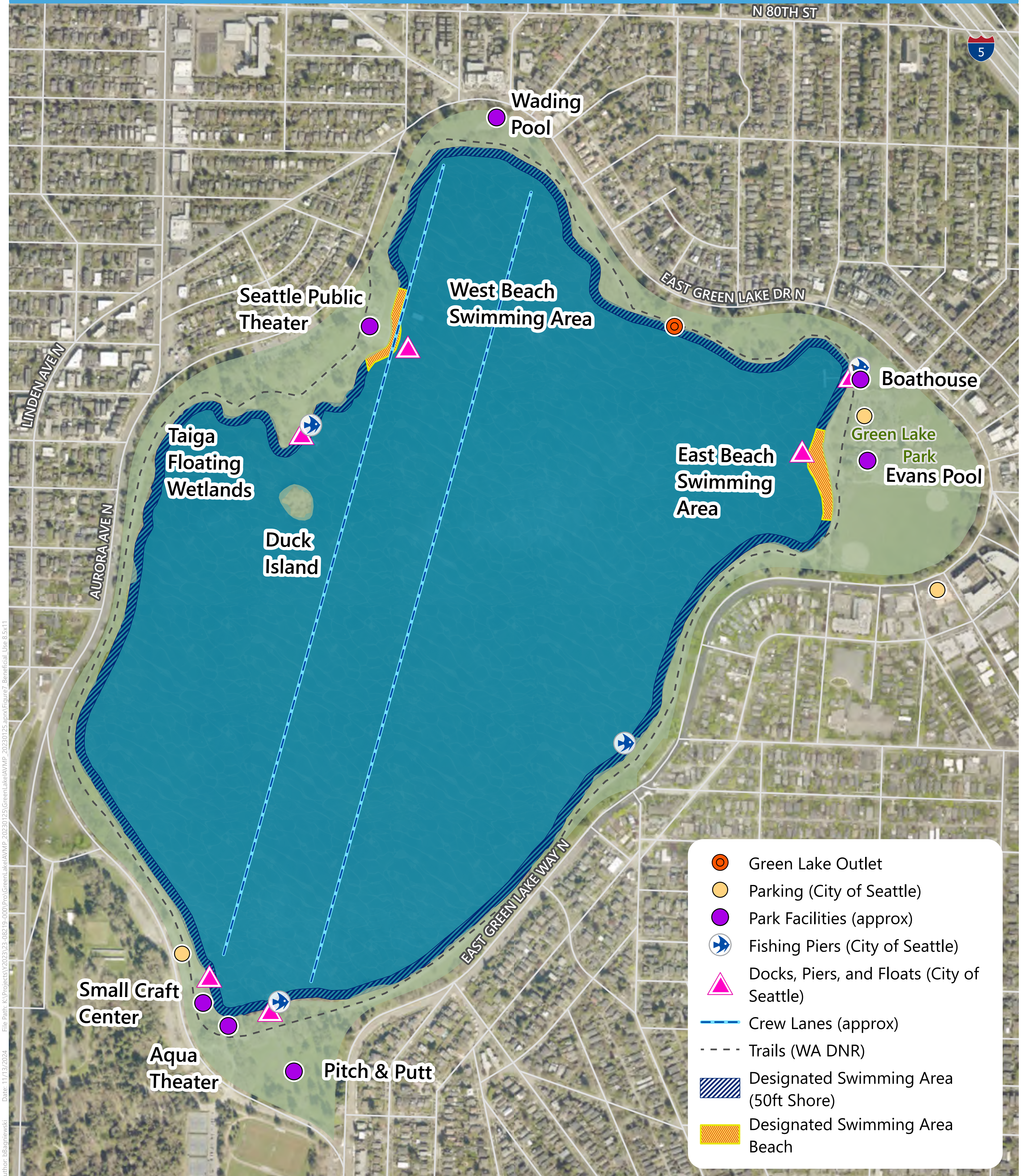
Figure 7.
Beneficial Use Areas on Green Lake in Seattle, Washington.



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Aquatic Plant Community

2022 Plant Distribution and Density

Herrera conducted the survey of submersed aquatic plants by boat on September 7, 2022, when the plant growth was at or near the summer maximum. Botanists Eliza Spear and Nick Bartish conducted the survey in 1 day, using an inflatable motorboat. The survey was conducted along transects extending across the lake and spaced no more than 150 feet apart.

An aquatic plant sampling rake was used to sample and identify the relative abundance or submersed aquatic plant species at 26 locations along the transects, and sample locations were recorded by GPS. Herrera did not conduct diver surveys or mapping of emergent plants.

Herrera used underwater sonar equipment with GPS (Lowrance HDS7) to gather plant height and density data. The acquired data were processed by BioBase EcoSound to prepare maps of submersed aquatic plant biovolume within the survey area. Plant biovolume represents the fraction (0 to 1) of the water column occupied by plant matter at each measurement location. Data were extrapolated based on observations, to fill areas where the boat could not access due to dense aquatic vegetation or recreational swimmers.

Herrera analyzed the aquatic plant biovolume data to map approximate species distribution in Green Lake. Biovolume values range from 0 to 100 percent, with 0 percent being classified as no plants in the water column and 100 percent being classified as plants growing up to the surface of the water. The remaining biovolume values were classified as follows:

- Values greater than 66 percent were classified as surfacing milfoil.
- Values between 66 and 30 percent were classified as subsurface milfoil.
- Values between 20 and 30 percent were classified as Egeria.
- Values less than 20 percent were classified as 'zero to low biovolume.'

These classifications were based on field observations and known growth patterns of the observed plant species.

The area of fragrant waterlily was mapped using the image from Google Maps survey conducted on July 31, 2022. Outer boundaries of the waterlily beds were confirmed during the survey using GPS.

Plant Cover and Density

Aquatic plant cover and density are presented in Figure 8. Submersed plant density is shown as biovolume in a gradient of colors ranging from light blue at 0 percent biovolume with no plants or low density, to yellow at 50 percent biovolume or moderate density, and to red at 100 percent biovolume or high density. The estimated aquatic plant species distribution based on biovolume is presented in Figure 9.

The results indicate that submersed aquatic plants expanded throughout Green Lake, aside from the deep trough on the eastern portion of the lake and along the southern shore. In the central and north regions of the lake, density remained moderate to low. In shallow nearshore areas and in the south-central region of the lake, density was high, with patches of vegetation reaching the surface of the water.

Figures 8 and 9 also present the cover of fragrant waterlily, which was similar to that observed in 2005 and restricted to within 240 feet of the west shore.

Species Identification and Distribution

No native aquatic plants were observed in Green Lake. Only three aquatic plant species were observed in Green Lake, and they are all noxious weeds (King County 2024a) (Table 1), including:

- Spiked watermilfoil (milfoil) (*Myriophyllum spicatum*), which is a submersed plant and a Class B noxious weed
- Egeria (*Egeria densa*), which is a submersed plant and a Class B noxious weed
- Fragrant waterlily (*Nymphaea odorata*), which is a floating leaved plant and a Class C noxious weed

The percent composition of submersed plant species in the 26 aquatic plant samples are listed in Table 2 and shown in Figure 10.

These results indicate that milfoil dominated the nearshore throughout the lake and in the south-central region of the lake. Egeria dominated the central and north regions of the lake. No plants were observed in several locations in the deep trough on the eastern area of the lake and on the southern shore.

Table 1. Aquatic Plant Species Identified in Green Lake, September 7, 2022.

Scientific Name	Common Name	Type	Control Designation
Myriophyllum spicatum	Spiked watermilfoil	Class B Noxious Weed	Recommended
Egeria densa	Egeria, Brazilian elodea	Class B Noxious Weed	Recommended
Nymphaea odorata	Fragrant waterlily	Class C Noxious Weed	Recommended

Figure 8.
Aquatic Plant Biovolume in Green Lake, September 7, 2022.

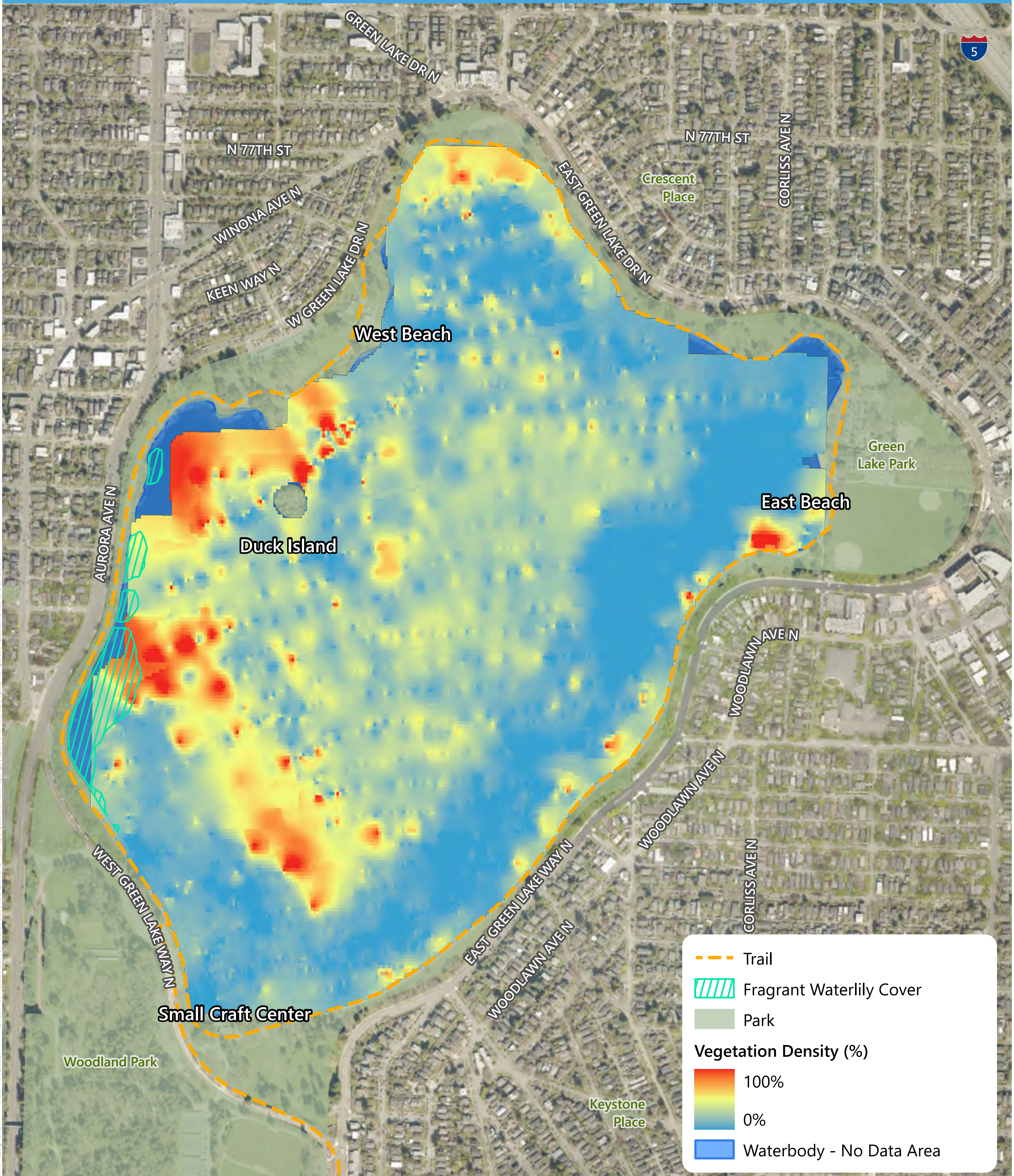

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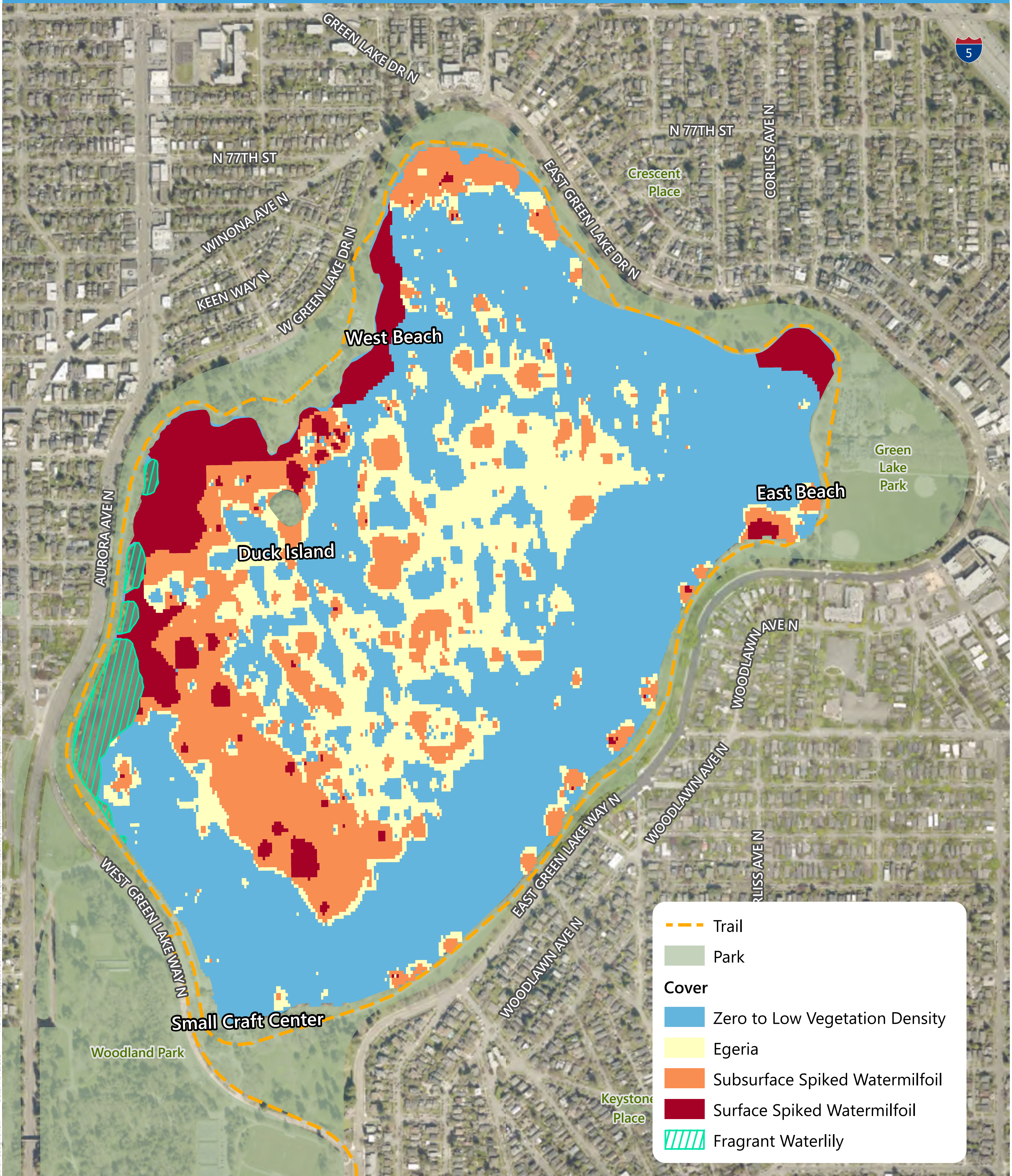
Figure 9. Estimated Aquatic Plant Species Distribution in Green Lake, September 7, 2022.



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Date: 11/13/2024
Author: bBagniewski

Produced by Herrera Environmental Consultants (herrerainc.com) | Sources: King County, Aerial (2021)

Figure 10. Aquatic Plant Species Composition in Samples at Green Lake, September 7, 2022.

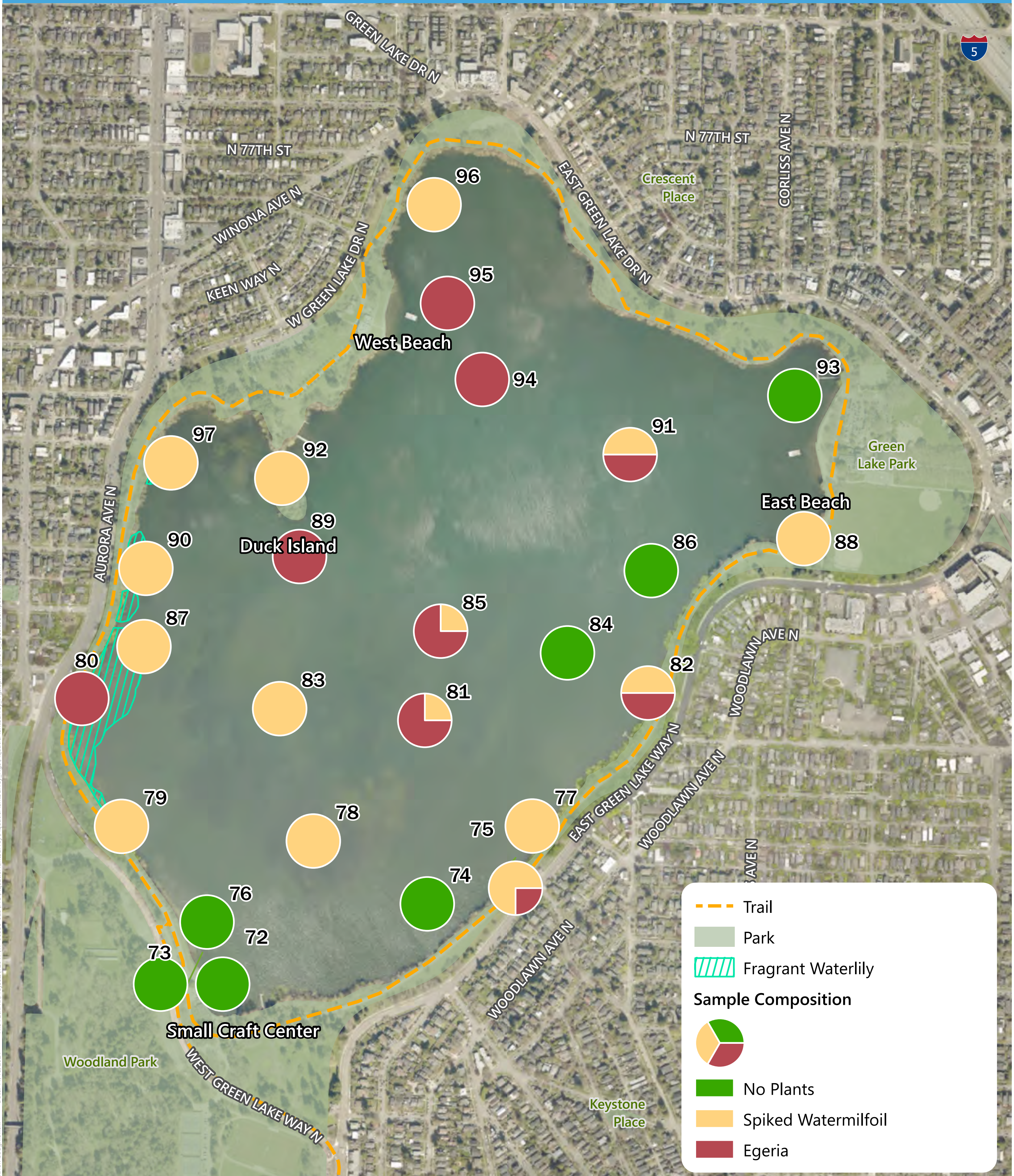


Table 2. Aquatic Plant Species Composition in Samples at Green Lake, September 7, 2022.	
Sample ID	**Plant Species (Percent Composition)**
72	No plants in sample
73	No plants in sample
74	No plants in sample
75	Spiked watermilfoil (75), Egeria (75)
76	No plants in sample
77	Spiked watermilfoil (100)
78	Spiked watermilfoil (100)
79	Spiked watermilfoil (100)
80	Egeria (100)
81	Egeria (75), Spiked watermilfoil (25)
82	Egeria (50), Spiked watermilfoil (50)
83	Spiked watermilfoil (100)
84	No plants in sample
85	Egeria (75), Spiked watermilfoil (25)
86	No plants in sample
87	Spiked watermilfoil (100)
88	Spiked watermilfoil (100)
89	Egeria (100)
90	Spiked watermilfoil (100)
91	Egeria (50), Spiked watermilfoil (50)
92	Spiked watermilfoil (100)
93	No plants in sample
94	Egeria (100)
95	Egeria (100)
96	Spiked watermilfoil (100)
97	Spiked watermilfoil (100)

Species Density Distribution

The aquatic plant species density distribution for milfoil (surface and subsurface densities), Egeria, waterlily, and no to low plant density is shown in Figures 9 and 10 and tabulated in Table 3. Surface milfoil and waterlily cover potentially impact recreational uses, while subsurface milfoil and Egeria cover are not likely to negatively impact recreational uses of the lake. These results show the following:

- Milfoil growing to the lake surface covered 19 acres (7 percent of the lake) that was primarily located in shallow waters adjacent to the west shore and in the cove north of east beach.
- Milfoil growing below the lake surface covered 50 acres (19 percent of the lake surface) that was primarily located in the west and southwest portions of the lake and including close to the east and north shores of the lake.
- Total milfoil cover in the lake increased from 10 acres (4 percent) in 2005 to 69 acres (27 percent) in 2022.
- Egeria fragments were first discovered during a Friends of Green Lake Beach cleanup in November 2020. Egeria was first surveyed in May of 2021. It was found to be widespread throughout the central north region of Green Lake. Thus, Egeria was introduced to the lake sometime between the 2005 plant survey and the 2020 beach cleanup, and likely after the 2009 beach cleanup when only milfoil was observed on the lake shore (see photos below).

Milfoil cleanup 12/19/2009

Egeria fragments 11/7/2020

- Based on results of the 2022 survey, Egeria cover increased to 52 acres (20 percent of the lake surface) since it was introduced into the lake. Assuming it took at least several years to cover that large of an area, Egeria was likely introduced to Green Lake between 2009 and 2017.
- Fragrant waterlily cover increased from 4.4 acres in 2005 to 5.3 acres (2 percent of lake cover) in 2022, representing a 17 percent increase in cover over 17 years.

Table 3. Aquatic Plant Cover in Green Lake, September 7, 2022.

Plant Category	Acres	Percent
Surface Milfoil	19	7%
Subsurface Milfoil	50	19%
Subtotal Milfoil	**69**	**27%**
Egeria	52	20%
Waterlily	5	2%
Low to No Plants	131	51%
Total Lake Area	**257**	**100%**

Aquatic Noxious Weeds

Three aquatic weeds were observed within the survey area: fragrant waterlily (*Nymphaea odorata*), which is a rooted floating-leaved plant; Brazilian elodea (*Egeria densa*), and Spiked watermilfoil (*Myriophyllum spicatum*), all of which are aquatic plants (see Figures 7 and 8). None of these species are required for control in this part of King County.

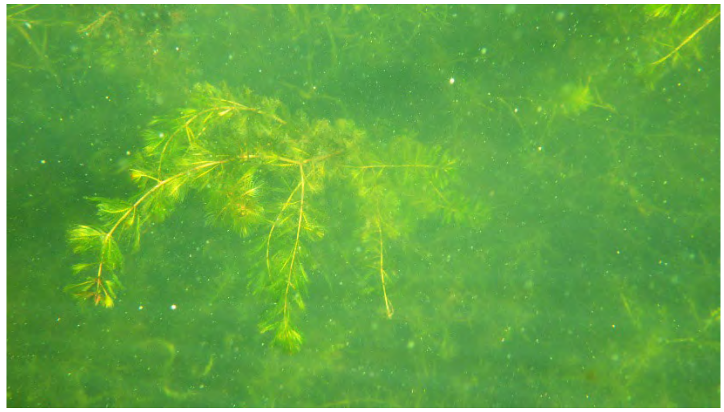
Fragrant waterlily, Spiked watermilfoil, and Egeria are targeted for control in this IAVMP. These plants are described below, based on *An Aquatic Plant Identification Manual for Washington's Freshwater Plants* (Ecology 2001).

Fragrant waterlily is native to the eastern half of North America. It is a Class C noxious weed, and it is not required for control in King County. It was most likely introduced into Washington in the late 1800s during the Alaska Pacific Yukon Exposition in Seattle. It has often been introduced to ponds and lakes, because of its beautiful, large, white or pink many-petaled flowers, which float on the water's surface, surrounded by large, round green leaves. The leaves are attached to flexible underwater stalks rising from thick fleshy rhizomes. Adventitious roots attach the horizontal creeping and branching rhizomes.

Fragrant waterlily (*Nymphaea odorata*)

This aquatic perennial herb spreads aggressively, rooting in murky or silty sediments in water up to 10 feet deep. It prefers quiet waters, such as ponds, lake margins, and slow streams, and will grow in a wide range of pH. Shallow lakes are particularly vulnerable to being totally covered by fragrant waterlilies. Fragrant waterlily spreads by seeds and by rhizome fragments. A planted rhizome will cover about a 15-foot-diameter circle in 5 years.

Spiked watermilfoil is native to Eurasia and northern Africa, but it is a widespread invasive plant in North America. It is a Class B noxious weed, but it is not required for control in King County. This is a dicot plant that spreads rapidly and outcompetes many other native aquatic plant species. It can also be easily confused with native milfoils, and sometimes genetic testing is needed to identify milfoils to species. Spiked watermilfoil is a submersed aquatic plant that spreads from plant fragments and rhizomes. The leaves are long and feather-like, and arranged in whorls of four around the stems, which are often reddish in color. Spiked watermilfoil is found in rivers, lakes, and ponds, and tolerates a wide variety of water quality conditions.



Spiked watermilfoil (*Myriophyllum spicatum*)

Egeria is a submersed aquatic plant. It is native to South America, but it is a widespread invasive plant in North America. It is a monocot and a Class B noxious weed, but it is not required for control in Green Lake. It is commonly sold as an aquarium plant in other parts of the U.S., but it is illegal to sell in the state of Washington. This plant spreads rapidly and outcompetes many other native aquatic plant species. The leaves are clumped densely in whorls of four to six in the upper part of the plant, and more spread apart in whorls of three near the base of the plant. The plant primarily reproduces from stem fragments.

Brazilian egeria (*Egeria densa*)

Past Management Efforts

In circa 1980, the lake was invaded by the noxious weed Spiked watermilfoil (*Myriophyllum spicatum*), which rapidly expanded to cover over 80 percent of the lake. In the 1990s, SPR managed milfoil to support recreational uses with bottom barriers at the swimming beaches and mechanical harvesting of the rowing (crew) lanes. Milfoil cover dramatically declined due to the planting of 777 grass carp in 2001. Algal blooms subsequently increased due to the dramatic die-off of the plant community. Herrera performed a quantitative aquatic plant survey of the lake in 2005; at that time, milfoil covered only 10.5 acres (4 percent), compared to 210 acres (81 percent) in 1991.

In November 2020, the Friends of Green Lake identified fragments of the noxious weed, Egeria (*Egeria densa*), on the lake shoreline during a beach cleanup. In May 2021, a qualitative survey identified Egeria throughout most of the central portion of the lake and milfoil along most of the nearshore region. It was determined that the extent and abundance of Egeria was too great to be considered for early infestation control by diver hand-pulling or suction dredge and that an integrated aquatic vegetation management plan should be developed.

Aquatic plant observations and management actions in Green Lake were summarized for the Phosphorus Management Plan prepared for the third alum treatment of the lake in 2016 (Herrera 2015). For background, this information is provided below, along with more recent observations. Table 4 summarizes the aquatic plant management history of Green Lake.

Table 4. Prior Green Lake Aquatic Plant Management History.

Period	Activity/Finding
1980–1991	Milfoil invaded lake in circa 1980 and covered most of lake by 1991.
1991	The first alum treatment did not substantially increase water clarity.
1991–1994	Annual surveys showed that milfoil dominated 75–90% of lake bottom; coontail was present; the first alum treatment occurred in 1992.
1991–2000	The mechanical harvesting program showed a decrease in the amounts of milfoil removal from 1,200 tons in 1991 to 30 tons in 1995, and then <30 tons (5–10 days)/year until it was suspended in 2000 due to low plant height/density.
1999–2003	Low water clarity and toxic algae closures occurred in 1999, 2002, and 2003.
2001	The lake was stocked with 177 grass carp at 4/vegetated acre (75% of lake vegetated) versus the higher WDFW-recommended rate of 24/vegetated acre.
2004	The second alum treatment increased clarity for about 10 years.
2005	The WDFW fish survey found grass carp median length increased from 32 to 66 cm between 2002 and 2005.
2005	The Herrera plant survey found 10 acres of milfoil (only nearshore), compared to 210 acres in 1991; minor amounts of coontail and *Elodea*; no change in 4.5 acres of fragrant water lily since 1991, but lost spatterdock; minor hand-pulling of milfoil in Duck Island Bay by a contractor.
2015	The FOGL plant survey found milfoil expanded since 2005.
2016	The third alum treatment slightly increased water clarity.
2020	FOGL found *Egeria densa* (*Egeria*) fragments on the shore at NE bay and other locations during the November 2020 milfoil beach cleanup.
2021	FOGL, Herrera, King County, Seattle Parks, and Ecology representatives surveyed the lake and observed numerous *Egeria* plants in the north central portion of the lake.

Aquatic Plant Control Alternatives

There are many methods used to control aquatic weeds. The methods chosen for aquatic plant control vary depending upon several factors, including: the species of aquatic plants targeted; whether the control goal is management or eradication; the cost of a method and availability of funds; the impacts to water quality and habitat; the safety and feasibility of a method; and support from community members. Control methods considered for Green Lake included the following:

- No Action
- Chemical herbicides
- Manual control methods
- Mechanical control methods
- Diver dredging
- Bottom screening

Table 5 provides a summary of each method considered, its advantages and disadvantages, and its suitability for Green Lake. Full descriptions of each method, as well as advantages and disadvantages, permits, costs, and suitability for Green Lake, are summarized in Appendix B. Much of the information in Appendix B is taken directly from Ecology (1994), or from Ecology's Aquatic Plant Management website (Ecology 2024). In addition, Appendix C provides information prepared by King County on best management practices for each target species.

Note that in the future there may be additional herbicides approved for use in Washington State, and other management strategies and tools may become available. The City of Seattle intends to leave open the possibility of examining and utilizing these other management strategies and tools in the future.

Table 5. Aquatic Plant Control Options Considered for Green Lake.					
Category	**Method**	**Description**	**Advantages**	**Disadvantages**	**Target Plants**
None	No Action	Nothing is done to control plant growth.	• No costs incurred	• No control achieved	
Chemical Methods	Aquatic herbicides	Chemicals are applied directly to plants or the lake to inhibit or restrict plant growth.	• Cost effective • High level of control	• Ecological impact concerns • Possibility of rapid plant die-off leading to algae bloom	• All plants
Manual Methods	Hand-pulling	Plants are removed by pulling out by hand.	• No equipment cost	• Small infestation eradications only	• Submersed
	Raking	Plants are removed with a large rake.	• Inexpensive equipment	• Small infestation eradications only	• Submersed
	Cutting	Plants are cut with a non-mechanical aquatic weed cutter.	• Inexpensive equipment	• Small infestation eradications only	• Submersed
Mechanical Methods	Mechanical harvesters	Plants are cut and collected using a large barge-mounted machine with conveyor.	• Collects the majority of cut plant biomass • No chemical residue	• Short period of effectiveness • Fragment drift and spread to new areas • Depth limitations to maximum cutting depth of 6 feet • Dock and woody debris obstructions • Fossil fuel use • High cost	• All plants
	Mechanical weed cutters	Plants are cut several feet below the water's surface; cut plants are not collected while the machinery operates.	• No chemical residue	• Short period of effectiveness • Fragment drift and cut biomass remaining in the lake or on shore to decay • Fossil fuel use • High cost	• All plants
	Diver dredging (DASH)	SCUBA divers use a hose attached to a dredge, to suck plants from the sediment underwater.	• Removes all plant biomass, including roots • Moderate infestation eradication	• Water quality impacts from sediment suspension • High cost	• Submersed
Other Methods	Bottom screening	A gas-permeable barrier, which compresses existing aquatic plants while blocking light to prevent further plant growth, is installed on the lake bottom.	• Effective for rooted plants in small areas around docks	• Remove in 2 years unless 100 percent biodegradable, including weights to keep in place • Moderate cost	• Submersed

Integrated Aquatic Plant Control Scenarios

The aquatic plant management goals for Green Lake are the following:

- Control noxious weeds and dominant weed species.
- Reduce impacts to beneficial uses, including swimming, crew, fishers, and paddlers.
- Maintain a healthy environment for fish and other wildlife.
- Return native aquatic plants to the lake.

No action, herbicides, mechanical harvesting, bottom barriers, and native aquatic plantings were among the control scenarios evaluated to accomplish the aquatic plant management goals for Green Lake.

No Action

The Steering Committee considered a No Action alternative, in which no aquatic plant control strategies are applied. In this scenario, the issues identified in the problem statement would continue. Aquatic plant densities would continue to increase to the greatest extent possible, worsening existing water quality impacts and disruption of beneficial uses. Due to the issues resulting from aquatic plants, the Steering Committee did not pursue this scenario.

Herbicide

Four primary herbicides were considered for use in this plan: ProcellaCOR, fluridone, glyphosate, and imazapyr, which are described below and summarized in Table 6. The dead plants are left to decay and are not removed for any type of treatment.

Fluridone can be used to treat milfoil and Egeria. Fluridone treatments are priced per treatment, rather than per acre. Costs are estimated for treating both weeds in the entire lake (259 acres) using liquid fluridone. Costs are also estimated for primarily targeting Egeria in a high-priority area (approximately 52 acres) using pelleted fluridone (see Table 6). ProcellaCOR can be used to treat only milfoil and costs approximately $1,200 to $1,300 per acre.

Glyphosate and imazapyr can be used to treat fragrant waterlily. Imazapyr was selected for control of fragrant waterlily, because it has been effectively used in Lake Washington and many other lakes in the region. Both glyphosate and imazapyr are relatively inexpensive with application costs around $350 and $700 per acre, respectively (personal communications, Terry McNabb, June 2024). No more than 2.5 acres of treatment of fragrant waterlily is anticipated in Green Lake, because only the outer portion of the waterlily area is targeted for control due to the low impact and priority of this noxious weed.

Table 6. Herbicide Targets, Restrictions, and Costs.			
Herbicide	**Target Plants**	**Use Restrictions**	**Approximate Cost**
Fluridone (complete lake treatment, liquid)	Spiked watermilfoil and Egeria	None	$350,000 for entire lake treatment
Fluridone (spot treatment. pellet)	Spiked watermilfoil and Egeria	None	$90,000/52 acre treatment area
ProcellaCOR	Spiked watermilfoil	None	$1,200-$1,300/acre
Glyphosate	Fragrant waterlily	None	$350/acre
Imazapyr	Fragrant waterlily	None	$700/acre

Glyphosate and imazapyr can also be used to treat emergent noxious weed species, including priority (Class B) species not in Green Lake (e.g., purple and garden loosestrife) and low priority (Class C) species in Green Lake (e.g., yellow flag iris and nonnative cattails, which are not being targeted for this plan due to their low impact and priority).

All four herbicides are approved for aquatic use in Washington State, based on environmental impact studies. As a result of these studies, there are many other herbicides allowed by the U.S. Environmental Protection Agency (EPA) but prohibited for use in Washington State. Full precautions will be taken during applications in Green Lake to ensure that herbicide levels do not exceed the amounts at which these hazards arise, by not exceeding amounts specified by EPA on the product label. Permit applicants should take care to observe all permit conditions, including notifications and public notices.

Fluridone: Fluridone (trade name Sonar®) is an approved aquatic herbicide that may be applied in liquid or pellet form. Fluridone is a systemic, non-selective herbicide that may be used for the control of submerged, emergent, and floating-leaf vegetation. Systemic herbicides kill the entire plant, whereas contact herbicides only burn the stems and leaves (leaving viable roots to sprout after treatment). Non-selective herbicides kill a wide variety of plant species, whereas selective herbicides kill one or a few species. There are no post-treatment restrictions for swimming, fishing, or pet use after fluridone application. Ecology requires that the herbicide applicator submit a fluridone vegetation management plan when fluridone application is proposed for more than 40 percent of the littoral zone in lakes the size of Green Lake (Ecology 2024).

Fluridone application requires low, sustained concentrations and a long contact exposure time (e.g., 2 months). Fluridone may be applied multiple times within a treatment period, to maintain the adequate contact exposure required for the effective control of aquatic plants. Fluridone treatments result in the plant's chlorophyll breaking down with exposure to sunlight. Treated plants will turn white or pink at the tips after 1 week and will decompose 1 to 2 months after treatment. Fluridone must be applied during the active growing season of the plant species.

ProcellaCOR™: With the common name florpyrauxifenbenzyl, ProcellaCOR™ is a recently approved aquatic herbicide. In February 2018, the EPA certified registration of ProcellaCOR™ as a selective herbicide that can be used to treat hydrilla, watermilfoil, and crested floating heart. ProcellaCOR™ is approved for aquatic use and has been given a Reduced Risk status from the EPA because of the reduced risk to human health and native plants in comparison to alternative herbicides.

ProcellaCOR™ is a systemic, selective herbicide that, as a liquid, is applied directly into the water or sprayed onto emergent foliage of aquatic plants (TRC 2017). Aquatic vascular plants quickly absorb ProcellaCOR™ through shoots and leaves. To be most effective, ProcellaCOR™ should be applied during active growth periods of targeted plant species. The rapid contact time (e.g., 6 hours) for this herbicide makes it very useful for spot treatment of small areas in lakes where those areas are rapidly diluted by lake currents. There are no human exposure restrictions for recreational purposes, including swimming and fishing. Due to its low aquatic toxicity, high effectiveness on Spiked watermilfoil, and high species-selectivity preventing harm to native plants, ProcellaCOR™ is recommended for treatment of Spiked watermilfoil in Green Lake. In the United States, ProcellaCOR™ is licensed to a limited number of applicators, who have been trained in its use, and at this time is only available through one local treatment company, Aquatechnex.

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 waterlilies and shoreline plants like purple loosestrife. It is generally applied as a liquid to the leaves. Glyphosate does not work on submersed plants. 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. The slow decay of waterlily roots (rhizomes) in large, treated areas may result in floating root mats that impact recreation or require costly mechanical removal to prevent recreational impacts. Floating root mat control is not addressed in this IAVMP, because large waterlily treatment areas are not anticipated for the project site.

Imazapyr: One trade name for Imazapyr is Habitat®. This systemic broad spectrum, slow-acting herbicide, applied as a liquid, is used to control emergent plants like spartina, reed canarygrass, and phragmites and floating-leaved plants like water lilies. Imazapyr does not work on underwater plants, such as Spiked watermilfoil. Although imazapyr 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. Blue dye can be used in the herbicide, so that the applicator can see where the herbicide has been applied. Aquatic surfactants may also be used to improve the performance of the herbicide. When using Imazapyr, plants can take 4 to 6 weeks to die off after treatment. A follow-up treatment is often necessary for plants that were missed during the first treatment of Imazapyr. The slow decay of waterlily roots (rhizomes) in large, treated areas may result in floating root mats that impact recreation or require costly mechanical removal to prevent recreational impacts. Floating root mat control is not addressed in this IAVMP, because large waterlily treatment areas are not anticipated for this project site. Imazapyr was allowed for use in Washington in 2004.

Herbicide Control Scenarios

Two herbicide control scenarios were considered for application at Green Lake. The first herbicide control scenario was lake-wide aquatic plant control with fluridone. The second was a series of targeted herbicide applications to manage aquatic plant populations in high priority areas using ProcellaCOR, Fluridone, and Imazapyr.

Lake-Wide Control with Fluridone

In the lake-wide control scenario, liquid fluridone would be applied throughout the lake to eliminate all submersed noxious weeds (and thus, both milfoil and Egeria) in Green Lake in the first year of plant control. One or two repeated applications during the initial treatment year may be necessary, to maintain the herbicide concentrations necessary for aquatic plant control over a 2-month period. A lake-wide treatment with liquid fluridone may incidentally control the outer edge of floating water lilies.

Advantages:

- This scenario would eliminate the current issues with aquatic plants. Follow-up applications of fluridone after the initial treatment year would not likely be necessary.
- This scenario would lessen the burden of plant management overtime by avoiding the need for repeated widespread plant control efforts. The City's efforts could transition to focusing on monitoring and control as aquatic plants repopulate the lake.
- This scenario would create the opportunity to plant native aquatic plants without immediate competition from noxious weeds.

Disadvantages:

- There is a risk of causing an algal bloom due to the widespread die-off of plants and the resultant release of nutrients into the water column. An alum treatment would likely be necessary, in tandem with, or soon after implementation of this control scenario, to prevent algae blooms.
- There is potential to elicit a negative public reaction to the temporarily barren lake conditions to result from the management efforts.
- This scenario could temporarily eliminate aquatic plant habitat for fish, insects, and amphibians in and around the lake before the natural repopulation or planting of aquatic plants.
- There is a high cost of approximately $350,000 for one period of application in the lake.

Targeted Herbicide Applications

The targeted herbicide application scenario is summarized in Table 7. This scenario would occur over multiple years. In this IAVMP, this scenario is described in a series of sequential years. Each year of treatment does not necessarily need to be sequential. Adjustments can be made based on plant community conditions and funding.

In Years 1, 2 and 3 of this scenario, SPR would target Spiked watermilfoil with ProcellaCOR, because it is the species that most interferes with beneficial uses on Green Lake. The treatment is split into 3 years to manage annual costs and to reduce the risk of plant die-off fueling an algal bloom. Each year, approximately 38 acres would be targeted for treatment. Treatment areas would be prioritized according to the most interference with beneficial use activities, likely beginning with the crew lanes. SPR may adjust treatment areas based on need each year, ultimately treating all 114 acres of Spiked watermilfoil shown in Figure 11

Table 7. Targeted Herbicide Application Scenario Summary.				
Management Year	**Target Species**	**Estimated Herbicide Treatment Area**	**Control Strategy**	**Approximate Cost**
1 to 3	Spiked watermilfoil	38/year	ProcellaCOR	$50,000/year
4	Egeria and Spiked watermilfoil	88	Granular fluridone	$90,000
5	Fragrant waterlily	2.5	Imazapyr	$1,750

In Year 4, the City would use granular fluridone to control Egeria and any remaining Spiked watermilfoil in the 88-acre Egeria control area located in the central portion of the lake shown in Figure 11. It is anticipated that Egeria will have reached the lake surface and interfere with boating by Year 4, and may have spread further in the lake requiring a larger treatment area. Also, portions of milfoil areas treated in Years 1 to 3 may need additional treatment at this time. Although plant decomposition is relatively slow from fluridone treatments, a treatment of this large area and biomass of plants growing up to 15 feet high may fuel an algae bloom. Thus, the City should consider spreading the treatment over 2 years—or conducting a whole-lake treatment, with liquid fluridone, and coordinating it with another alum treatment to reduce the algae bloom potential.

Finally, in Year 5, the City would use imazapyr to control the outermost areas of the fragrant waterlily patch on the western shore, to prevent its further spread (Figure 11). This order of control is prioritized based on relative impact of the target species. Management years could be extended to occur more than 1 year apart.

Advantages:

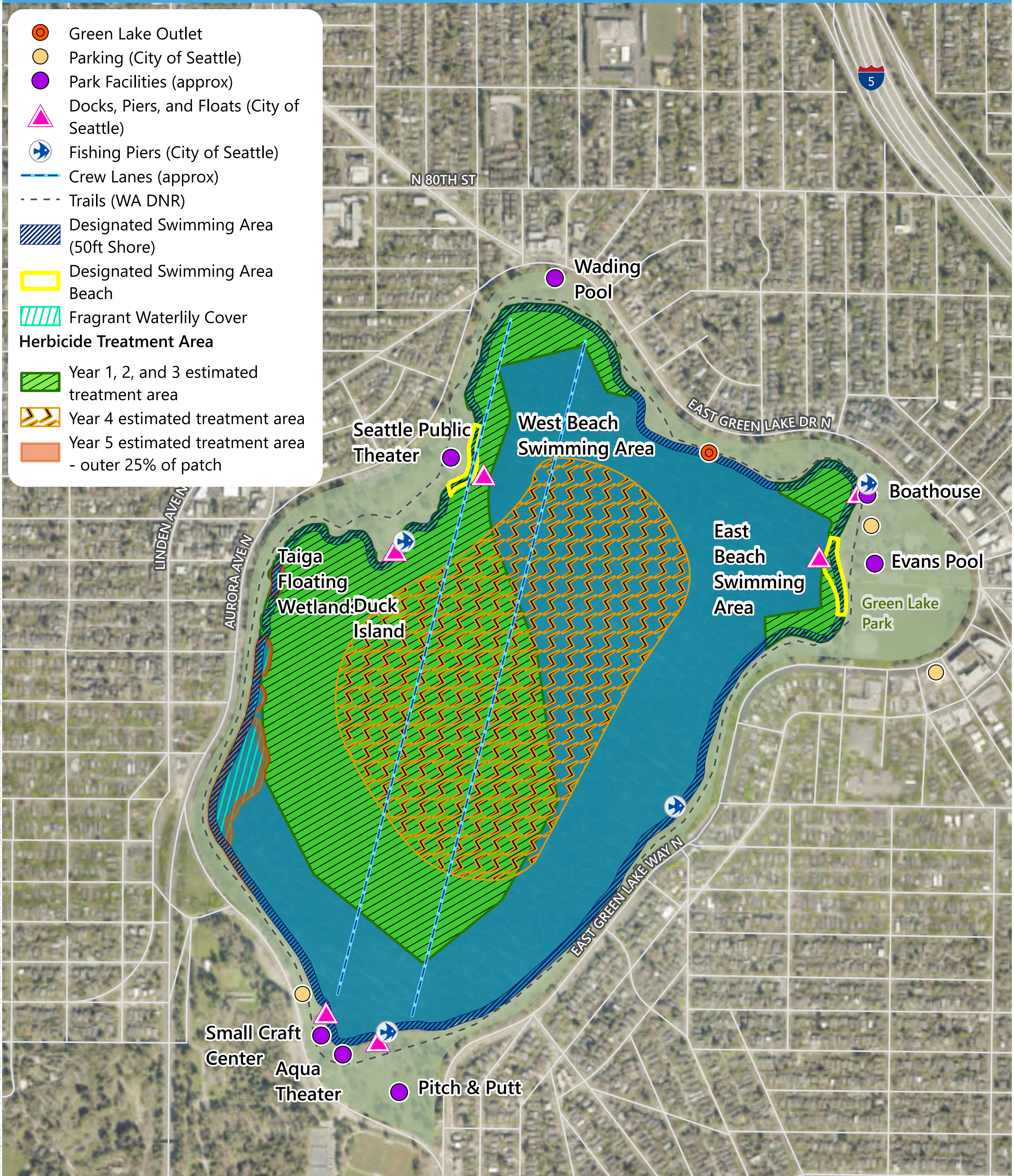
- This scenario includes greater selectivity than lake-wide control with fluridone, and it avoids complete die-off of plant population in 1 year.
- This scenario accomplishes plant management in high-priority areas throughout the lake.
- This scenario leaves plants intact in areas without beneficial use impacts, providing habitat for fish and wildlife.
- There is less risk of an algal bloom being fueled by widespread plant die-off throughout Green Lake.
- The cost is spread over 3 years (or more) and is a lower cost than that of other control scenarios.

Disadvantages

- There is a need for ongoing and repeated management efforts over several years to accomplish goals.
- There is less widespread control of aquatic plants.

The native plant repopulation efforts would need to be more strategic to maximize the likelihood for success, with remaining competition resulting from the continued vegetation by noxious weed species.

Figure 11.
Targeted Herbicide Application Scenario.



Produced by Herrera Environmental Consultants (herrerainc.com) | Sources: City of Seattle, King County, Aerial (2021)

Mechanical Harvesting

Mechanical harvesting was not identified as a suitable control method for Green Lake in the short term, because it requires intensive labor repeated regularly throughout the growing season and is not the most cost-effective approach to managing the plant population.

Mechanical harvesters are large machines, which both cut and collect aquatic plants 2 to 6 feet below the water's surface (exact depth depends on lake conditions and harvester used). 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. Ecology does not recommend harvesting milfoil or Egeria, because it can create plant fragments that help spread these invasive plants. However, fragment spread is less of a concern for this project area, because these invasive plants are well established and widespread. Also, throughout the summer, milfoil naturally produces large numbers of autofragments that have a higher carbohydrate content and are therefore much more viable than fragments cut by a harvester (Cooke et al 2005). Thus, milfoil fragments generated by harvesting may be less problematic than naturally produced autofragments, and harvesting may reduce the parent stock producing autofragments.

Mechanical harvesting is ideally suited for large areas that are free from most obstacles, such as docks. The harvesters are also difficult to maneuver in shallow water. The cost of using a mechanical harvester is about $3,780 per acre for two to three harvests/year (not including disposal) (personal communications, Terry McNabb, June 2024).

Bottom Barriers

The use of bottom barriers around docks and swim areas is a method of plant control considered for Green Lake. Bottom screens can be installed by the City 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 screen installation. Bottom barriers are a viable choice for small areas of control (e.g., less than 1 acre), such as at the swimming beaches. For many years in the 1980s and 1990s, bottom barriers consisting of fiberglass screen (Aquascreen®) were installed at both beaches in the spring and removed by divers in the fall. The Washington Department of Fish and Wildlife (WDFW) requires barriers to be removed after a 2-year period, unless the bottom barrier, including the weights to hold it in place, is made entirely of biodegradable material (WDFW 2015). Covering noxious weeds along more than 50 percent of the lake shoreline requires an individual Hydraulic Project Approval (HPA) permit from WDFW.

Burlap is a cost-effective material for bottom barrier, because it is relatively inexpensive ($3,000/acre) and does not need to be removed. Burlap is densely woven for adequate plant cover while allowing for gas transfer to prevent flotation from underlying plant decomposition. For example, volunteers at Lake Leelanau in Michigan developed an efficient installation method using 20- by 100-foot folded sheets of burlap and burlap bags containing pea gravel for anchors (LLLA 2024). Two divers can install one sheet in 30 minutes (4,000 square feet/hour) with help from boat and shore teams. In 2023, they installed over 4 acres at rates of up to 32,000 square feet (0.7 acre) per day. Based on the conditions in the 2022 aquatic plant survey and observations since then, the extent of invasive aquatic weeds is too great for bottom barriers to be cost effective. In the future, bottom barriers at the swimming beaches or other high use areas may be considered if the plant population is reduced throughout the lake.

Native Planting

During the 2022 aquatic plant survey, no native plants were observed in Green Lake. After management efforts are implemented in the lake to reduce the cover by noxious weed species, a planting effort could be implemented to introduce native aquatic plants into the lake. This would provide habitat and water quality benefits to the lake by fostering a healthy and diverse aquatic plant community. Suitable plant species for establishment in the lake may include, but are not limited to, hornwort (*Ceratophyllum demersum*), pondweeds (*Potamogeton* spp.), and waterweed (*Elodea canadensis*).

Aquatic planting remains a somewhat experimental field. Methods include the "clay ball" technique, where plantings have clay balls packed around their roots to help them sink to the lake bottom, with clay as the starting soil for root formation (CLFLWD Watershed District 2023). Native aquatic plant seeds could also be collected from a nearby source and dispersed in the lake (Verhoeven et al 2024). Another method found during research for this IAVMP involves constructing a floating PVC cube that disperses plants that reproduce by fragments throughout the lake (Hobbs, Thomas; personal communication; January 2024). Using nursery enclosures is another method that has been successful for establishing native aquatic plants in lakes. Como Lake has successfully established native plants following a fluridone treatment of curly leaf pondweed. A variety of native plants were transferred from a nearby donor lake into 10- by 13-foot enclosures constructed of steel fence posts, wire mesh, and burlap (Belden 2024).

Future Considerations

As noted in Aquatic Plant Control Alternatives, the SPR recognizes that best practices in the management of aquatic weeds are continually evolving. There may be additional herbicides approved for use in Washington State in the future, and other management strategies and tools may become available. SPR intends to leave open the possibility of examining and utilizing any or all of these in the future.

Selected Action Strategy and Implementation

Action Strategy

After assessing the control scenarios, the Steering Committee prioritized a maintenance level of control for the target plants that meets IAVMP goals using an integrated approach.

The following plant management strategies were assessed to determine if they could meet the goals of the IAVMP:

- Herbicide treatment of invasive, nonnative, submersed plants and fragrant waterlily (complete control with fluridone or targeted herbicide applications)
- Manual control methods
- Mechanical control methods
- Diver dredging
- Bottom screening
- Native plantings

The Steering Committee elected to proceed with the targeted herbicide application control scenario followed by a native planting effort.

The targeted herbicide application scenario is summarized in Table 7. In Years 1, 2, and 3 of this scenario, the City would target Spiked watermilfoil with ProcellaCOR, because it is the species that most interferes with beneficial uses on Green Lake. In Year 4, the City would use granular fluridone to control Egeria in the central portion of the lake where it is expected to have reached the water surface. This would include treatment of Spiked watermilfoil in this area, and could include other areas to control the spread of Egeria in the lake and continue the control of Spiked watermilfoil after the efforts in Years 1, 2, and 3. Finally, in Year 5, the City would use imazapyr to control the outermost areas of the fragrant waterlily patch on the western shore, to prevent its further spread. This order of control is prioritized based on relative impact of the target species. Management years could be extended to occur more than 1 year apart.

Herrera recommends beginning native planting efforts in fall of Year 4, after Year 4 of the herbicide treatments and the successful reduction of Spiked watermilfoil and Egeria. Herrera recommends trying multiple techniques, such as the clay ball, floating cube, and nursery enclosure methods, in areas where the Spiked watermilfoil and Egeria populations are significantly reduced or eliminated by treatments in Years 1 and 2. The initial planting event should occur in fall of Year 2. Planting areas for these methods should be separate from each other and monitored to compare the performance of each planting method. Planting efforts should occur in the nearshore, where depths are less than or equal to 10 feet. A mix of hornwort (coontail), pondweeds, and waterweed should be planted, as these species are readily available in the greater Seattle area and are known to grow well in the lakes in this region. A detailed plan for planting quantity, location, species, and methodology along with performance monitoring methods, should be prepared prior to each planting effort based on conditions of the lake at the time of planting and funding available to implement the planting effort.

Herrera recommends monitoring planting areas to evaluate the performance of planting efforts. Based on the results of monitoring and planting events, supplemental plantings should occur in order to continue the repopulation of native plants in Green Lake.

Implementation

The Seattle Department of Construction and Inspections (SDCI) is responsible for oversight of proposed development and permitting throughout the City of Seattle. This includes regulating activities along the shoreline to ensure implementation of the Shoreline Management Act of 1971 (Washington State Legislature 2017), which recognizes that “the shorelines of the state are among the most valuable and fragile of its natural resources” and provides guidelines for permitted uses “designed and conducted in a manner to minimize, insofar as practical, any resultant damage to the ecology and environment of the shoreline area and any interference with the public’s use of the water” (RCW 90.58.020). In addition, unless eligible for a Shoreline Substantial Development Permit (SSDP) exemption, permit requesters must complete a SEPA Environmental Checklist to determine whether the environmental impacts of any management efforts are significant. If a Shoreline Exemption is sought in lieu of a Shoreline Substantial Development Permit, applicants are responsible for demonstrating compliance with exemption criteria. SDCI will review all permits submitted to the City of Seattle for compliance with the Shoreline Management Act of 1971 and the State Environmental Policy Act (SEPA). Fees for permits or exemptions issued by the City of Seattle are based on the Fee Resolution in effect at the time of application. In general, work performed within the scope of this IAVMP will qualify for a Shoreline Exemption rather than a Shoreline Substantial Development Permit.

The Washington Department of Ecology administers the aquatic plant and algae management general permit. This permit controls chemical treatments for the management of aquatic noxious weeds, native nuisance plants, and algae. These chemicals are limited to a specific list of aquatic-labeled herbicides, algaecides, biological water clarifiers, adjuvants, marker dyes, shading products, and phosphorus sequestration products. They can be used directly in fresh water (lakes, streams, and rivers) or along shorelines, roadsides, dikes/levees, and ditch banks. The Environmental Protection Agency (EPA) regulates active ingredients in herbicides under the Federal Insecticide, Fungicide, and Rodenticide Act and Federal Facilities.

Because there are multiple jurisdictions and agencies concerned with Green Lake, additional permits may be required by others. To determine what specific permits are required, anyone desiring to implement any of the strategies contained in this Plan should complete a Project Questionnaire at the Governor’s Office for Regulatory Innovation and Assistance website (<www.oria.wa.gov>). The completed questionnaire generates a list of permits required for the project under consideration. Required permits for each plant management strategy are summarized in Table 8. See Appendix B for additional permit information.

Table 8. Required Permits.

Method	Shoreline Permit Exemption from City of Seattle	Aquatic Plant and Algae Management Permits from Ecology	Hydraulic Project Approval (HPA) Permit from WDFW
Herbicide	Exemption required	General permit required for water lily, Egeria, and milfoil (Ecology 2024) Noxious weed permit required for yellow flag iris (Ecology 2024)	HPA not required
Mechanical Harvesting	Exemption required	Not required	HPA required for native plants, see pamphlet for noxious weeds (WDFW 2015)
Bottom Barrier	Exemption required	Not required	See pamphlet for noxious weeds or native plants (WDFW 2015)
Native plantings	Not required	Not required	Not required

For projects implemented by SPR, SPR will regularly evaluate the status of aquatic weeds and the effectiveness of plant management strategies employed to date. SPR will hire contractors to do work in public areas, such as large herbicide treatments and/or harvesting.

Successful implementation of this plan revolves around a collective sharing of information. SPR will work to solicit public input, and keep residents and businesses informed of current and future plant management strategies. As noted earlier, the City of Seattle has published a webpage with useful links for permit and other information (LINK PENDING).

Monitoring and Evaluation Plan

Several different plant control-related monitoring and evaluation needs are identified for the City of Seattle, including aquatic plant surveys and evaluation of aquatic plant management activities. These evaluation activities are described in the following sections.

Aquatic Plant Surveys

Ongoing surveys and mapping will be necessary to evaluate the effectiveness of management strategies, to inform future efforts, and to detect new infestations of invasive plants. In response to the planned treatments, the aquatic plant community in the City of Seattle may be in flux. It is critical that frequent and thorough surveys be conducted to document these changes and to detect new problems.

Subject to funding availability, a GPS/GIS survey and mapping effort may be performed by a contractor as a regular component of the long-term surveillance and management program. This survey effort will identify all plant species present in the lake and their relative abundance at each location. The survey map will include past management areas for comparison to plant densities observed in previous surveys and assessment of management effectiveness. These plant surveys will also help provide guidance for aquatic plant management in future years.

Aquatic plant surveys are recommended to occur near the peak of growth in August or September on the year before treatment, the year of the treatment, and at 2- to 5-year intervals after treatment.

Evaluation

Also subject to funding and staffing resources, a complete evaluation including a plant management report may be completed as needed. This report would describe which elements of the management plan have been implemented, relate the existing plant community to established goals, and make recommendations for the next year’s activities.

This evaluation should begin with a description of which elements of the plan have been fully implemented, which elements have not, and why. It should also include a summary of the plant survey results, both those obtained by volunteers and those obtained by professionals. The evaluations should also provide a map of all management areas for each year. The survey results should be used to determine whether goals have been met. The community should also be asked for input on their satisfaction with aquatic plant and water body conditions. It is possible that the IAVMP goals will be met but that some people will remain dissatisfied.

Although it is unlikely that the needs of all relevant parties will be met (and it is possible that the IAVMP goals will be met but that some people will remain dissatisfied), an effort should be made to track concerns, especially if they are widespread. This information should be used to decide on the following:

- Has there been a quantifiable increase or decrease in the amount of nuisance plants in the lake?
- Have any other noxious aquatic plants been identified?
- Has there been a change in the occurrence and frequency of algae?
- What control methods work best, and should other control methods (newly approved herbicides, for example) be considered?
- Is it necessary to revise the plan?
- Is funding adequate for the control measures in place?

Over the long term, adequate evaluations can make the difference between project success and failure, and the City of Seattle will regularly monitor and evaluate the effectiveness of the various management strategies that have been employed. In addition, as noted earlier, potential new herbicides, management strategies, and tools will be considered as they become available.

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Appendix A

Steering Committee and Public Meeting Presentations

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Green Lake IAVMP Steering Committee:

Bridget Kelsh, Jason Coffman and Adam Bailey; City of Seattle Parks and Recreation
Ben Peterson, King County Noxious Weed Program
Wes Glisson, Washington Department of Ecology
Julian Douglas and Justin Spinelli, Washington Department of Fish and Wildlife
Tamara Oki, Green Lake Small Craft Center
Kim Tennican, Friends of Green Lake

Facilitators:

Kevin Bergsrud, Senior Planning and Development Specialist, City of Seattle

Rob Zisette, Herrera Environmental Consultants

Eliza Spear, Herrera Environmental Consultants

Green Lake Integrated Aquatic Vegetation Management Plan

Stakeholder Kickoff Meeting

February 7, 2024

Colin Campbell, Seattle Parks and Recreation

Rob Zisette and Eliza Spear, Herrera Environmental Consultants

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Presentation Objectives and Agenda

Introductions

Lake Background

- Aquatic Plant Management
- Toxic Algae

Aquatic Plant Management Techniques

- Physical
- Mechanical
- Chemical

IAVMP Project

- Develop Problem Statement (5 minutes)
- Identify Beneficial Use Areas (5 minutes)
- Develop Plant Management Goals (15 minutes)
- Next steps

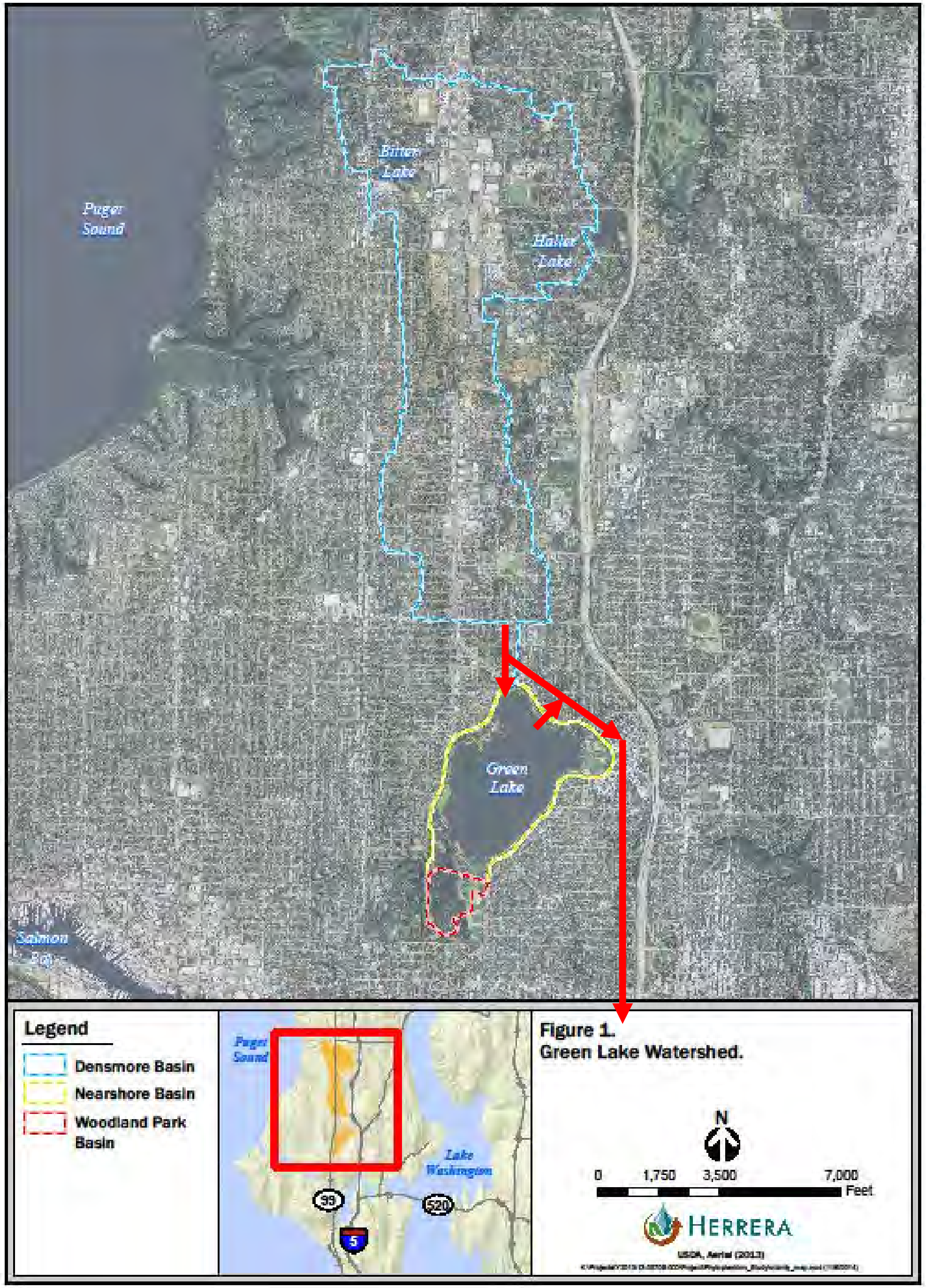

Figure 1.
Green Lake Watershed.

Lake Management History

Lake Management Actions Since 1990 Restoration Plan:

- Alum treatment (1991, 2004, 2016)
- Stormwater treatment (1991), diversion (1993), and source control (2004, 2009)
- Geese management (1987-2004)
- Dilution (reservoir cleaning only)
- Milfoil harvesting/grass carp (1992-2002)
- Monitoring and education (ongoing)

Water Quality Goals:

- Summer Secchi depth >2.5 meters (>8.2 feet)
- Summer total phosphorus <20 μg/L (reduced from 30 μg/L in 2003 and from 25 μg/L in 2016)
- No toxic bloom closures (added in 2016)

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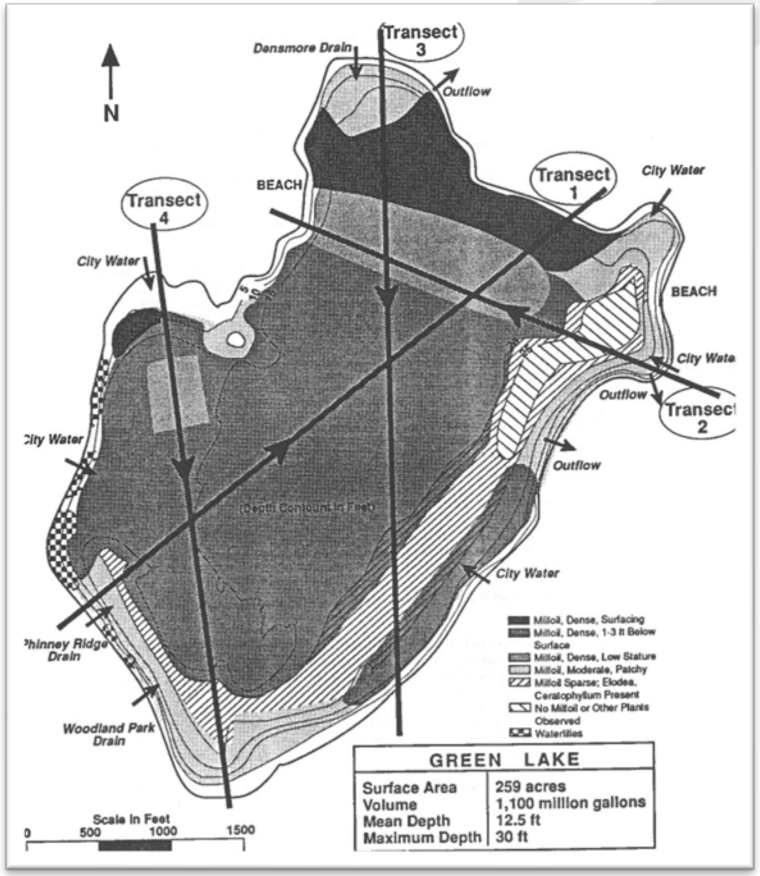
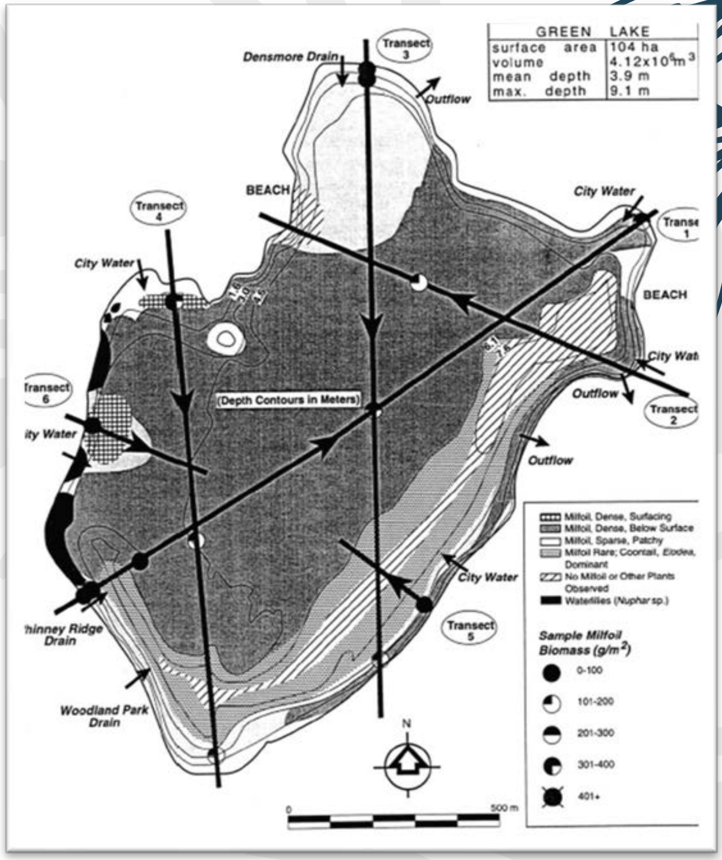
Milfoil Invasion

Period	Activity/Finding
1981	**Milfoil invaded lake, only minor amounts of native species present; bottom barriers at east beach in late 80s**
1991-1994	**Milfoil covered 75 – 90% of lake; native Elodea and coontail in east trough**

Year	Mean Milfoil Biomass (g/m^3)
1991 (Pre-Harvesting)	483
1992 (Post-Harvesting)	131
1993 (Post-Harvesting)	180
1994 (Post-Harvesting)	118



9/29/1992 Survey



9/14/1994 Survey

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Milfoil Harvesting

Period	Activity/Finding
1981	Milfoil invaded lake, only minor amounts of native species present; bottom barriers at east beach in late 80s
1991-1994	Milfoil covered 75 – 90% (210 acres) of lake; native Elodea and coontail in east trough
1992-2000	**Mechanical harvesting program (herbicides prohibited)**

Year	Milfoil Removed (tons)
1992 (Year 1)	1,200
1995 (Year 4)	30
1996-2000	<30

1995 Restoration Report Recommended:

- Prepare IAVMP for long-term management
- Bottom barriers at swimming beaches
- Consider Triclopyr treatment
- Stock grass carp to eradicate milfoil and allow natives upon their death

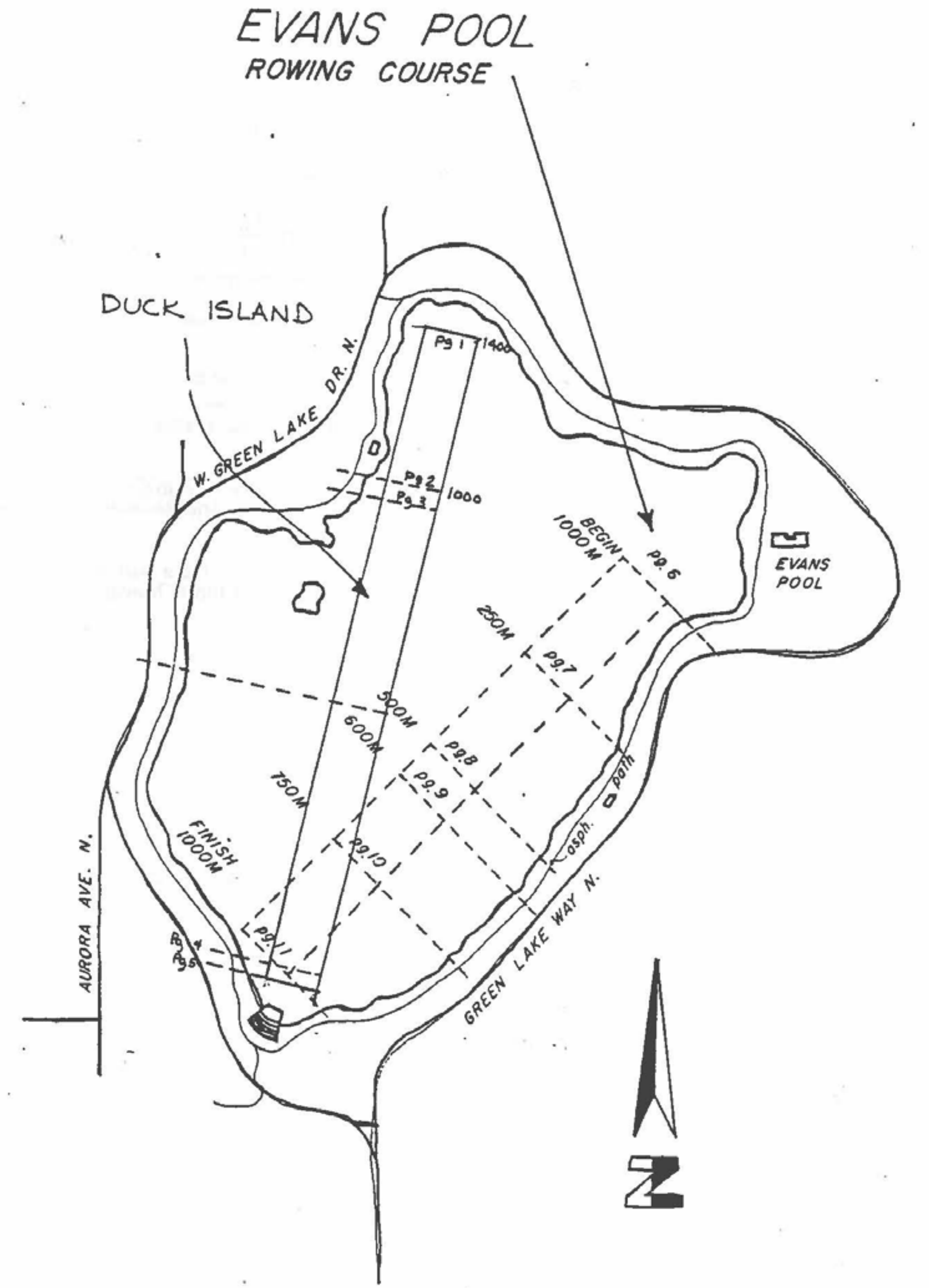

Figure 2. Green Lake showing established rowing courses.

Grass Carp Stocking

Period	Activity/Finding
1981	Milfoil invaded lake; only minor amounts of native species present; bottom barriers at east beach in late 80's
1991-1994	Milfoil covered 75 – 90% of lake; native Elodea and coontail in east trough
1992-2000	Mechanical harvesting program (herbicides prohibited)
2001	**Grass carp stocked**

- Grass carp stocking of 177 adults is low at 4/vegetated acre compared to 24/acre recommended by WDFW.
- Grass carp are sterile and live for 5-9 years on average and some over 20 years at up to 5 feet and 99 pounds.
- Grass carp prefer native plants over milfoil.
- Grass carp doubled in length within 4 years.

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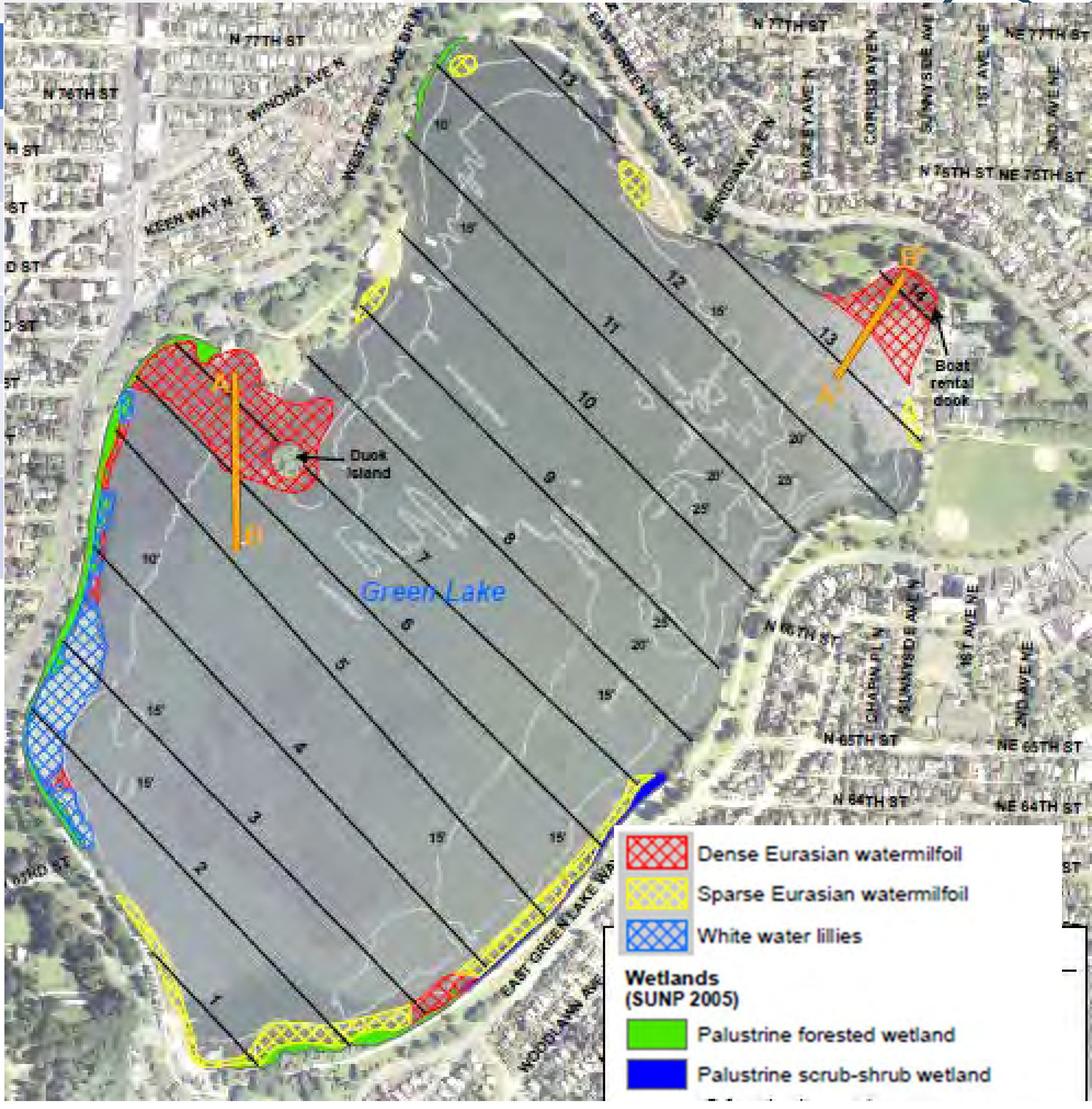
2005 Aquatic Plant Survey

Period	Activity/Finding
1981	Milfoil invaded lake, only minor amounts of native species present; bottom barriers at east beach in late 80s
1991-1994	Milfoil covered 75 – 90% (210 acres) of lake; native Elodea and coontail in east trough
1992-2000	Mechanical harvesting program (herbicides prohibited)
2001	Grass carp stocked (low amount of 177)
2005	**Milfoil covered only 4% (10 acres), minor diver handpulling west of Duck Island**

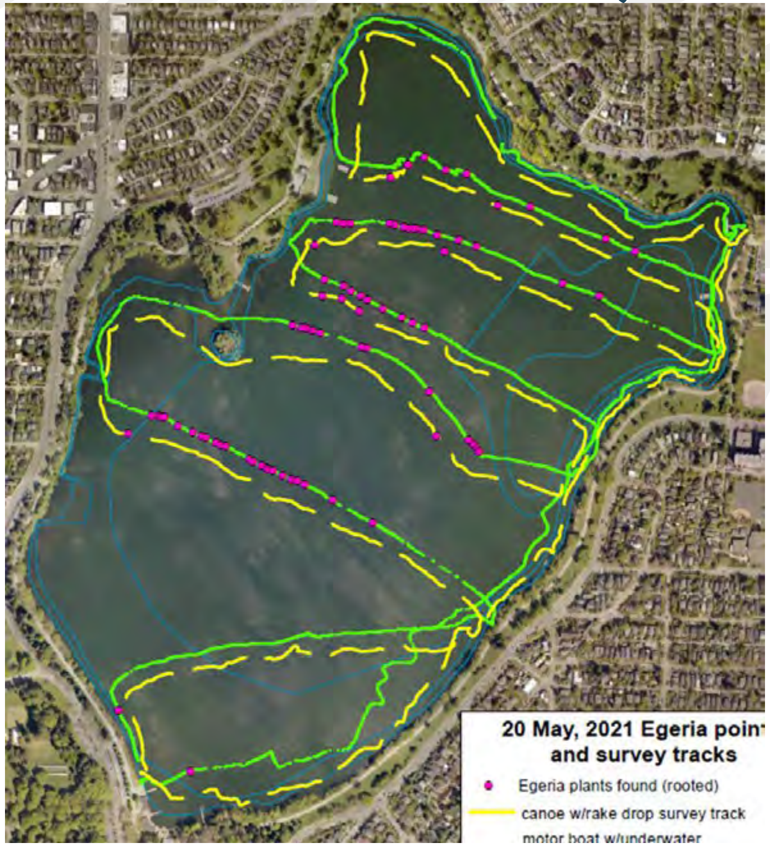
- Milfoil cover decreased 95% in 1991-2005 (210 to 10 acres).
- No change in fragrant waterlily cover.
- Low amounts of native species as in 1994.
- Emergent plants not mapped.
- Wetlands mapped by Seattle Urban Nature Project.



Egeria Discovery in 2020

Period	Activity/Finding
1981	Milfoil invaded lake, only minor amounts of native species present; bottom barriers at east beach in late 80s
1991-1994	Milfoil covered 75 – 90% (210 acres) of lake; native Elodea and coontail in east trough
1992-2000	Mechanical harvesting program (herbicides prohibited)
2001	Grass carp stocked (low amount of 177)
2005	Milfoil covered only 4% (10 acres), minor diver handpulling west of Duck Island
2020	**Egeria fragments on shore during November 2020 beach milfoil cleanup; qualitative survey in May 2021**

- Egeria (Brazilian elodea) fragments discovered during FOGL beach cleanup on 11/7/2020.
- Surveyed presence in lake on 5/20/21.
- Low growth and widespread throughout central north region.
- Class B weed required for control in Green Lake (not in Lake Washington).
- Too late for manual eradication by diver handpulling.



2022 Aquatic Plant Survey and IAVMP

Period	Activity/Finding
1981	Milfoil invaded lake, only minor amounts of native species present; bottom barriers at east beach in late 80s
1991-1994	Milfoil covered 75 – 90% (210 acres) of lake; native Elodea and coontail in east trough
1991-2000	Mechanical harvesting program (herbicides prohibited)
2001	Grass carp stocked (low amount of 177)
2005	Milfoil covered only 4% (10 acres), minor diver handpulling west of Duck Island
2020	Egeria fragments on shore during November 2020 beach milfoil cleanup; qualitative survey in May 2021
2022	**Milfoil covered 26% (69 acres) and Egeria covered 20% (52 acres)**
2024	**Parks to prepare Integrated Aquatic Vegetation Management Plan**

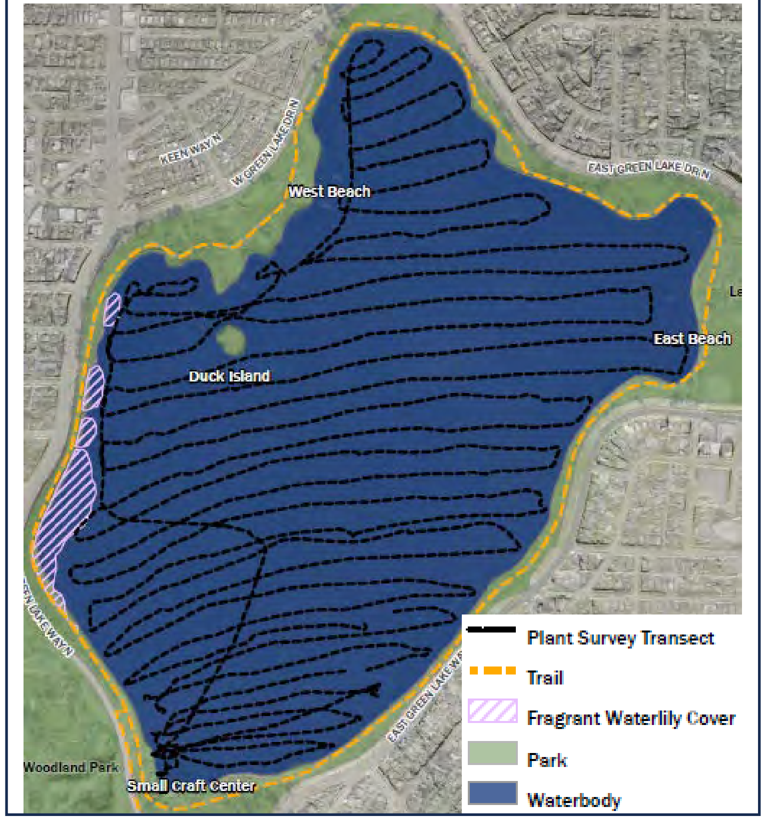
2022 Aquatic Plant Survey

2022 Survey Method

Sonar transects <100 feet apart on 9/7/22

26 composition samples (3 species)

Lilies mapped by Google on 7/31/22



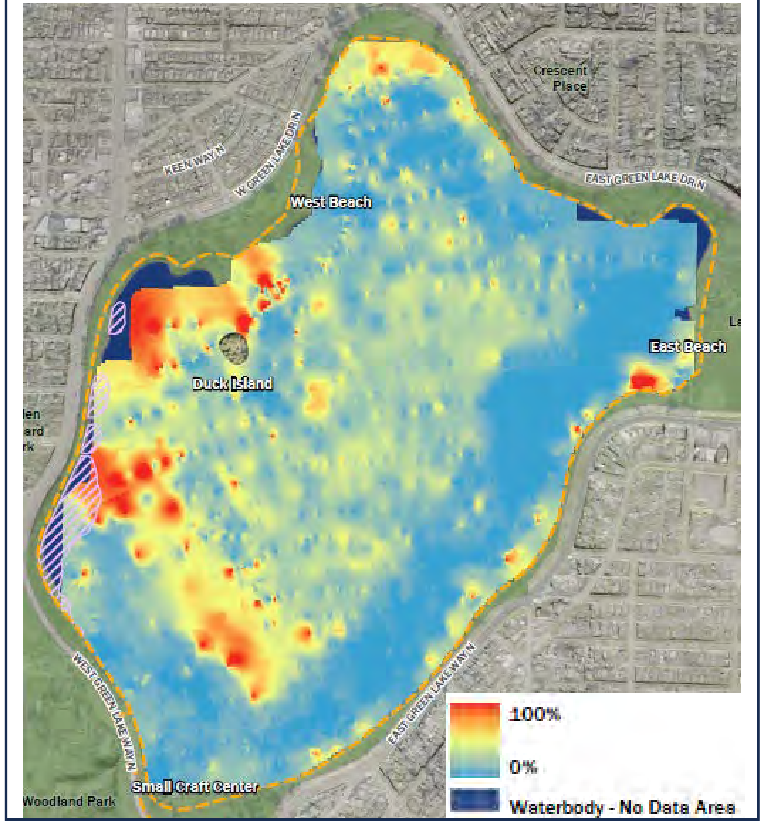
2022 Plant Biovolume

0% Blue

50% Yellow

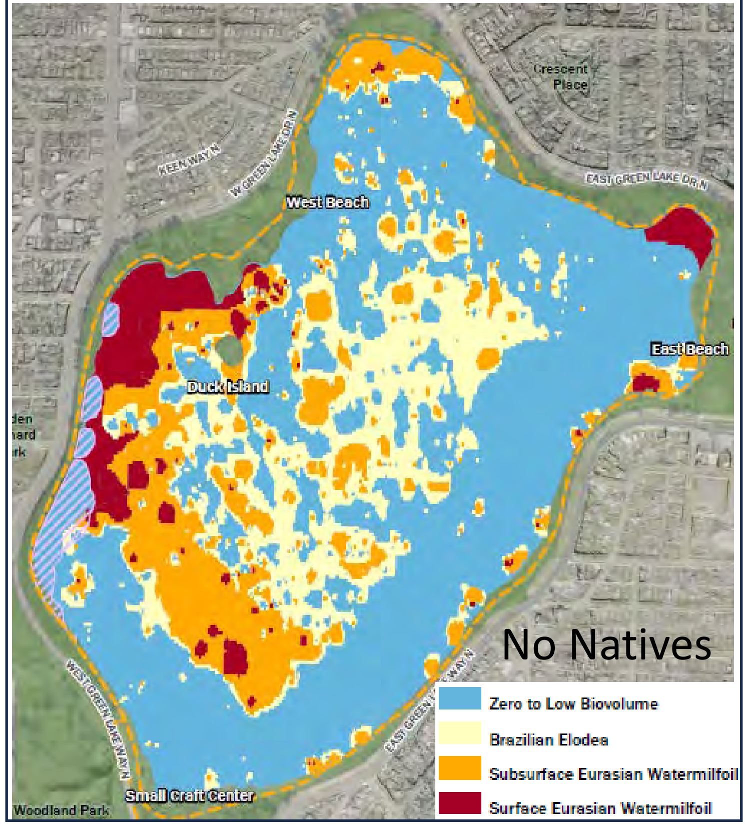
75% Orange

100% Red



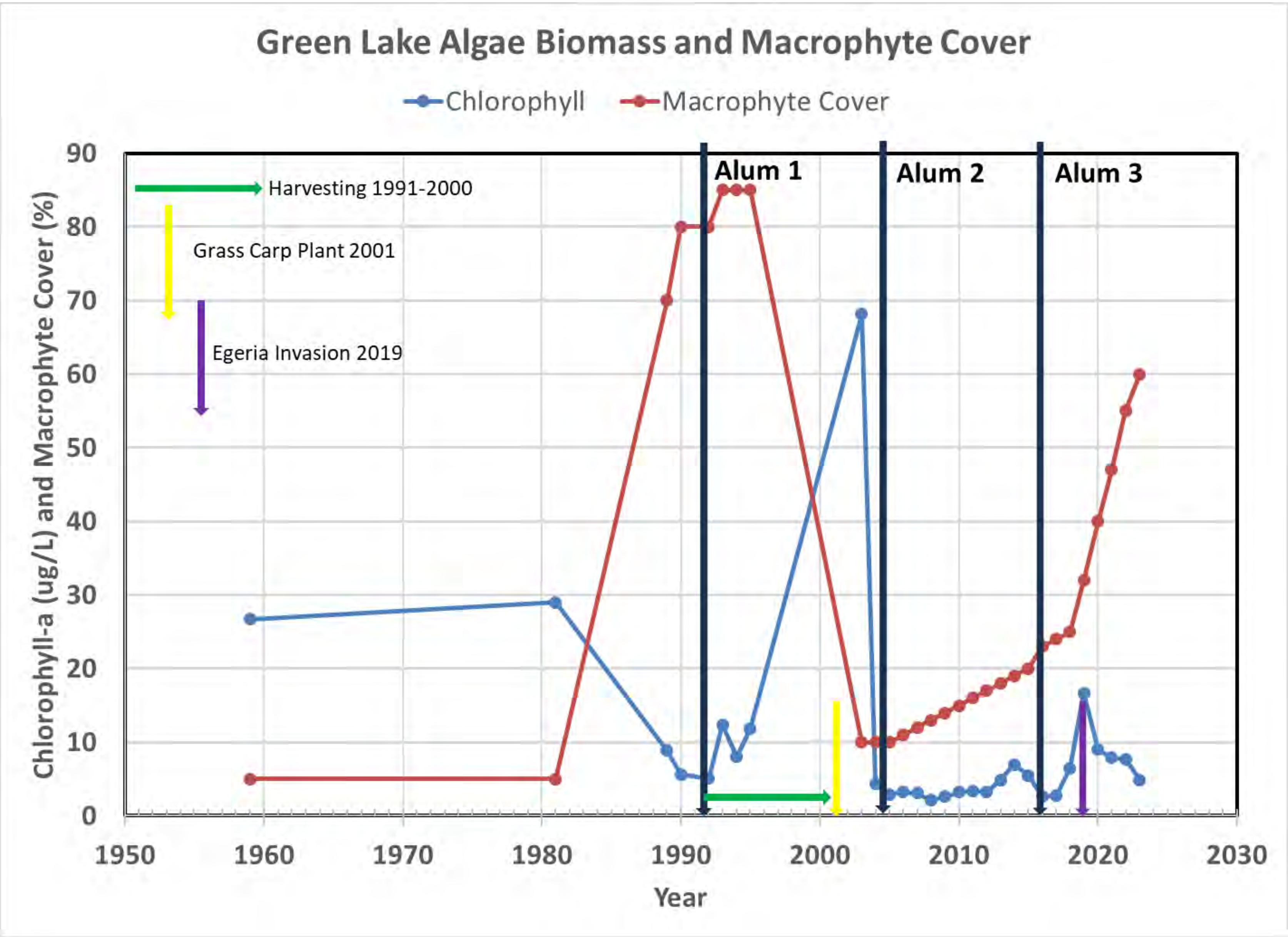
2022 Plant Cover

Plant	Acres	Percent
Surface Milfoil (red)	19	7%
Subsurface Milfoil (orange)	50	19%
Egeria (yellow)	52	20%
Waterlily (hatching)	5	2%
Low to No Plants	131	51%



Algae-Aquatic Plant Alternative Stable State

- Pre-treat Period:
  Milfoil expansion and algae decline 1981-1991
- Alum 1 Period:
  Milfoil crash and algae bloom 2001-2003
- Alum 2 Period:
  Slow Milfoil expansion and low algae 2004-2018
- Alum 3 Period:
  Rapid Egeria expansion and slight algae decline 2019-2023

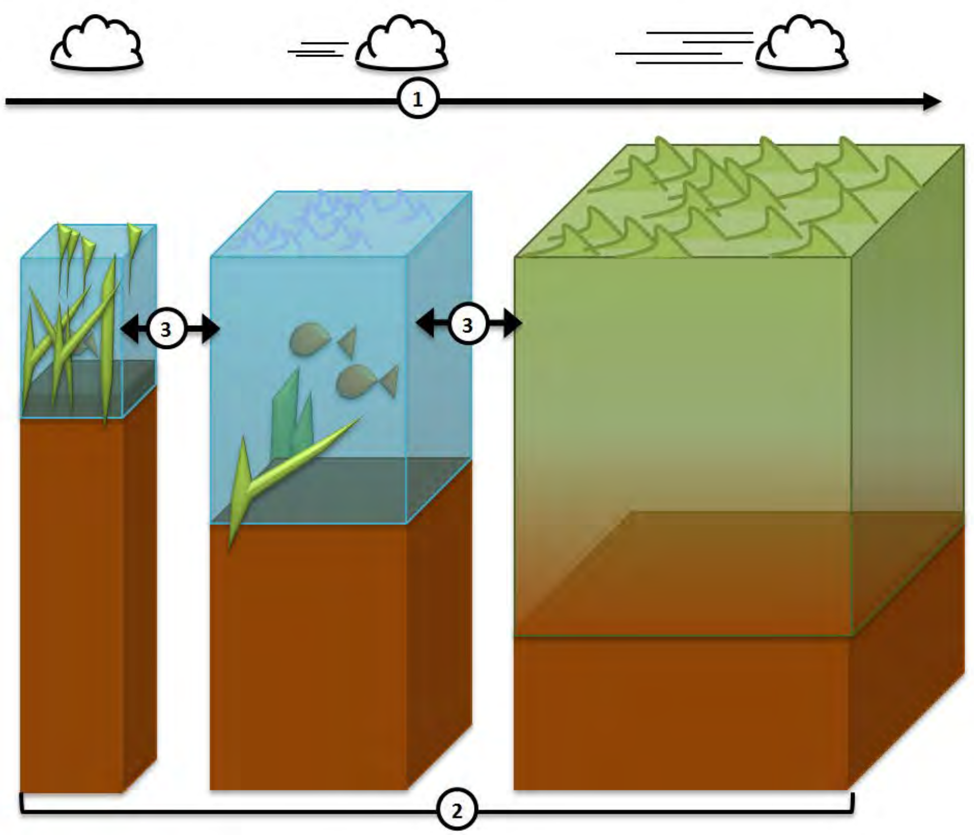


Alternative Stable State: ---------------- Algae ------------|-----Plant-----|--------Algae-------|-Plant

Data Analysis Conclusions

Aquatic Plants:

- Egeria and Milfoil may reduce algae growth and internal phosphorus loading, creating stable state conditions without native plants.
- Currently, only Milfoil surfacing near shore impacts recreation and fish habitat.
- Uncontrolled, Egeria and Milfoil growth will severely impact recreation and fish habitat.



Alternative Stable States in a Shallow Lake

Aquatic Plant Management Options

Table 6. Potential Aquatic Plant Management Methods for Green Lake.			
Alternative	**Milfoil**	**Egeria**	**Waterlily**
No action	+		+
Diver hand-pulling	(+)	(+)	
Diver dredging	+	+	
Mechanical harvesting	+		+
Bottom barrier	+		+
Herbicides			
ProcellaCOR	+		
Fluridone	+	+	
Diquat	(+)	+	
Triclopyr TEA	(+)		
2, 4-D amine	+		
Imazapyr			+
Glyphosate			+
Grass carp	(+)	(+)	

+–Feasible management alternative

(+) Possible but least preferred management alternative

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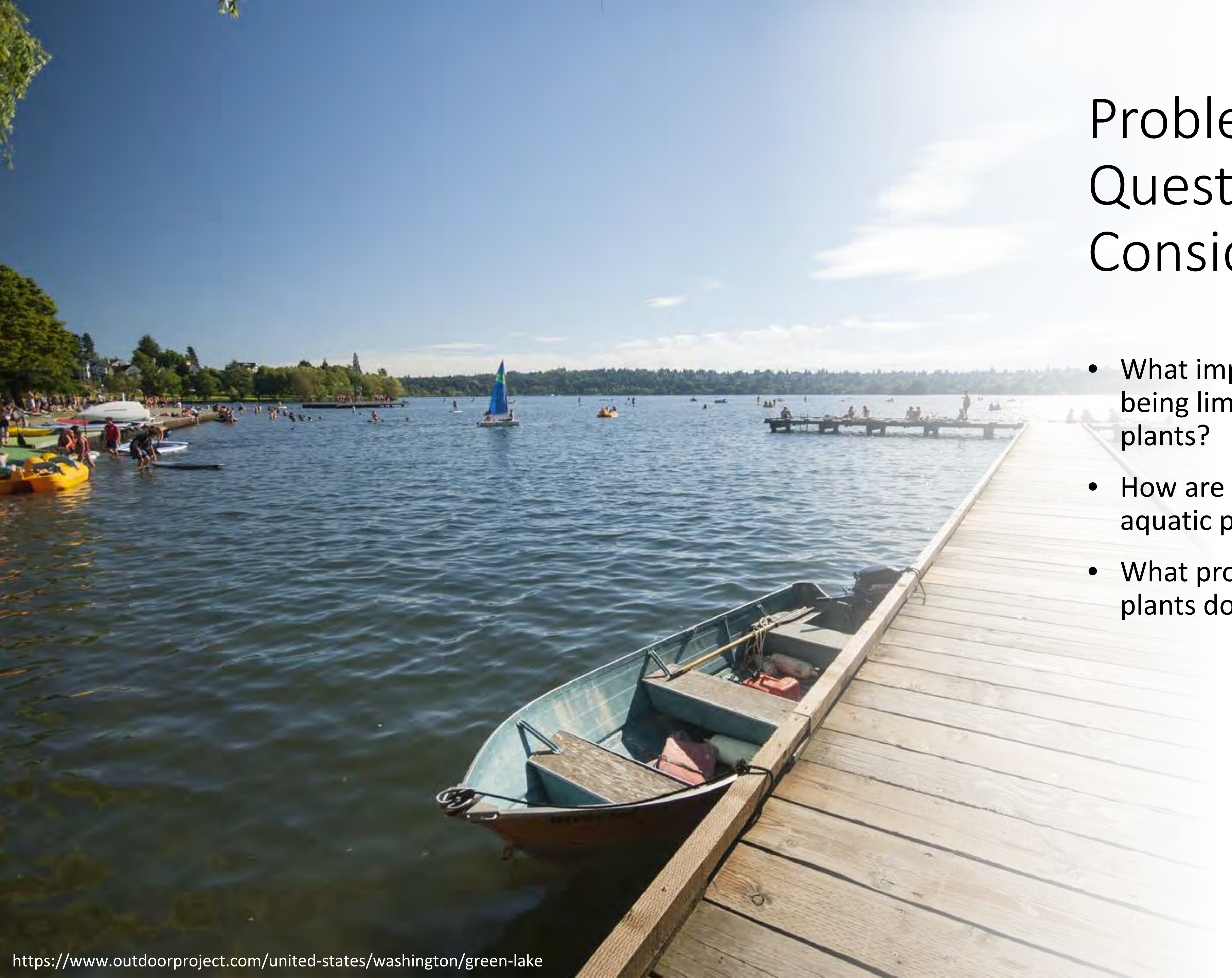
Discussion

Problem Statement: Questions to Consider

- What important water body uses are being limited because of aquatic plants?
- How are these uses being limited by aquatic plants?
- What problems resulting from aquatic plants do we anticipate in the future?



https://www.outdoorproject.com/united-states/washington/green-lake

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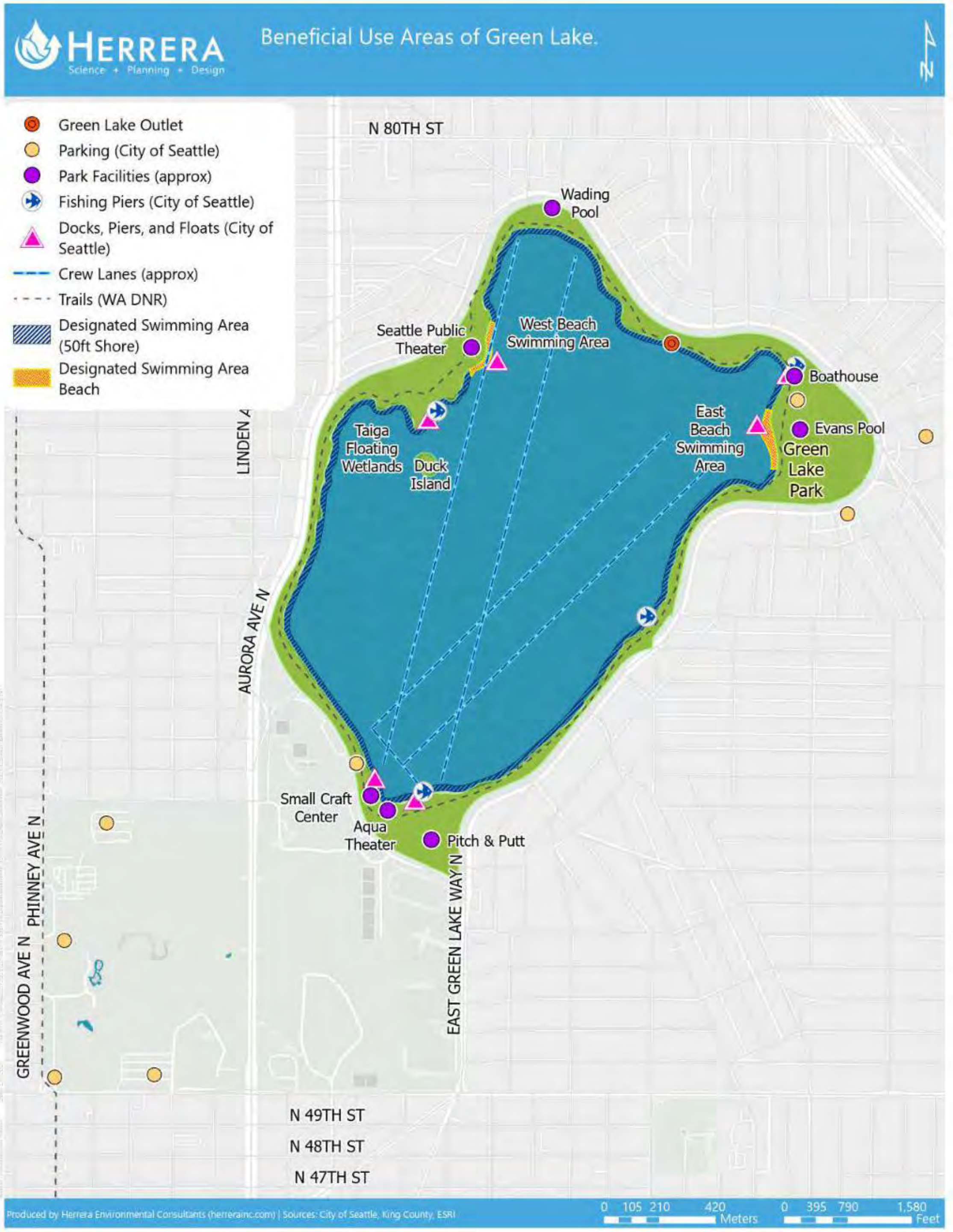
Draft Problem Statement

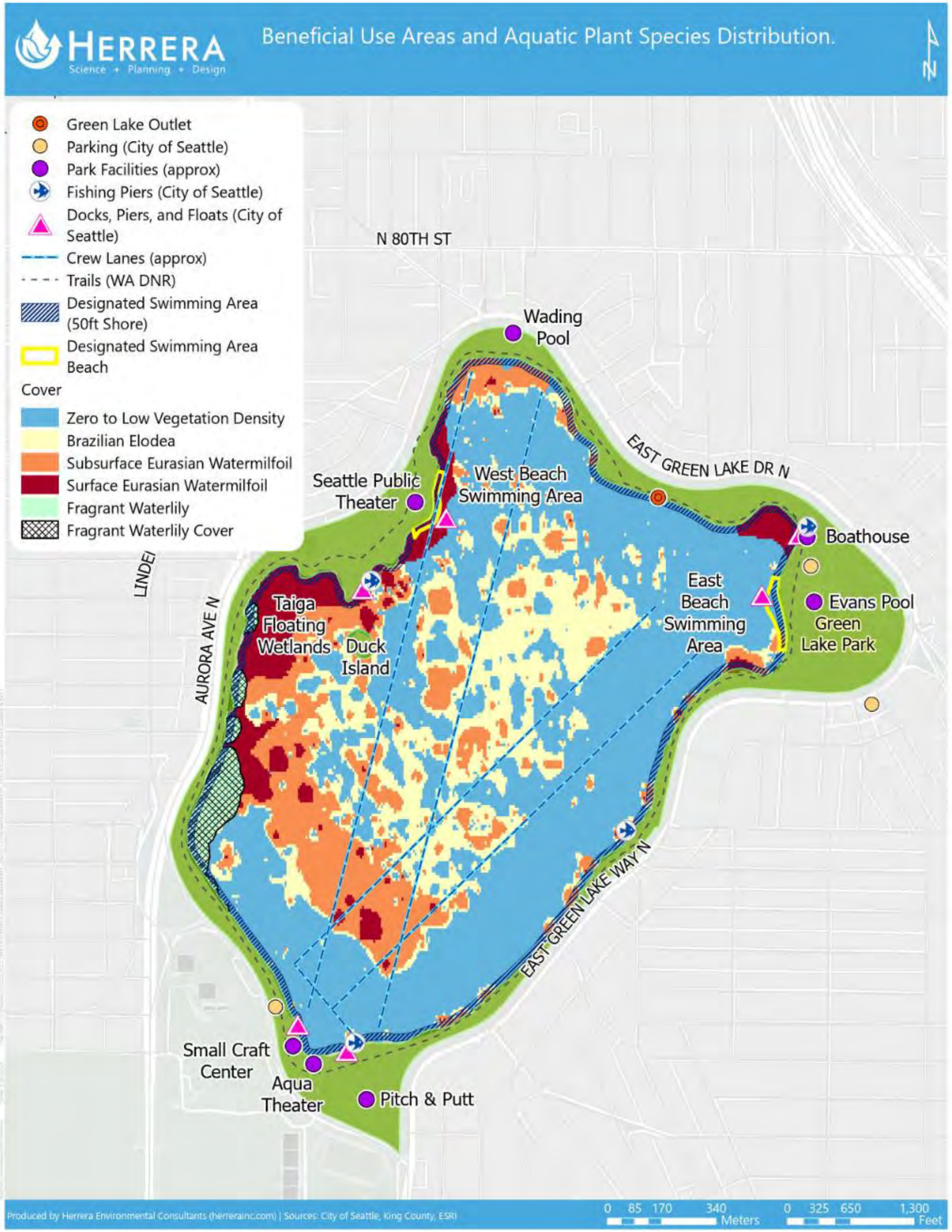
- Dense growth of invasive aquatic plants interferes with recreational uses in some areas of Green Lake during the summer. Beneficial uses are primarily impacted by the Eurasian watermilfoil, Brazilian elodea, and fragrant waterlily. The cover of invasive plants is rapidly increasing over time. There are no native plants to support wildlife and habitat within the lake.

Beneficial Use Areas

- Recreational use
  - Boating
    - Crew
    - Rentals
    - Hand carried (kayaks, SUPs)
  - Fishing
    - Piers
    - Shoreline
  - Swimming
    - Beaches
    - Open water
  - Aesthetic and wildlife observation
    - Duck Island Wildlife Refuge, Taiga Wetlands
    - Shoreline
    - Green Lake Trail
- Wildlife use
  - Waterfowl and other birds
  - Fish and other aquatic organisms



Beneficial Use Areas and Aquatic Plant Species Distribution



Plant Management Goals

- Control versus Eradication
  - Eurasian watermilfoil
  - Brazilian elodea
  - Fragrant waterlily
  - Other noxious weeds

https://greatruns.com/seattle-green-lake/

Plant Management Goals

- Control versus Eradication

- **Control areas**
    - Swimming beaches
    - Crew lanes

Plant Management Goals

- Control versus Eradication
- Control areas
- **Conservation areas and native planting**
    - Shoreline conservation areas (west and east)

Plant Management Goals

- Control versus Eradication
- Control areas
- Conservation areas and native planting
- **Use of chemicals**

Plant Management Goals

- Control versus Eradication
- Control areas
    - Swimming beaches
    - Crew lanes
- Conservation areas
- Use of chemicals
- **Cost and funding**

Next Steps and Schedule

Activity	Start Date	End Date
Preliminary Draft IAVMP	3/27/2024	6/30/2024
Draft IAVMP	7/27/2024	8/25/2024
Final IAVMP	9/15/2024	10/20/2024
Steering Committee Meeting 1 - Project Kickoff	1/25/2024	1/29/2024
Steering Committee Meeting 2 – Control Strategies	3/20/2024	3/24/2024
Public Meeting 1 – Project Goals and Control Strategies	4/17/2024	4/28/2024
Steering Committee Meeting 3 – Preliminary Draft IAVMP	7/23/2024	7/27/2024
Public Meeting 2 – Draft IAVMP	9/12/2024	9/15/2024

Questions?

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Rob Zisette
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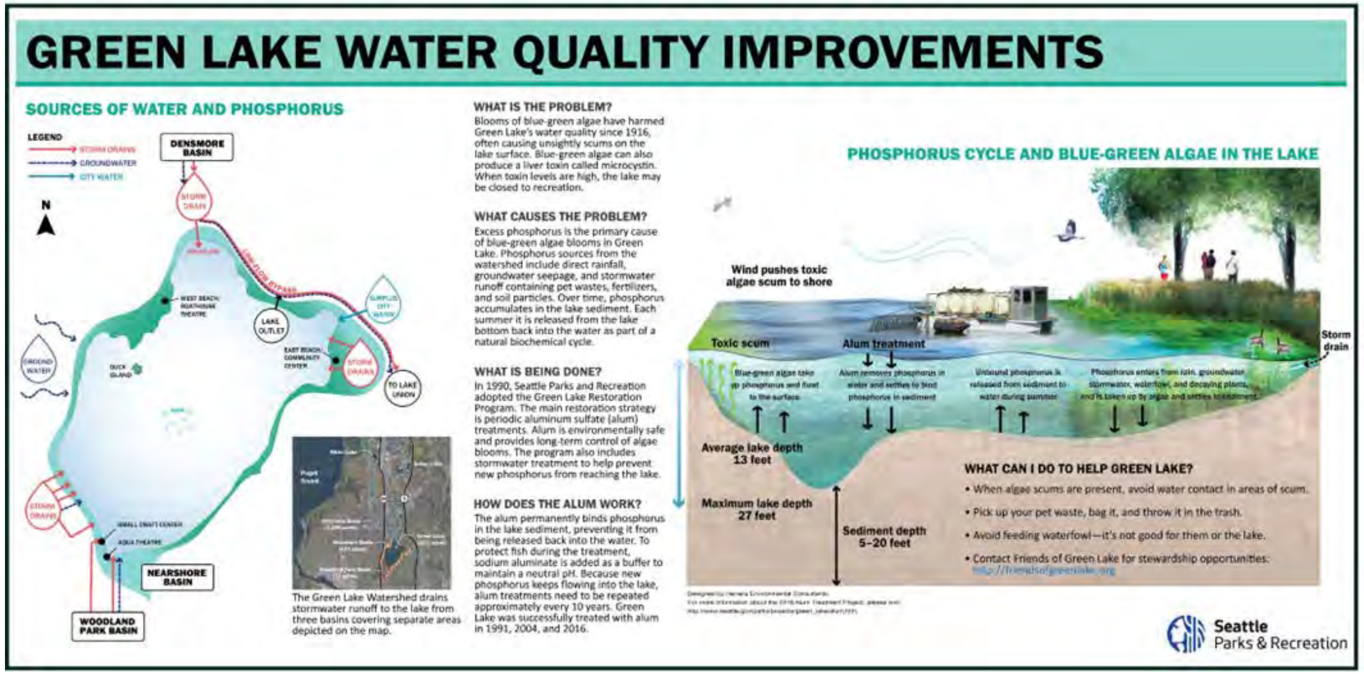

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Invasive Plant Management Recommendations

Prepare IAVMP for invasive plant control, not eradication

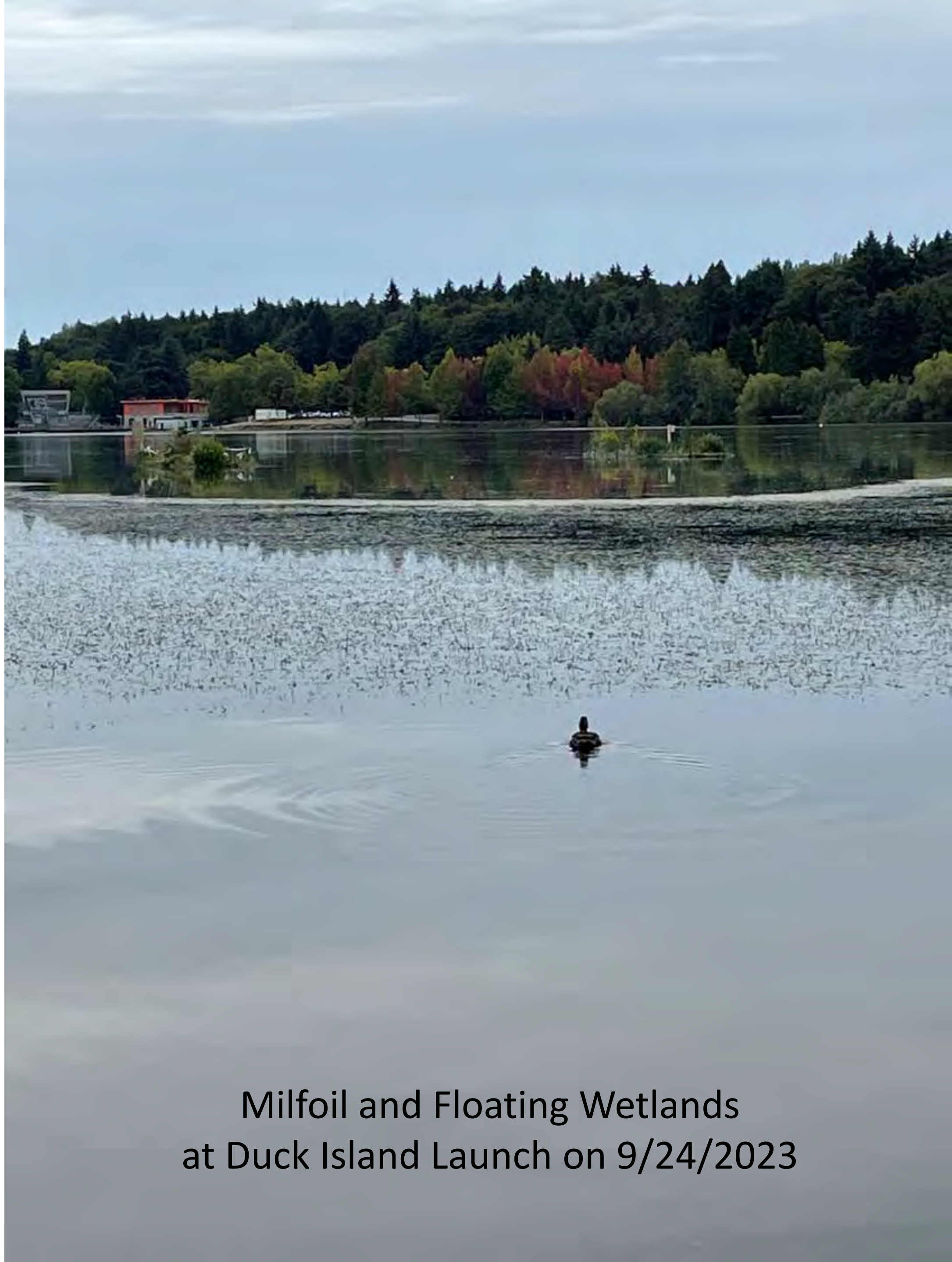
Engage the public early to evaluate impacts and control options

Physical controls are not practical

Fluoridone (Sonar) is cost-effective for Egeria and Milfoil, and suitable for lake conditions

Consider first treating milfoil with ProcellaCOR and then Egeria when it reaches water surface.

Consider planting native species for habitat and reduced algae blooms.



Milfoil and Floating Wetlands
at Duck Island Launch on 9/24/2023

Algae Bloom Management Recommendations

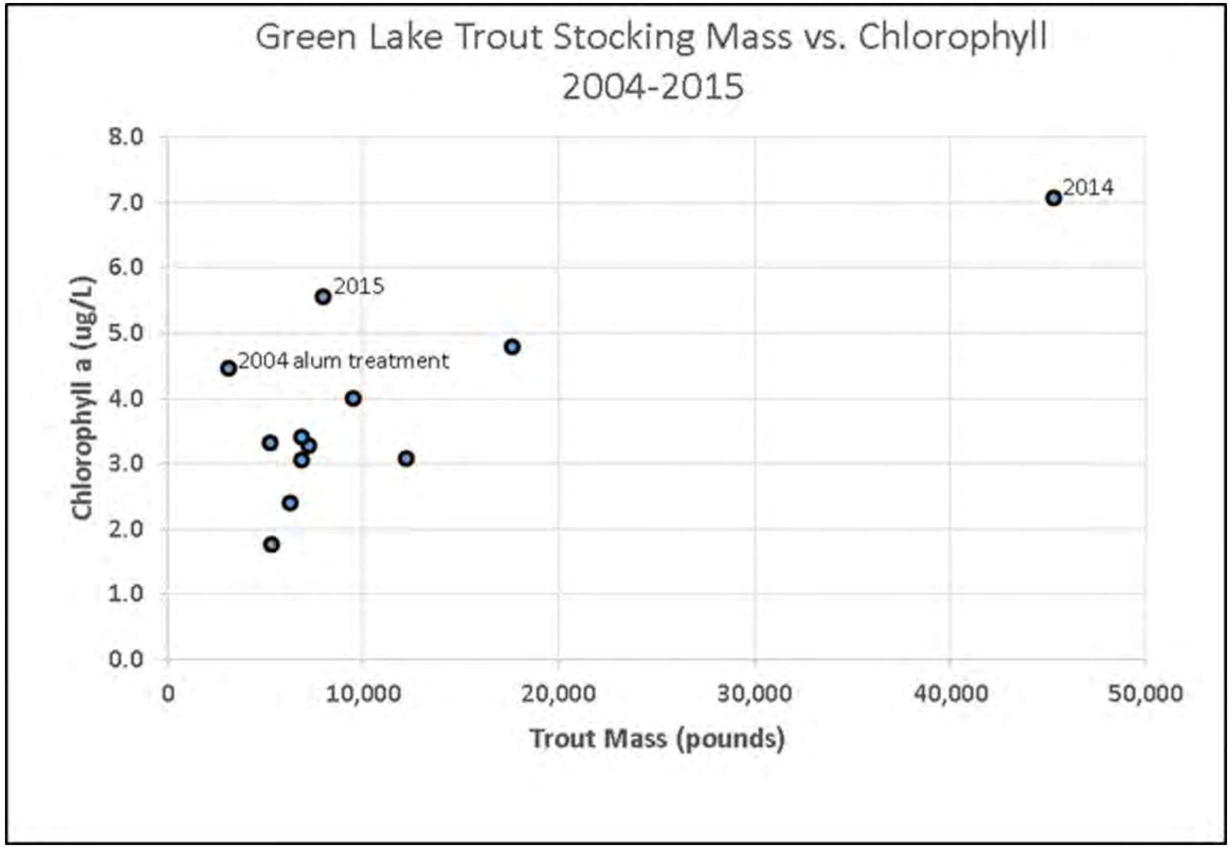
- Plan for Alum 4 following invasive plant treatment
- Develop water and phosphorus budgets to assess other algae bloom management options
- Regularly analyze phytoplankton species composition
- Develop lake-specific toxic bloom closure protocols to account for temporal small scums and reduce user impacts
- Install permanent education signs (When in Doubt, Stay Out!) with ability to add Warning or Danger signs as needed

Toxic Algae Sign at Duck Island Launch 8/14/2023

Fish Management History

Fish Management Actions:

- Sterile tiger muskie plant (2000)
- Sterile grass carp plant (2001: low rate)
- Fish surveys (2001-2003: 75% common carp)
- Common carp removal experiments (2004-2005)
- Carp bioturbation modeling
- Catchable trout stocking every spring
- Algae biomass increased with trout plant biomass in 2004-2015



Aquatic Plant Control Techniques: Physical/Manual

Technique	Advantages*	Disadvantages
Bottom barriers	• long-term treatment	• Expensive for large treatment area
Hand pulling by divers	• applicable to all weed species	• Expensive for large treatment area • Takes significant time to implement in the field (several weeks) • Not a viable long-term solution
Suction dredging by divers	• applicable to all weed species • Faster and less expensive than hand pulling	• Expensive for large treatment area
Mechanical harvesting	• applicable to all weed species	• Short window of effectiveness because roots and shoots are left intact

*All these techniques have the benefit of avoiding or reducing herbicide use

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Aquatic Plant Control Techniques: Chemical

Herbicide	Advantages	Disadvantages
ProcellaCOR	• Systemic, selective herbicide with no human exposure restrictions	• Of the plants present on GL, only treats watermilfoil
Glyphosate	• Systemic, non-selective herbicide that can be used on floating-leaved plants (fragrant waterlily)	• Does not treat submersed aquatic plants • Plants can take several weeks to die and repeat application is often necessary
Triclopyr	• Fast-acting, systemic, selective herbicide commonly used to control Eurasian watermilfoil	• 12-hour swimming restriction for eye irritation
Diquat	• Fast-acting, non-selective contact herbicide that destroys vegetative plant matter but not the roots	• Short-term (one season) control • Turbid water or dense algal blooms can interfere with effectiveness
Imazapyr	• Systemic, broad spectrum herbicide that can be used on floating-leaved plants (fragrant waterlily)	• Does not treat submersed plants • Plants can take several weeks to die and repeat application can be necessary

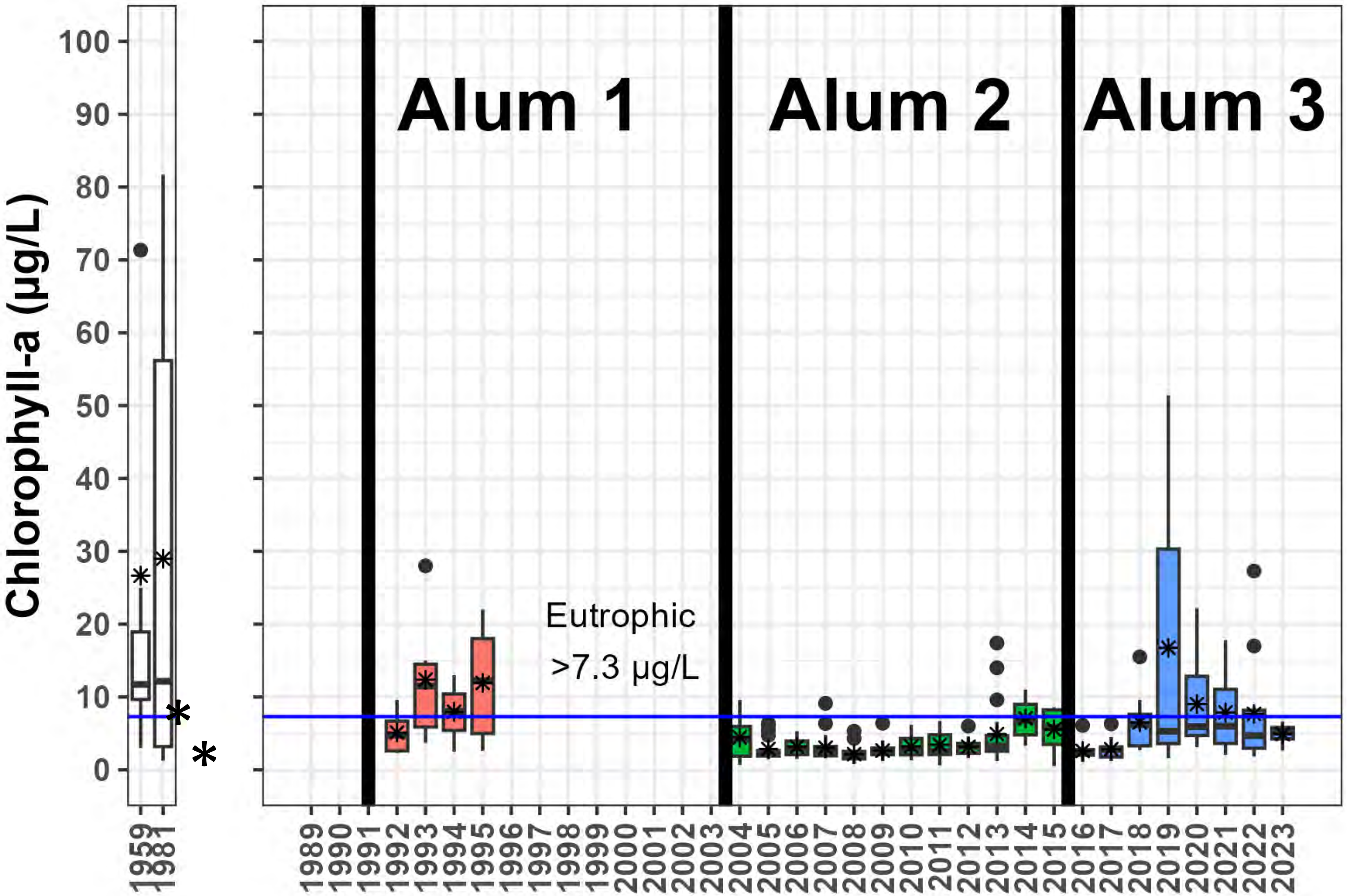
Algae Biomass

Chlorophyll-a

- No chlorophyll goal established in 1990 Restoration Plan (goals for total phosphorus and Secchi depth)

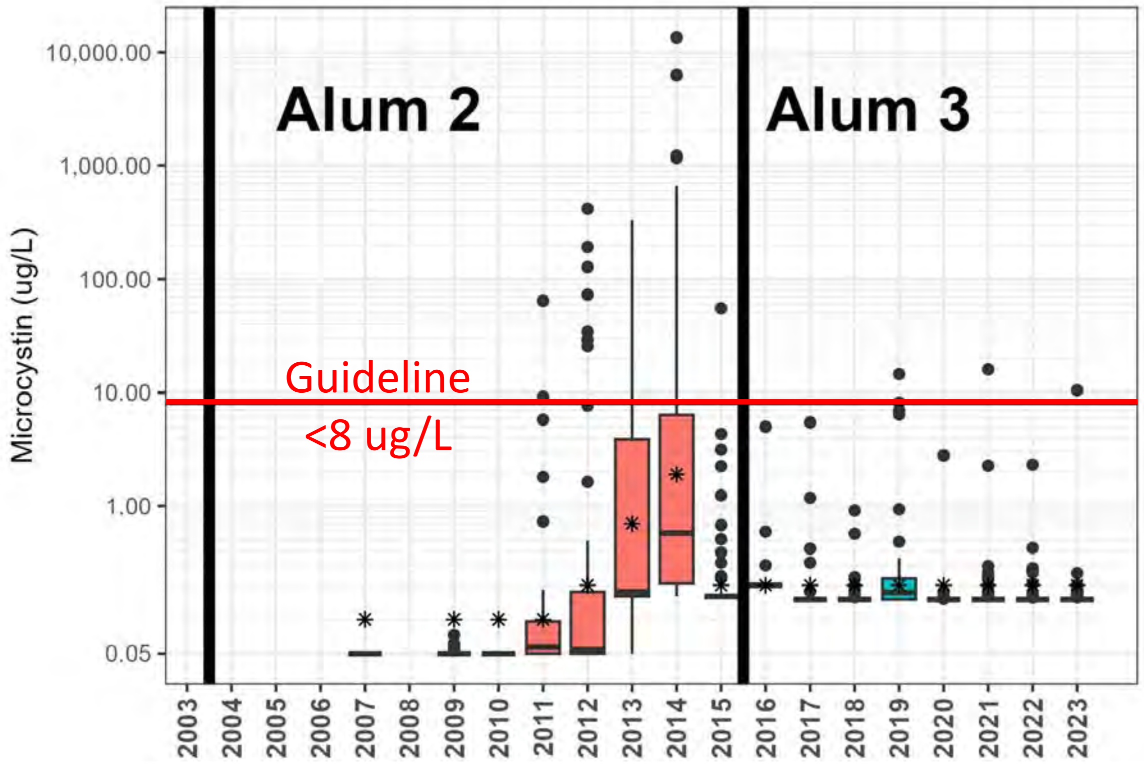
- Exceeded eutrophic threshold (7.3 ug/L summer mean):
  - Before and 2 years after Alum 1 in 1991
  - Not after Alum 2 in 2004
  - 3 years after Alum 3 in 2016

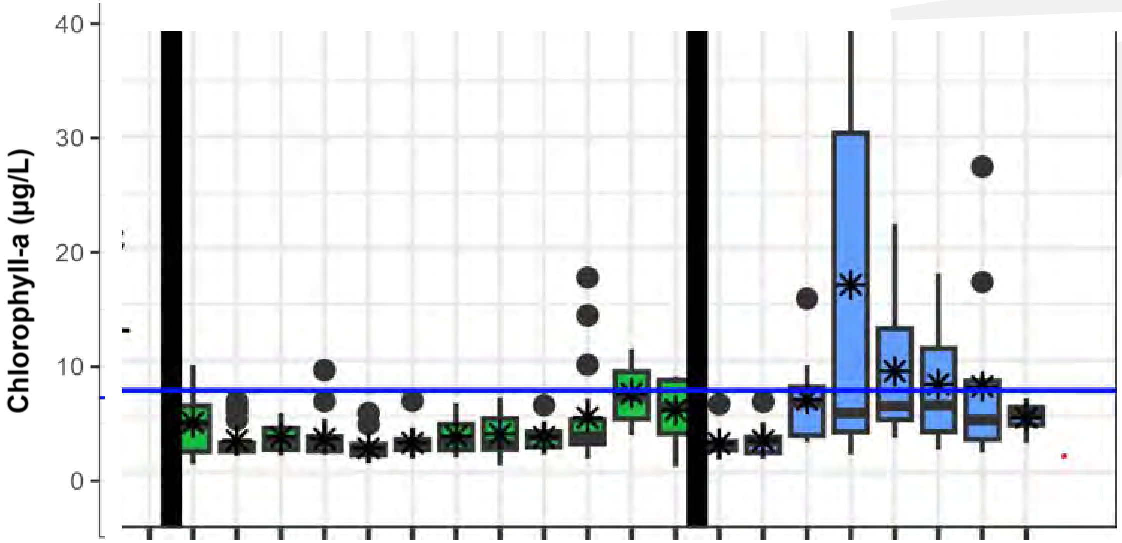
- Recent decline since peak in 2019 (2023 incomplete)



Toxic Cyanobacteria

- Cyanobacteria (blue-green algae) produce cyanotoxins measured since 2007 and used to close lake recreation to protect dogs and humans from ingesting cyanotoxins.
- Microcystin samples exceeded state guideline (8 µg/L) in 2011 and increased frequency until Alum 2 treatment in 2016 (other toxins not detected).
- Microcystin guideline exceeded at low frequency after Alum 3 treatment in 2016 (once in 2019 and 2021, and twice in 2023).
- Microcystin does not positively relate to algae biomass because cyanobacteria proportion and toxin production is highly variable and unpredictable.





Green Lake Integrated Aquatic Vegetation Management Plan

Stakeholder Meeting #2

April 16, 2024

Kevin Bergsrud, Seattle Parks and Recreation

Rob Zisette and Eliza Spear, Herrera Environmental Consultants

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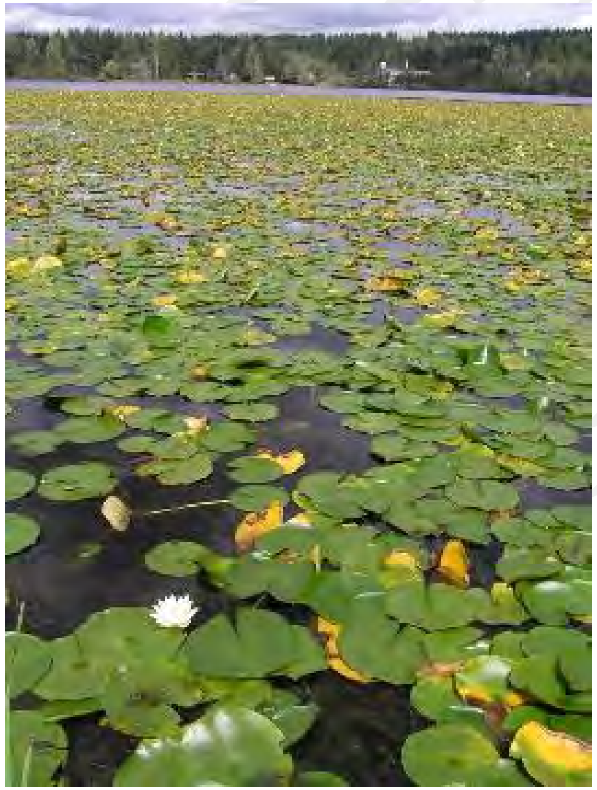
Presentation Objectives and Agenda

- Introductions and Recap
- Problem Statement and Goals for Aquatic Plant Control
- Control Strategies and Scenarios

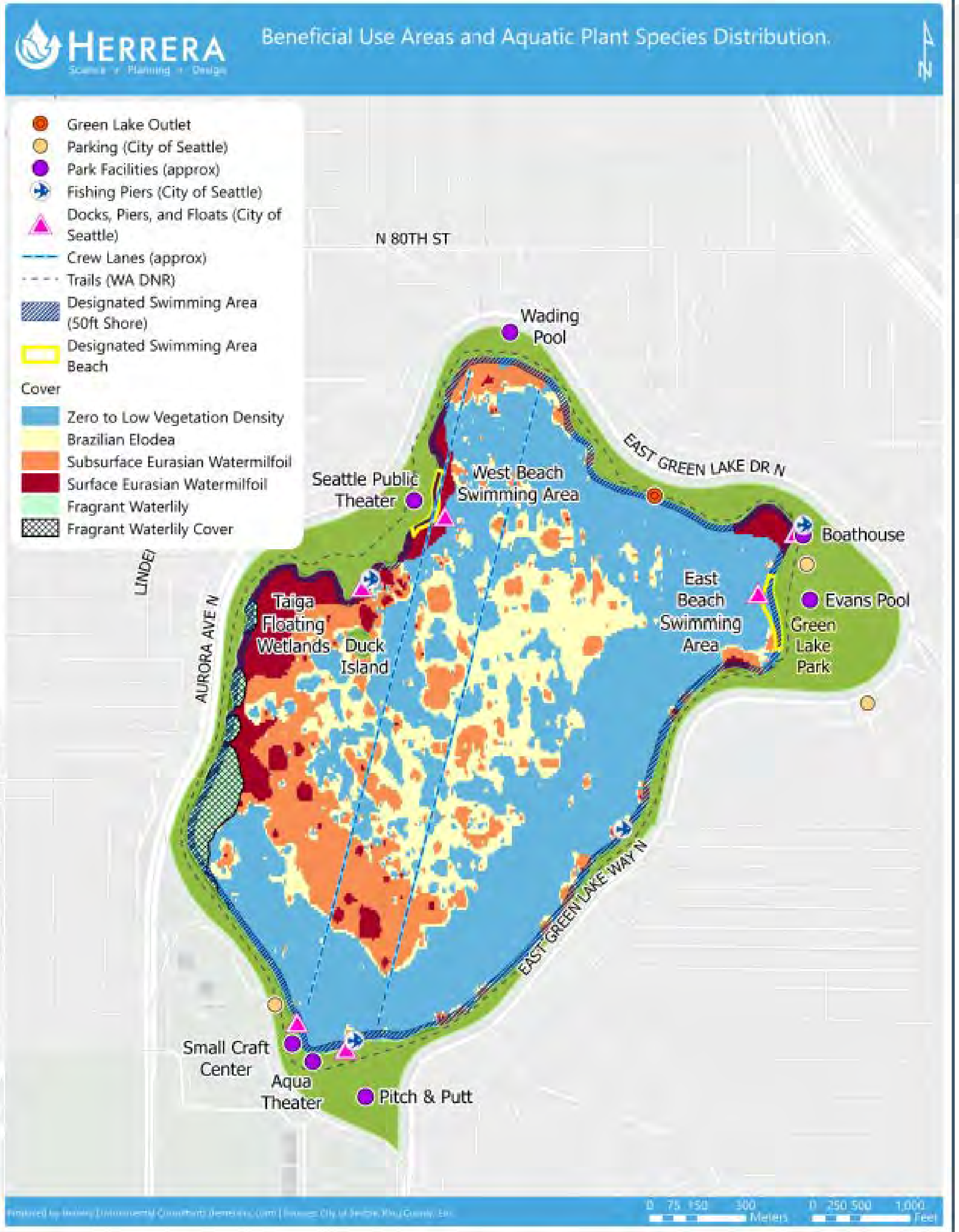
Problem Statement

Dense growth of invasive aquatic plants interferes with recreational uses in some areas of Green Lake during the summer. Beneficial uses are primarily impacted by the Eurasian watermilfoil, Brazilian elodea, and fragrant waterlily. The cover of invasive plants is rapidly increasing over time. There are no native plants to support wildlife and habitat within the lake.



Plant Management Goals

- Control of regulated noxious weeds and dominant weed species
- Reduce impacts to beneficial uses including swimming, crew, and paddlers
- Maintain a healthy environment for fish and other wildlife



Beneficial Use Areas and Aquatic Species Distribution

Aquatic Plant Management Tools

Alternative	Milfoil	Egeria	Waterlily
No Action			
Diver hand-pulling			
Diver dredging			
Mechanical harvesting			
Bottom barrier			
ProcellaCOR			
Fluridone			
Diquat			
Imazapyr			
Glyphosate			

Table Key		
Feasible	Possible, but least preferred	Not feasible

Control Scenarios

Control Scenarios

Control Scenarios	
A. Lake-wide Control with Fluridone	Treat entire lake in Year 1 for milfoil and Egeria control
B. Targeted Herbicide Applications	Successively treat noxious weeds in three years
B1. Treat Milfoil with ProcellaCOR	Treat dense milfoil stands in Year 1, follow up as needed
B2-A. Spot treat Egeria with Diquat	Treat Egeria as needed
B2-B. Spot treat Egeria and milfoil with Fluridone	Treat Egeria as needed
B3. Treat Water Lilies with Glyphosate or Imazapyr	Treat water lilies as needed
C. Physical Control	
C1. Harvesting	Implement a regular harvesting program in June, July, and August of each year
C2. Diver Dredging	Implement a regular diver dredging program in June and August of each year
D. Native Plantings	Option in all scenarios, optimal with Scenario A

Control Scenario A: Complete Control with Fluridone

Fluridone	
Advantages	Disadvantages
• Single treatment • Eliminates current issues with aquatic plants • Lessons the burden over time, avoids repeated need for widespread treatments and transitions to focus on monitoring and control as species re-populate • Creates opportunities to plant native aquatic species without immediate competition • No fishing/swimming restrictions	• Eliminates entire plant population, no selectivity • Risk of algal bloom being fueled by plant die-off, need for alum treatment • High need for public engagement to avoid negative impression of temporarily barren lake • Potential impact to FTWs, need to mitigate for this risk • Habitat loss for fish, insects, amphibians • Expensive up-front cost

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Control Scenario B: Separate Herbicide Applications

Separate Herbicide Applications - General	
Advantages	Disadvantages
• More selectivity than complete fluridone treatment • Accomplishes plant management in high priority areas • Leaves plants intact in areas without beneficial use impacts, providing habitat for fish and wildlife • Fewer water quality impacts	• Need for ongoing and repeated treatment efforts over several years • Less widespread control • Less optimal for native plant revegetation

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Control Scenario B1: Eurasian watermilfoil
(*Myriophyllum spicatum*)

- Species with the highest impact on beneficial uses in current conditions
- Chemical treatment method: ProcellaCOR
  - ProcellaCOR is highly selective and will only kill Eurasian watermilfoil
  - It does not have any required swimming or fishing restrictions
  - With effective treatment, ProcellaCOR can reduce the population of Eurasian watermilfoil to a point where follow up with manual control methods may be feasible and more cost-effective than in current conditions
  - Expensive, one-time cost

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Control Scenario B2-A: Egeria (*Egeria densa*)

Diquat Spot Treatment	
Advantages	Disadvantages
• Fast acting • Also impacts Eurasian watermilfoil, but not as effective on EUWA as other options	• 24-hour swimming advisory • Turbid water and dense algal blooms can interfere with effectiveness • Vegetative control only, requires repeated treatments • Not selective

Control Scenario B2-B: Egeria and Milfoil

Fluridone Spot Treatment	
Advantages	Disadvantages
• No swimming or fishing restrictions • Systemic herbicide (as opposed to Diquat) • Would also treat watermilfoil	• Not selective • Expensive • Would not be effective in shallow areas

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Control Scenario B3: Fragrant waterlily

(*Nymphaea odorata*)

Glyphosate or Imazapyr	
Advantages	Disadvantages
• No swimming/fishing restrictions • Control growth of patch along western shoreline while leaving some areas intact to provide habitat	• Multiple applications often required and die-off can occur slowly • Floating root mats possible, but can control this with extent of treatment area • Not selective but can be controlled with skilled application.

Target Species	Herbicide	Advantages	Disadvantages	Approx. Cost/Acre	Treatment Area (acres)	Total Cost	Repetition Anticipated in Short Term?
All species	Fluridone (complete)	Single treatment period	Complete impact to GL, potential WQ, habitat impacts; cost	N/A	257	$306,250	No
	Fluridone (spot)	Single treatment period, less WQ, habitat impacts	Cost	N/A	Crew lanes	$150,000	No
Eurasian watermilfoil	ProcellaCOR	Systemic, selective herbicide, no human exposure restrictions	Only treats watermilfoil, cost	$1,200-$1,300	69	$82,800-$89,700	No
Fragrant waterlily	Glyphosate	Systemic, non-selective herbicide	Plants can take several weeks to die and repeat application is often necessary	$350	5 acres total, proposing to treat 2.5 acres	$875	Yes, depending on extent of control targeted
	Imazapyr	Systemic, broad-spectrum herbicide	Plants can take several weeks to die and repeat application can be necessary	$700	5 acres total, proposing to treat 2.5 acres	$1,750	Yes, depending on extent of control targeted
Egeria	Diquat	Fast-acting	Turbid water or dense algal blooms can interfere with effectiveness, vegetative control only	$300	52	$15,600	Yes

Physical Control Scenario C: Techniques Not Recommended

Bottom Barriers	
Advantages	**Disadvantages**
• Avoids use of chemicals	• Expensive if applied in large areas • Labor intensive • Short period of effectiveness

Hand Pulling	
Advantages	**Disadvantages**
• Avoids use of chemicals • Longer period of effectiveness when compared to harvesting	• Expensive if applied in large areas • Labor intensive and time consuming • Not a viable long-term solution unless plant populations are significantly reduced with more efficient methods first

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Control Scenario C – Physical Control

C1: Harvesting	
Advantages	Disadvantages
• Avoids use of chemicals • Applicable for crew lanes	• Requires use of gasoline and transport of harvested material offsite to prevent regrowth from fragments • Expensive • Labor intensive • Short period of effectiveness • Increase fragment accumulation on shore

C2: Diver Suction Dredging	
Advantages	Disadvantages
• Most cost-effective form of physical control • Avoids use of chemicals • Longer period of effectiveness when compared to harvesting	• Expensive if applied in large areas • Labor intensive

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Technique	Advantages	Disadvantages	Unit Costs	Anticipated Treatment Area	Total Cost
Bottom barriers	• long-term treatment • Avoids or reduces herbicide use	• Expensive for large treatment area • Maintenance issue	• $74,052/acre, $1.70/square foot	• Not feasible based on extent of vegetation in need of control	N/A
Hand pulling by divers	• Applicable to all weed species • Avoids or reduces herbicide use	• Expensive for large treatment area • Takes significant time to implement in the field (several weeks) • Not a viable long-term solution	• $13,800/acre • 0.2 acres/day • $2,760/day	• Not feasible based on extent of vegetation in need of control	N/A
Suction dredging by divers	• Applicable to all weed species • Faster and less expensive than hand pulling • Avoids or reduces herbicide use	• Expensive for large treatment area	• $5,000-$6,400/acre • 0.7 acres/day • $3,500-$4,500/day	• 54 acres	• $270,000-$345,600
Mechanical harvesting	• applicable to all weed species • Avoids or reduces	• Short window of effectiveness because roots and	• $3,780/acre • 1-1.5 acres/day • $1,750	• 54 acres	• $204,120

Scenario D: Native Planting

- Native aquatic plant revegetation
  - Hornwort (*Ceratophyllum demersum*)
  - Pondweeds (*Potamogeton* spp.)
  - Waterweed (*Elodea canadensis*)
  - Others…
- Control Scenario A: most conducive due to a complete reset of plant community
- Control Scenarios B and C: possible, but with more competition from invasive species

Image Source: CLFLWD Watershed District. 2023. Moody Lake Native Aquatic Plant Transplanting Project.

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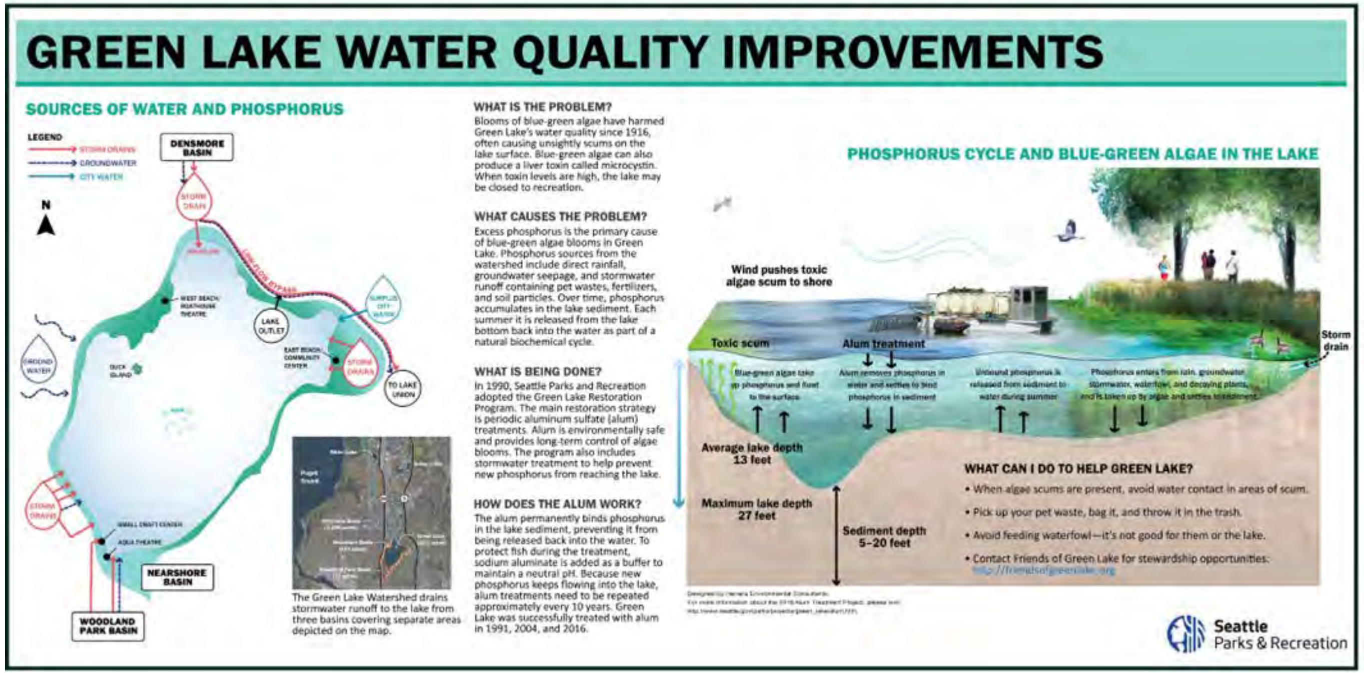
Control Scenarios Summary			
Control Scenario	*Effectiveness*	*Cost*	*Impact/Risk*
A. Lake-wide Control with Fluridone	High	High	High
B. Targeted Herbicide Applications			
B1. Treat Milfoil with ProcellaCOR	High	Moderate	Low
B2-A. Spot treat Egeria with Diquat	Moderate	Moderate	Moderate
B2-B. Spot treat Egeria and milfoil with Fluridone	High, but only in areas treated	Moderate	Low
B3. Treat Water Lilies with Glyphosate or Imazapyr	Moderate	Low	Low
C. Physical Control			
C1. Harvesting	Moderate	High	Low
C2. Diver Dredging	Moderate	High	Low
D. Native Plantings	Option in all scenarios, optimal with Scenario A		



Questions?

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Green Lake Integrated Aquatic Vegetation Management Plan

Public Meeting

June 26, 2024

Kevin Bergsrud
Seattle Parks and Recreation

Eliza Spear and Rob Zisette
Herrera Environmental Consultants

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Presentation Objectives and Agenda

- Introductions
- Green Lake Background Information
- IAVMP Development Process
- Evaluated Control Scenarios and Strategies
- Preferred Control Scenario

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Lake Management History

Lake Management Actions Since 1990 Restoration Plan:

- Alum treatment for toxic algae (1991, 2004, 2016)
- Stormwater treatment (1991), diversion (1993), and source control (2004, 2009)
- Geese management (1987-2004)
- Dilution (reservoir cleaning only)
- Milfoil harvesting/grass carp (1992-2002)
- Monitoring and education (ongoing)

Water Quality Goals:

- Summer Secchi depth (clearer water) >2.5 meters (>8.2 feet)
- Summer total phosphorus <20 µg/L (reduced from 30 µg/L in 2003 and from 25 µg/L in 2016)
- No toxic bloom closures (added in 2016)

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Milfoil Invasion/Expansion 1981-1995

1981 Study:

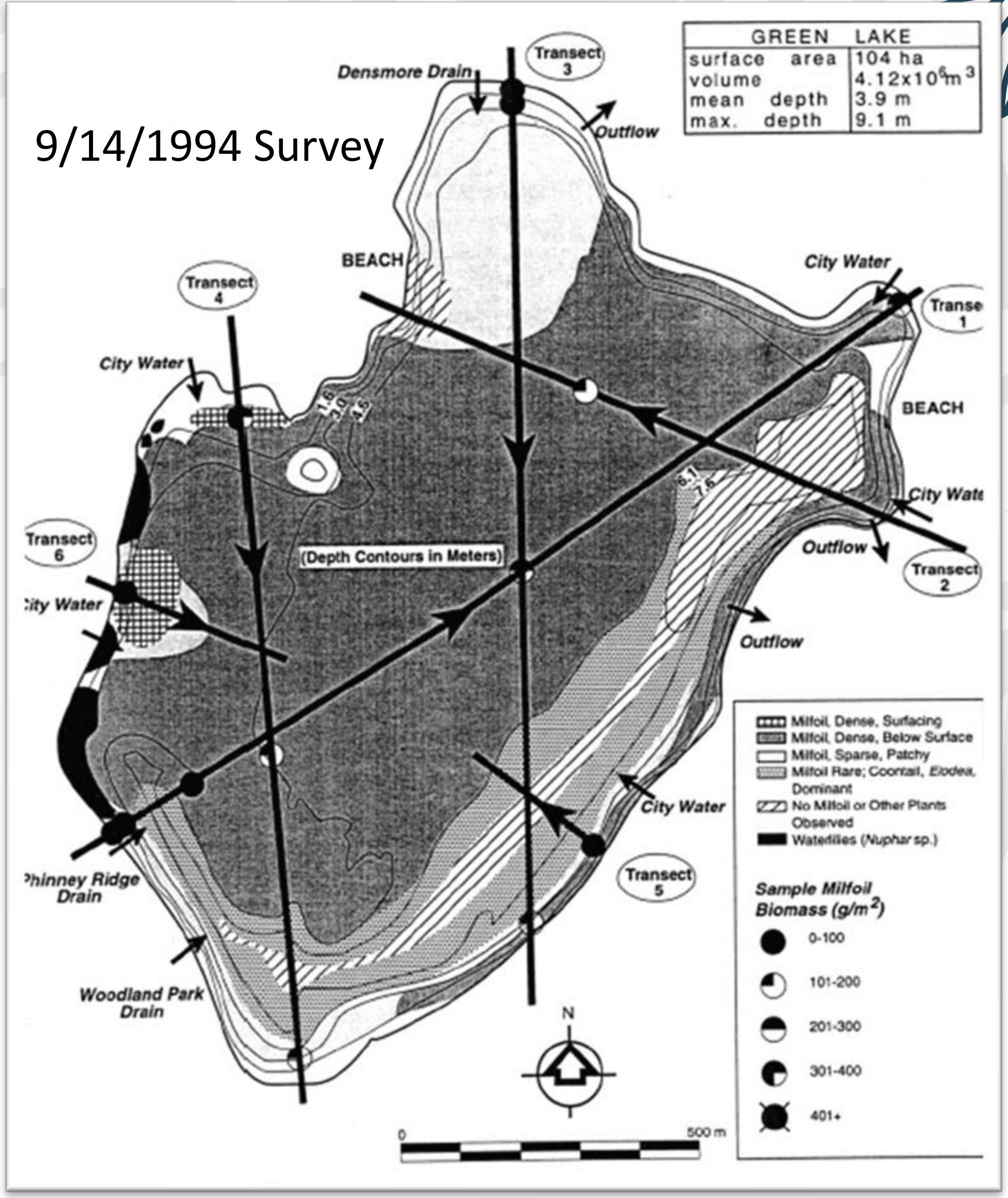
- Milfoil, a noxious weed, invaded lake from Lake Washington
- Only minor amounts of native species present
- Bottom barriers for milfoil control at east beach in late 80s

1991-1994 Surveys:

- Milfoil covered 75 – 90% of lake
- Native aquatic plants, Elodea and coontail in east trough

1995 Restoration Report Recommended:

- Continue mechanical harvesting
- Prepare IAVMP for long-term management
- Bottom barriers at swimming beaches
- Consider Triclopyr, aquatic herbicide, treatment
- Stock grass carp to eradicate milfoil and allow native plants upon their death



Milfoil Harvesting 1992-2000

- Mechanical harvesting program for 8 years by Parks (herbicides prohibited)
- Targeted crew lanes
- Removal rate and density decrease in first year

Year	Milfoil Removed (tons)
1992 (Year 1)	1,200
1995 (Year 4)	30
1996-2000	<30

Year	Mean Milfoil Biomass Density (g/m^3)
1991 (Pre-Harvesting)	483
1992 (Post-Harvesting)	131
1993 (Post-Harvesting)	180
1994 (Post-Harvesting)	118

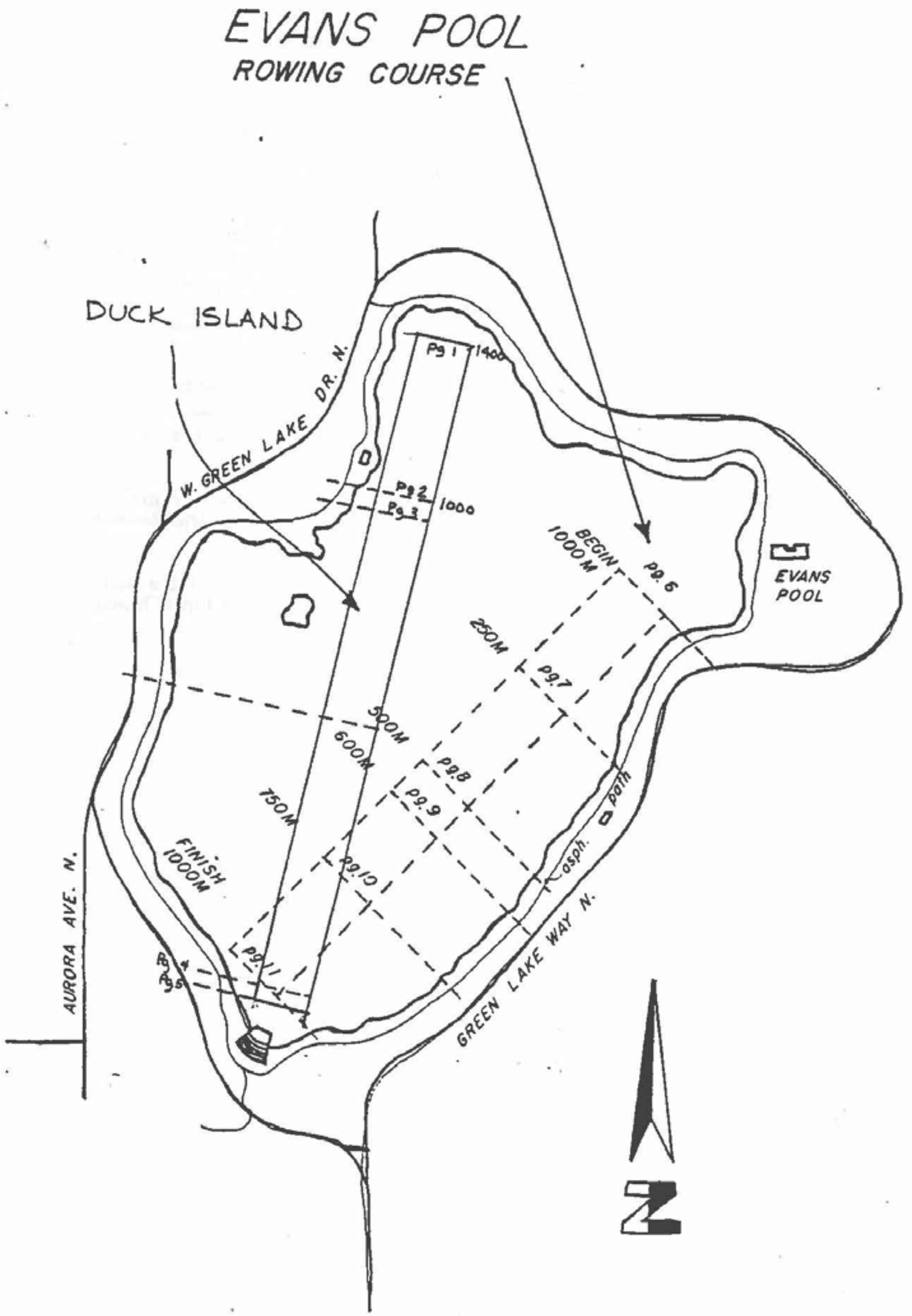


Figure 2. Green Lake showing established rowing courses.

Grass Carp Stocking 2001

- Grass carp stocking of 177 adults is low at 4/vegetated acre compared to 24/acre recommended by WDFW.
- Grass carp are sterile and live for 5-9 years on average and some over 20 years at up to 5 feet and 99 pounds.
- Grass carp prefer native plants over milfoil.
- Grass carp doubled in length within 4 years.

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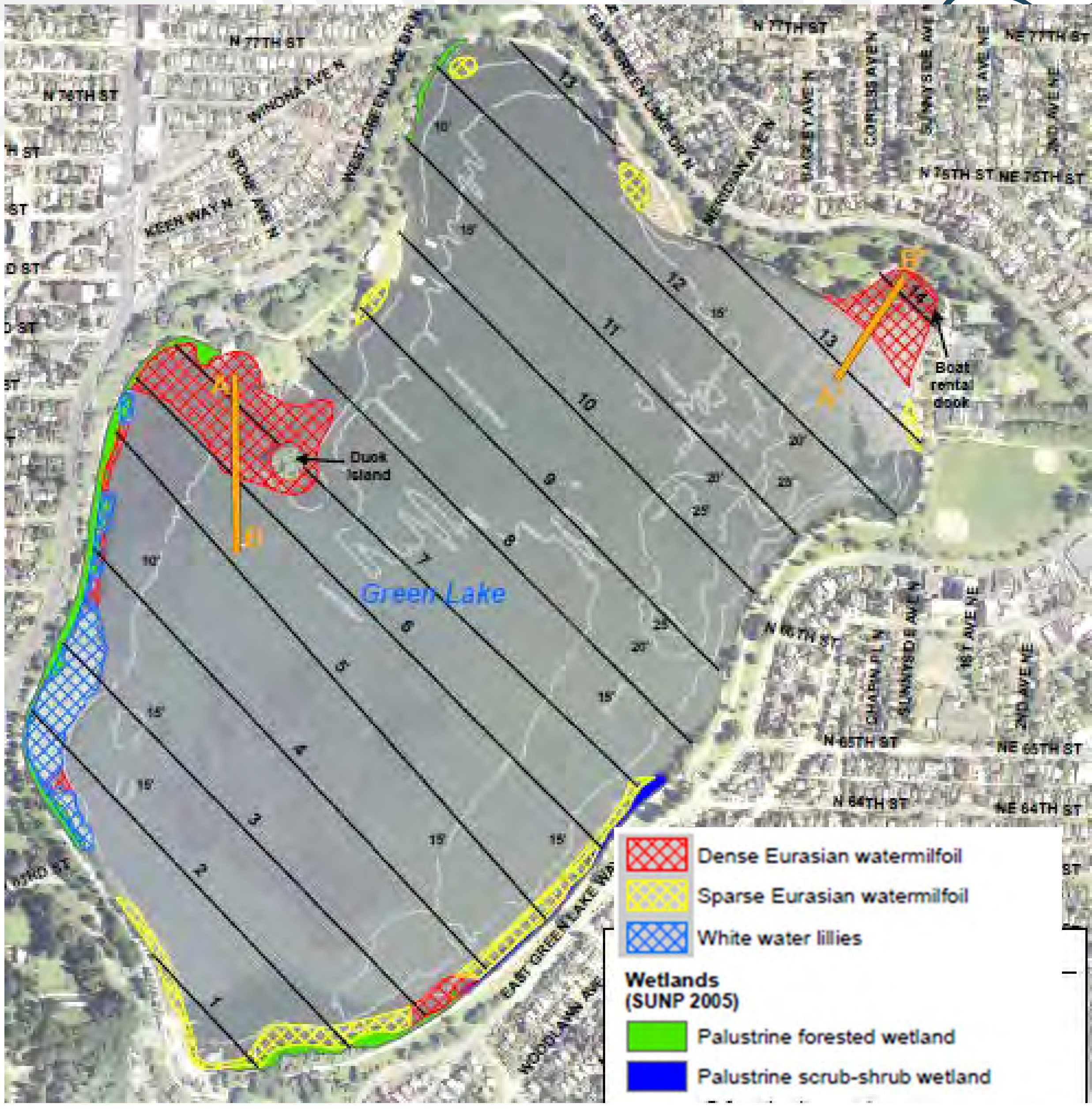
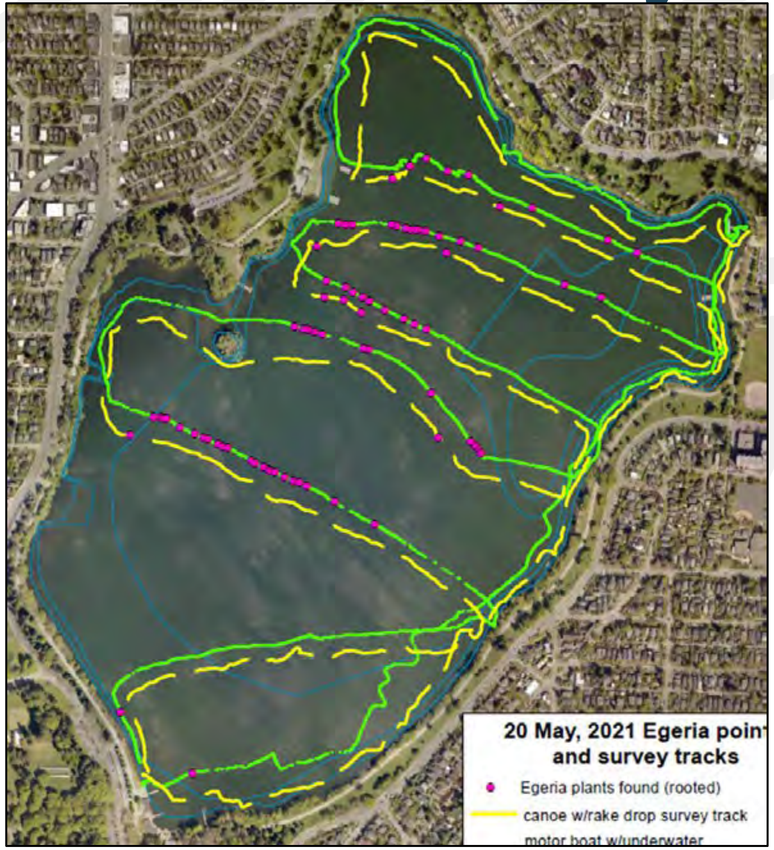
2005 Aquatic Plant Survey

- Milfoil covered only 4% (10 acres), minor diver handpulling west of Duck Island
- Milfoil cover decreased 95% in 1991-2005 (210 to 10 acres).
- No change in fragrant waterlily cover.
- Low amounts of native species, as in 1994.
- Emergent plants not mapped.
- Wetlands mapped by Seattle Urban Nature Project.



Egeria Discovery in 2020

- Egeria (Brazilian elodea), a noxious weed, fragments discovered during FOGL beach cleanup on 11/7/2020.
- Surveyed presence in lake on 5/20/21.
- Low growth and widespread throughout central north region.
- Class B weed was required for control in Green Lake (not in Lake Washington and not now in Green Lake).
- Too late for manual eradication by diver handpulling.



Aquatic Plant Species Summary

Egeria
(*Egeria densa*)

Eurasian watermilfoil
(*Myriophyllum spicatum*)

Fragrant water lily
(*Nymphaea odorata*)

All aquatic plant species in Green Lake are noxious weed species. No native aquatic plants have been observed in surveys.

IAVMP Development Process

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Stakeholder Committee

- Kevin Bergsrud, Bridget Kelsh, Jason Coffman and Adam Bailey; City of Seattle Parks and Recreation
- Ben Peterson, King County Noxious Weed Program
- Wes Glisson, Washington Department of Ecology
- Julian Douglas and Justin Spinelli, Washington Department of Fish and Wildlife
- Tamara Oki, Green Lake Small Craft Center
- Kim Tennican, Friends of Green Lake
- Rob Zisette and Eliza Spear, Herrera

2022 Aquatic Plant Survey and 2024 IAVMP

2022 Aquatic Plant Survey:

- Milfoil covered 26% (69 acres) and Egeria covered 20% (52 acres)

2024 IAVMP

- Seattle Parks and Recreation to prepare Integrated Aquatic Vegetation Management Plan

Egeria on Milfoil Fragments at Densmore Drain on 9/27/2023

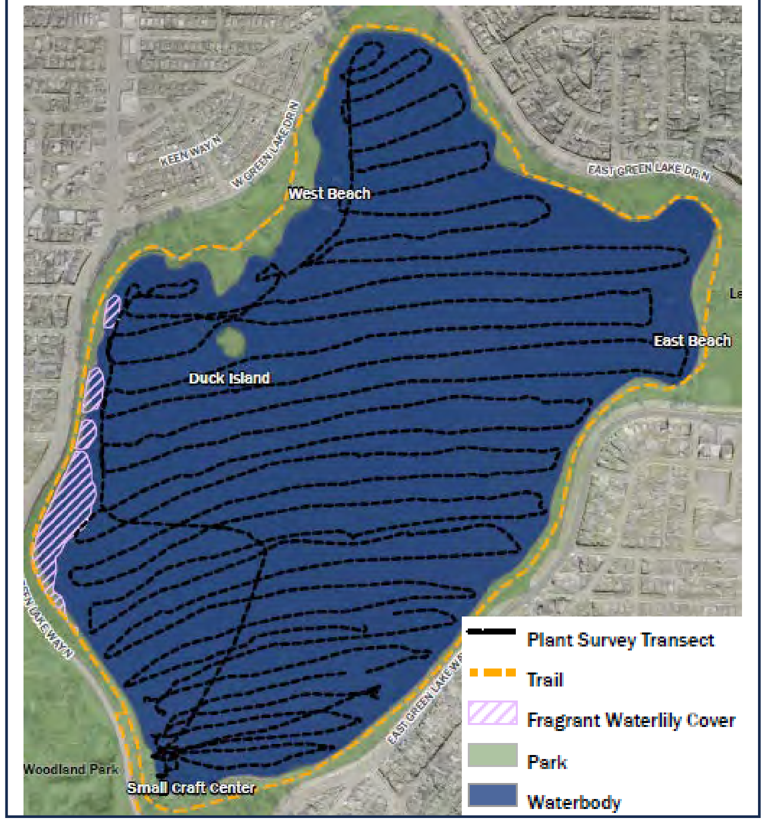
2022 Aquatic Plant Survey

2022 Survey Method

Sonar transects <100 feet apart on 9/7/22

26 composition samples (3 species)

Lilies mapped by Google on 7/31/22



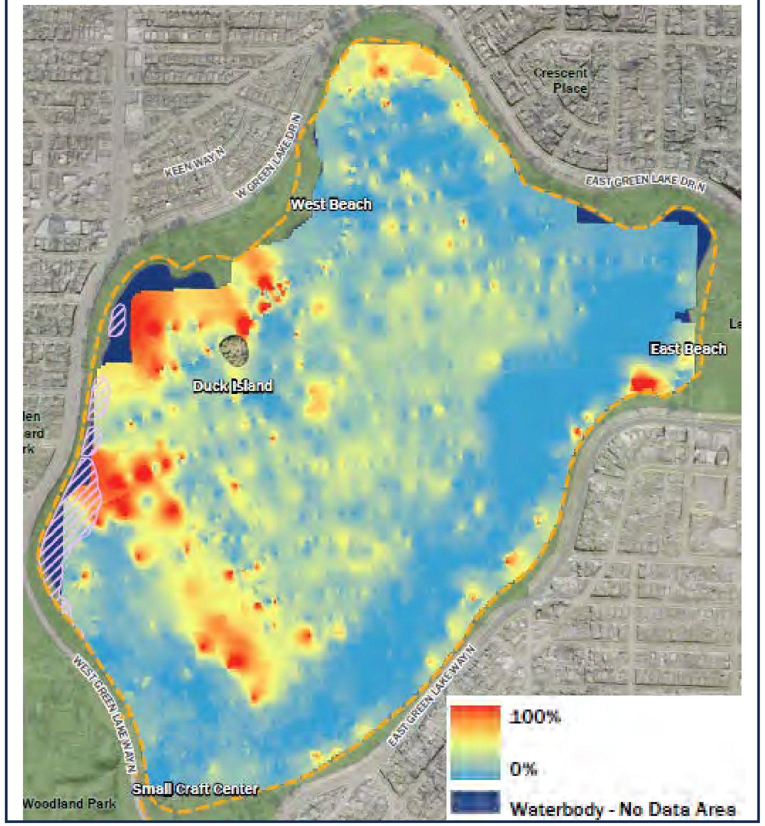
2022 Plant Biovolume

0% Blue

50% Yellow

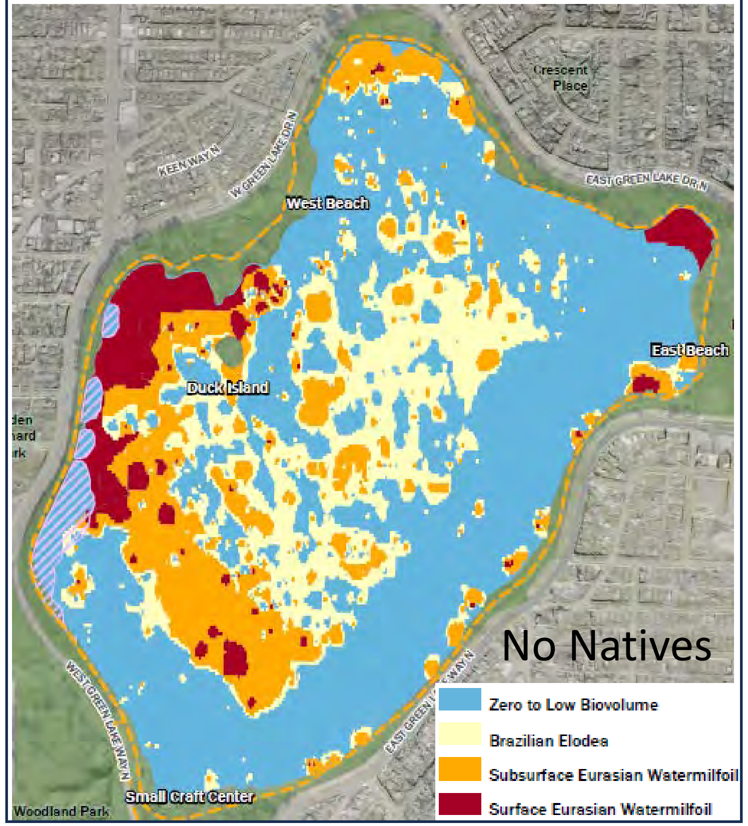
75% Orange

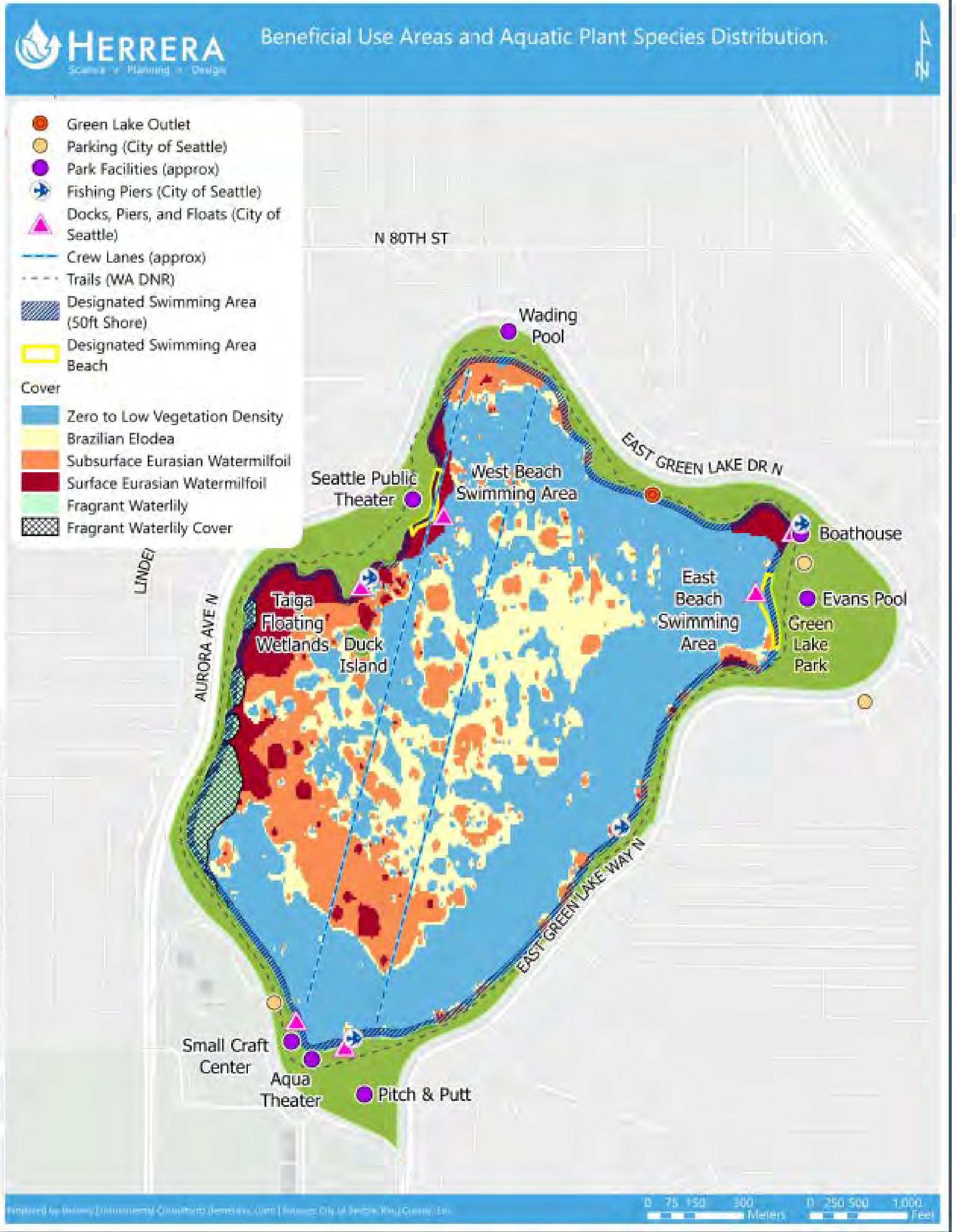
100% Red



2022 Plant Cover

Plant	Acres	Percent
Surface Milfoil (red)	19	7%
Subsurface Milfoil (orange)	50	19%
Egeria (yellow)	52	20%
Waterlily (hatching)	5	2%
Low to No Plants	131	51%

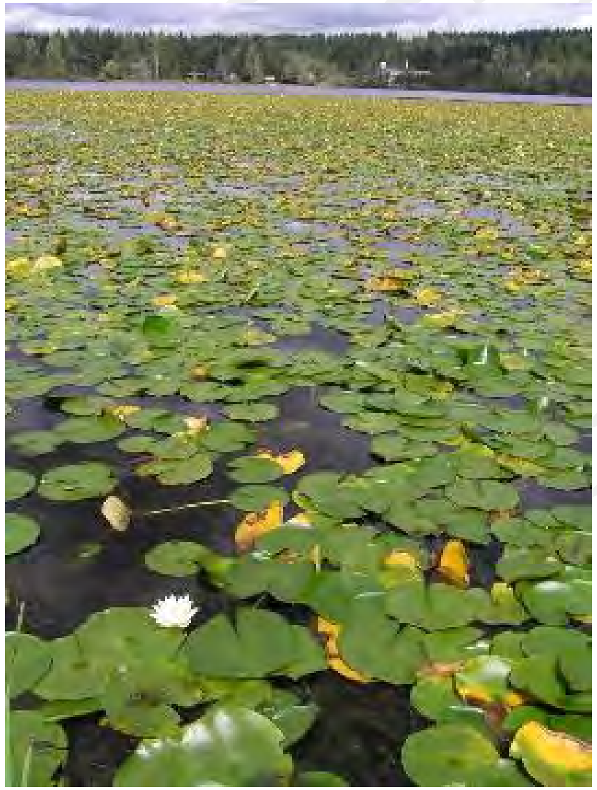




Beneficial Use Areas and Aquatic Species Distribution

Problem Statement

Dense growth of invasive aquatic plants interferes with recreational uses in some areas of Green Lake during the summer. Beneficial uses are primarily impacted by the Eurasian watermilfoil, Egeria, and fragrant waterlily. The cover of invasive plants is rapidly increasing over time. There are no native plants to support wildlife and habitat within the lake.



Plant Management Goals

- Control of noxious weeds and dominant weed species
- Reduce impacts to beneficial uses including swimming, crew, fishers and paddlers
- Maintain a healthy environment for fish and other wildlife

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Aquatic Plant Management Tools

Aquatic Plant Management Tools

Type	Alternative	Milfoil	Egeria	Waterlily
	No Action			
Physical	Diver hand-pulling			
	Diver dredging			
	Mechanical harvesting			
	Bottom barrier			
Chemical	ProcellaCOR			
	Fluridone			
	Imazapyr			
	Glyphosate			

Table Key	
Feasible	Not feasible

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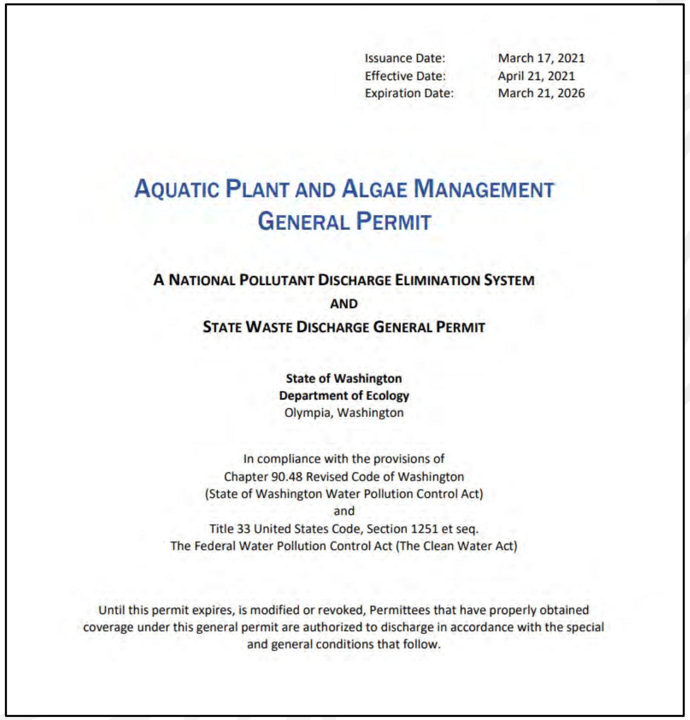
Aquatic Plant & Algae Management General Permit

- Issued by Washington Department of Ecology for herbicide treatment of noxious weeds and nuisance native aquatic plants in lakes
- Issued to licensed applicator or local government
- Must prevent impairment for phosphorus release to 303(d) listed lakes
- No treatment timing windows for Green Lake
- Specific herbicide restrictions in Washington State based on EIS for SEPA
- Permits administered within federal regulations
- Ecology and Public notification and reporting requirements



Issuance Date:	March 17, 2021
Effective Date:	April 21, 2021
Expiration Date:	March 21, 2026

AQUATIC PLANT AND ALGAE MANAGEMENT
GENERAL PERMIT

A NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM
AND
STATE WASTE DISCHARGE GENERAL PERMIT

State of Washington
Department of Ecology
Olympia, Washington

In compliance with the provisions of
Chapter 90.48 Revised Code of Washington
(State of Washington Water Pollution Control Act)
and
Title 33 United States Code, Section 1251 et seq.
The Federal Water Pollution Control Act (The Clean Water Act)

Until this permit expires, is modified or revoked, Permittees that have properly obtained coverage under this general permit are authorized to discharge in accordance with the special and general conditions that follow.

ProcellaCOR for Eurasian Watermilfoil

General Use

- Control of submerged, floating and emergent aquatic plants
- Systemic herbicide

Restrictions

- No drinking water or recreational use restrictions

Toxicity

- Nontoxic to freshwater fish and invertebrates, birds, bees, reptiles, amphibians and mammals
- No risks of concern to human health due to lack of short- or long-term adverse effects

Fluridone for Egeria and Milfoil

General Use

- Control of submerged, emergent, and floating-leaf vegetation
- Systemic herbicide

Restrictions

- No recreational use restrictions, including swimming and fishing
- No pet/livestock drinking restrictions

Toxicity

- Slightly to moderately toxic to freshwater fish and invertebrates, but does not appear to have long- or short-term effects on fish at approved application rates
- Short-term risk to humans applying herbicide, which can be avoided with proper PPE

Imazapyr for Water Lilies

General Use

- Control of emergent and floating-leaf vegetation
- Systemic herbicide

Restrictions

- No recreational use restrictions
- No pet/livestock drinking restrictions

Toxicity

- Non-toxic to freshwater fish, invertebrates, birds and mammals
- May be slightly toxic to bullfrog tadpoles
- Short-term risk to humans applying herbicide, which can be avoided by using PPE

Glyphosate for Water Lilies

General Use

- Control of emergent vegetation
- Systemic herbicide

Restrictions

- No recreational use restrictions
- Drinking water restrictions for 48 hours after application

Toxicity

- Low toxicity to animals
- Non-toxic to slightly toxic to freshwater fish, invertebrates, and birds
- Short-term risk to humans applying herbicide, which can be avoided by using PPE

Successful Use Examples in Washington State

- Fluridone
  - Lake Limerick (Egeria)
  - Long Lake (Eurasian watermilfoil)
  - Goss Lake (Eurasian watermilfoil)
  - Lake McMurray (Eurasian watermilfoil)

- ProcellaCOR
  - American Lake
  - Vancouver Lake


Aquatic Plant Management Tools

Control Scenarios

Control Scenario A: Complete Lake Control with Fluridone

Fluridone	
Advantages	**Disadvantages**
• Single treatment • Eliminates current issues with aquatic plants • Lessons the burden over time, avoids repeated need for widespread treatments, and transitions to focus on monitoring and control as species re-populate • Creates opportunities to plant native aquatic species without immediate competition or impact from more treatments	• Eliminates entire plant population, no selectivity • Risk of algal bloom being fueled by plant die-off, likely need for alum treatment • Potential impact to floating wetlands, need to mitigate for this risk • Habitat loss for fish, insects, amphibians

Control Scenario B: Separate Herbicide Applications

Separate Herbicide Applications	
Advantages	Disadvantages
• More selectivity than complete fluridone treatment • Accomplishes plant management in high priority areas • Leaves plants intact in areas without beneficial use impacts, providing habitat for fish and wildlife • Fewer water quality impacts	• Need for ongoing and repeated treatment efforts over several years • Less widespread control • Less optimal for native plant revegetation

Control Scenario C – Physical Control

C1: Harvesting	
Advantages	Disadvantages
• Avoids use of chemicals • Applicable for crew lanes	• Requires use of gasoline and transport of harvested material offsite to prevent regrowth from fragments • Expensive • Labor intensive • Short period of effectiveness • Increased fragment accumulation on shore

C2: Diver Suction Dredging	
Advantages	Disadvantages
• Most cost-effective form of physical control • Avoids use of chemicals • Longer period of effectiveness when compared to harvesting	• Cost prohibitive if applied in large areas • Labor intensive

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Physical Control Techniques Not Recommended

Bottom Barriers	
Advantages	Disadvantages
• Avoids use of chemicals • Natural products do not need removal	• Expensive if applied in large areas • Labor intensive • Short period of effectiveness • Synthetic barriers must be removed after 2 years

Hand Pulling	
Advantages	Disadvantages
• Avoids use of chemicals • Longer period of effectiveness compared to harvesting	• Expensive if applied in large areas • Labor intensive and time consuming • Not a viable long-term solution unless plant populations are significantly reduced with more efficient methods first

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Scenario D: Native Planting

- Native aquatic plant revegetation:
  - Hornwort (*Ceratophyllum demersum*)
  - Pondweeds (*Potamogeton* spp.)
  - Waterweed (*Elodea canadensis*)
  - Others…
- Control Scenario A: most conducive due to a complete reset of plant community
- Control Scenarios B and C: possible, but with more competition from invasive species

Image Source: CLFLWD Watershed District. 2023. Moody Lake Native Aquatic Plant Transplanting Project.

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Chemical Control Cost Comparison

Target Species	Herbicide	Approx. Cost/Acre	Treatment Acres (Location)	Total Cost	Repetition Anticipated in Short Term?
All species	Fluridone (complete)	N/A	257 (whole lake)	$350,000	No
	Fluridone (spot)	N/A	52	$90,000	No
Eurasian watermilfoil	ProcellaCOR	$1,200 - $1,300	114	$142,500	No
Fragrant waterlily	Glyphosate	$350	2.5 (50% total area)	$875	Possible
	Imazapyr	$700	2.5 (50% total area)	$1,750	Possible

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Physical Control Cost Comparison

Technique	Unit Costs	Anticipated Treatment Area	Total Cost	Repetition Anticipated in Short Term?
Bottom barriers	$74,052/acre $1.70/square foot	Not feasible based on extent of vegetation in need of control	N/A	N/A
Hand pulling by divers	$13,800/acre 0.2 acres/day $2,760/day	Not feasible based on extent of vegetation in need of control	N/A	N/A
Suction dredging by divers	$5,000 - $6,400/acre 0.7 acres/day $3,500 - $4,500/day	54 acres	$270,000 - $345,600	Yes
Mechanical harvesting	$3,780/acre 1-1.5 acres/day $1,750 -$5,670/day	54 acres	$204,120	Yes

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Control Scenarios Summary	
A. Lake-wide Control with Fluridone	Treat entire lake in Year 1 for milfoil and Egeria control using liquid
B. Targeted Herbicide Applications	Successively treat noxious weeds as needed to reduce impact
B1. Treat Milfoil with ProcellaCOR	Treat dense milfoil stands in Year 1, follow up as needed
B2. Spot treat Egeria and milfoil with Fluridone	Spot treat Egeria and milfoil as needed using granular
B3. Treat Water Lilies with Glyphosate or Imazapyr	Treat outer 25-50% of water lilies
C. Physical Control*	
C1. Harvesting	Implement a regular harvesting program in June, July, and August of each year
C2. Diver Dredging	Implement a regular diver dredging program in June and August of each year
D. Native Plantings	Option in all scenarios, optimal with Scenario A

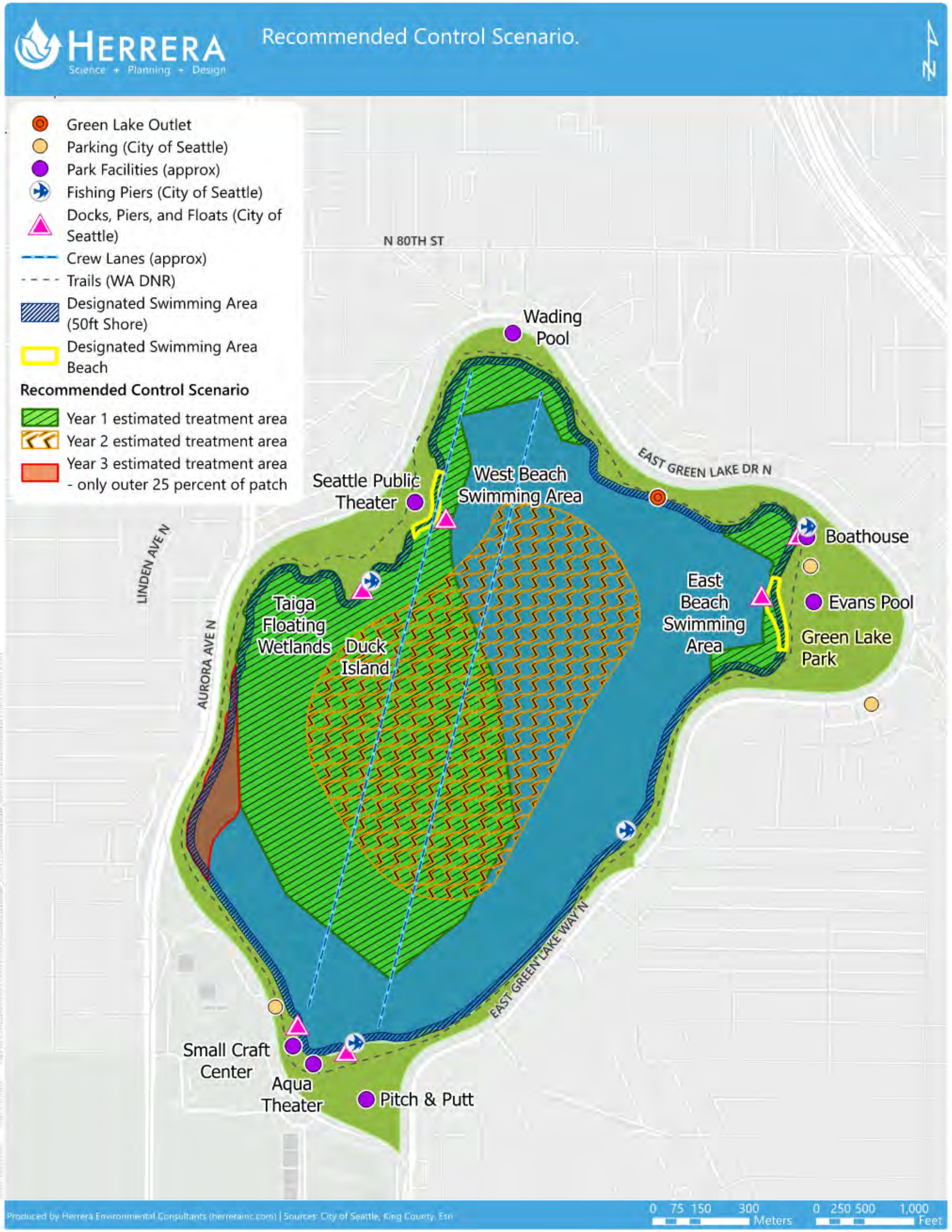
*Scenario C could be implemented in tandem with other scenarios

Plant Management Goals

- Control of aquatic noxious weeds and dominant weed species
- Reduce impacts to beneficial uses including swimming, crew, fishers and paddlers
- Maintain a healthy environment for fish and other wildlife

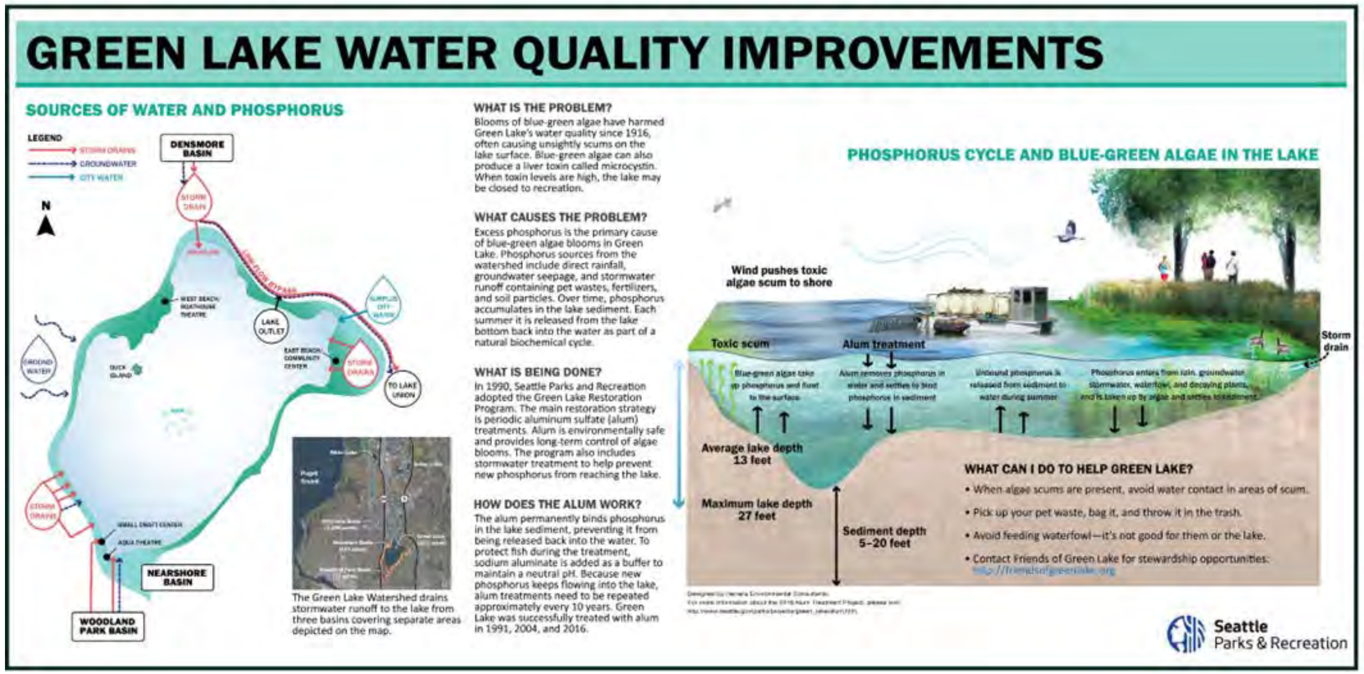
Photo courtesy of Corinne Whiting

Recommended Control Scenario B and Plant Management Goals			
Recommended Control Scenario B	Does the control scenario help meet plant management goals?		
	Control of aquatic noxious weeds	Reduced impacts to beneficial use including swimming, crew, fishers and paddlers	Maintain a healthy environment for fish and wildlife
Year 1: Treat Eurasian watermilfoil with ProcellaCOR in high density areas interfering with lake use	✓	✓	✓
Year 2: Treat Egeria with granular fluridone in high use areas	✓	✓	✓
Year 3: Treat outer 25 percent of water lily patch with imazapyr and install native plantings	✓	✓	✓
Long term: regularly monitor aquatic weed population and adaptively manage aquatic weeds as necessary to maintain beneficial uses and achieve plant management goals	✓	✓	✓



Recommended Control Scenario Summary

Treatment Year	Target Species	Estimated Treatment Area (acres)	Control Strategy	Cost
1	Eurasian watermilfoil	114	ProcellaCOR	$142,500
2	Egeria and Eurasian watermilfoil	88	Granular fluridone	$90,000
3	Waterlily	2.5	Imazapyr	$1,750



Questions?

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Appendix B

Aquatic Plant Control Alternatives

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Plant Control Alternatives

Contents

Introduction

This appendix presents information about common methods used to control aquatic weeds. Much of the information in this section was obtained from the Citizen's Manual for Developing IAVMPs (Ecology 1994) and Washington State Department of Ecology (Ecology) Aquatic Plant Management website (Ecology 2024).

Control and eradication methods discussed below include: chemical treatments; manual methods, such as mechanical hand-pulling, raking, and cutting; mechanical methods, such as mechanical harvester; diver dredging; biological control methods, such as the introduction of grass carp; and other methods, including bottom screening. Table B-1 designates plant control activities that need an Aquatic Plant and Algae Management General Permit from Ecology or a Hydraulic Project Approval (HPA) permit/authorization from the Washington Department of Fish and Wildlife (WDFW).

Table B-1. Permit Requirements for Aquatic Noxious Weed and Beneficial Plant Control.

	Aquatic Noxious Weeds			Aquatic Beneficial Plants		
Control Method	Pamphlet HPA	Pamphlet HPA and WDFW Authorization	Individual HPA	Pamphlet HPA	Pamphlet HPA and WDFW Authorization	Individual HPA[a]
Chemical Herbicides	Requires Aquatic Plant and Algae Management General Permit from Ecology					
Hand Pulling or Other Hand Tools	X			X	X[b]	
Mechanical Cutting and Harvesters	X				X	
Diver Dredges	X	X[b]			X	
Grass Carp	Requires Grass Carp Stocking Permit and Individual HPA (for outlet structure) from WDFW					
Bottom Barriers	X	X[b]		X	X[b]	

[a] Applicants may apply for Individual HPAs for projects that exceed pamphlet limitations.

[b] Prior authorization is needed from WDFW for projects that exceed specified thresholds.

HPA =- Hydraulic Project Approval

WDFW = Washington State Department of Wildlife

Source: WDFW 2024.

No Action

The first alternative considered was the "No Action" alternative to let aquatic weeds continue to grow and do nothing to control them. 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" alternative would preclude any integrated treatment and/or control effort.

Noxious plants reduce the beneficial uses of the lake. Several different alternatives to control (or eradicate) these plants are presented in this plan. However, the "no action" alternative was examined as a reference for all other proposed control techniques.

It is very likely that all beneficial uses of the lake will continue to be further degraded if no aquatic plant control methods are implemented. Because the lake is eutrophic, a shallow lake with high nutrient conditions, the aquatic plants absorb nutrients from sediments and the water column, making the likelihood of further plant growth certain. Therefore, the "no-action" alternative is not acceptable due to the further reduction of beneficial uses of the lake (boating, fishing, paddling, and swimming). Other negative environmental impacts include a definite degradation of the overall aesthetics. The fish communities may be impacted directly (e.g., lack of dissolved oxygen) or indirectly (i.e., changes in food web dynamics) with an overabundance of aquatic plants. Loss of open water may also restrict waterfowl use and habitat. Excessive aquatic plants also influence water quality by causing more pronounced temperature stratification and potentially a reduction in water circulation.

Chemical parameters, such as pH, alkalinity, and dissolved oxygen, may also be impacted through alteration of biological processes, such as photosynthesis, respiration, and decomposition.

Advantages and Disadvantages

Advantages of the No Action alternative include the following:

- No treatment cost
- No herbicide concerns
- No need for permits

Disadvantages of the No Action Alternative include the following:

- Quality of the lake will continue to decline.
- Recreational opportunities will decline.
- Fish and wildlife habitat will be reduced or impaired.
- Property values will decline.

Suitability for Green Lake

Unless control measures are enacted, the coverage of aquatic plants is likely to increase. This could degrade water quality and restrict beneficial uses. The “no action” alternative is not acceptable by members of the Green Lake steering committee.

Chemical Herbicides

Aquatic herbicides are chemicals specifically formulated for use in water to eradicate or control aquatic plants. Aquatic herbicides are sprayed directly onto floating or emergent aquatic plants or are applied to the water in either a liquid or pellet form. Systemic herbicides can kill 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 regrowth (chemical mowing). Non-selective herbicides will generally affect all plants that they contact. Selective herbicides will affect only some plants.

To be approved for use in aquatic environments, an herbicide must pass stringent toxicity testing by the federal government. These tests are designed to assess impacts to the target population (plants) as well as non-target populations, such as fish, aquatic insects, and other organisms. The tests also examine what happens to the chemical over the long term to ensure the chemical quickly breaks down into a nontoxic form or becomes unavailable for uptake by aquatic organisms. Washington State has set more stringent standards. Therefore, some of the aquatic herbicides approved for use in the United States are not approved for use in Washington.

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, an Aquatic Plant and Algae Management General Permit is required from Ecology for herbicide applications. This permit is a combined National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge General Permit. It covers the in-water and shoreline (including roadsides and ditch banks) treatment of native and noxious plants and algae. It also covers nutrient inactivation treatments. The permit allows the discharge of a specific list of aquatic labeled herbicides, algaecides, biological water clarifiers, adjuvants, marker dyes, and nutrient inactivation products into the freshwaters of Washington (Ecology 2024).

Only herbicides known to be effective on the target species and approved for use in Washington State were considered for this plan. A brief discussion of these herbicides from Ecology follows below:

- 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 waterlilies and shoreline plants like purple loosestrife. It is generally applied as a liquid to the leaves. Glyphosate does not work on submersed plants. 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.
- Imazapyr: The trade name for Imazapyr is Habitat®. This systemic broad spectrum, slow-acting herbicide, applied as a liquid, is used to control emergent plants like spartina, reed canarygrass, and phragmites and floating-leaved plants like water lilies. Imazapyr does not work on underwater plants, such as Eurasian watermilfoil. Although imazapyr 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. Imazapyr was allowed for use in Washington in 2004.

- **ProcellaCOR™:** With the common name florpyrauxifenbenzyl, ProcellaCOR™ is a recently approved aquatic herbicide. In February 2018, the EPA certified registration of ProcellaCOR™ as a selective herbicide that can be used to treat hydrilla, watermilfoil, and crested floating heart. ProcellaCOR™ is approved for aquatic use and has been given a Reduced Risk status from the EPA because of the reduced risk to human health and native plants in comparison to alternative herbicides.
- **Fluridone:** Fluridone (trade name Sonar®) is an approved aquatic herbicide that may be applied in liquid or pellet form. Fluridone is a systemic herbicide that may be used for the control of submerged, emergent, and floating-leaf vegetation. There are no post-treatment restrictions for swimming, fishing, or pet use after fluridone application. If applied as a widespread treatment throughout the lake, a liquid form would be used. If using for spot treatment, the pellet form would be used.

Advantages and Disadvantages

Advantages of herbicides include the following:

- Aquatic herbicide application can be less expensive than other aquatic plant control methods.
- Aquatic herbicides generally provide a high level of control.
- Aquatic herbicides are easily applied around docks and underwater obstructions.
- Many herbicides are fast acting.

Disadvantages of herbicides include the following:

- Some herbicides have swimming, drinking, fishing, irrigation, and water use restrictions.
- Herbicide use may have unwanted impacts to people who use the water and to the environment.
- 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.
- To be most effective, generally herbicides must be applied to rapidly growing plants.
- Some expertise in using herbicides is necessary to be successful and to avoid unwanted impacts.
- Many people have strong feelings against using chemicals in water.

Permits and Costs

An Aquatic Plant and Algae Management General Permit is needed for any herbicide application. The City of Seattle may be required to monitor herbicide levels in the lake as part of the permit process. The requirement of monitoring of herbicide levels started in 2003; monitoring is required whether the chemical has been applied directly to the water or along the shoreline where it may have gotten into the adjacent surface water. The applicator must apply to Ecology for coverage under their permit every

5 years. The permit is approximately $500 and will be billed once the permit is approved. Ecology requires that a Discharge Management Plan and State Environmental Protection Act checklist be submitted with the permit application. An IAVMP may be submitted in lieu of a Discharge Management Plan. There are no additional permit requirements from the City of Seattle.

Ecology requires that the herbicide applicator submit a fluridone vegetation management plan when fluridone application is proposed for more than 40 percent of the littoral zone in lakes the size of Green Lake (Ecology 2024).

Approximate costs for herbicide treatment (costs will vary from site to site) are as follows:

- **Glyphosate:** $350/acre
- **Imazapyr:** $700/acre
- **ProcellaCOR:** $1,300/acre
- **Fluridone:** $350,000 for a complete lake treatment, or $150,000 for spot treatment of high priority areas on Green Lake

Other Considerations

The EPA conducts very thorough risk assessments of all pesticides approved for use in the United States. These tests evaluate human exposure risks, as well as risks posed to the environment resulting from persistence, accumulation, and mobility in the environment. Complete assessments are available from EPA or the pesticide manufacturers. The state of Washington sets more stringent standards than the EPA when considering which pesticides to allow.

Suitability for Green Lake

Aquatic herbicides can provide an effective method for control and eventual eradication of noxious weeds. Four primary herbicides were considered for use in this plan: glyphosate, imazapyr, ProcellaCOR, and fluridone. Glyphosate and imazapyr can be used to treat fragrant waterlily. Imazapyr was selected for control of fragrant waterlily, because it has been effectively used in Lake Washington and many other lakes in the region. ProcellaCOR can be used to treat Eurasian watermilfoil and was chosen because of its low toxicity, the high impact of Eurasian watermilfoil on Green Lake users, and its successful history of use in Washington. Fluridone pellets may be used to treat all three species in Green Lake, and this was chosen as a method for treating Eurasian watermilfoil and Egeria.

All herbicides described here are approved for aquatic use in Washington State, based on environmental impact studies. As a result of these studies, there are many other herbicides allowed by the U.S. Environmental Protection Agency (EPA) but prohibited for use in Washington State. Full precautions will be taken during applications in Green Lake, to ensure that herbicide levels do not exceed the amounts at which these hazards arise by not exceeding amounts specified by EPA on the product label.

Manual Methods

Manual methods include hand-pulling, raking, and cutting, described as follows.

- **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 3 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, such as areas where deep flocculent sediments may cause a person hand pulling to sink deeply into the sediment, may not be suitable for hand pulling.
- **Raking** requires a sturdy rake for removing aquatic plants. Attaching a rope to the rake allows removal of a greater area of weeds. Raking fully 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.
- **Cutting** differs from hand pulling in that plants are cut and 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 to 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.

Advantages and Disadvantages

Advantages of manual methods include the following:

- Small infestations can be eradicated.
- The equipment is inexpensive.
- These methods are easy to use around docks and swimming areas.
- Many manual methods can be carried out by trained volunteers and shoreline residents.
- Hand-pulling allows the flexibility to remove undesirable aquatic plants while leaving desirable plants.
- These methods are environmentally safe.

Disadvantages of manual methods include the following:

- Hand-pulling is a high-cost method.
- Because these methods are labor intensive, they may not be practical for large areas or for thick weed beds.
- As plants regrow or fragments recolonize the cleared area, the treatment may need to be repeated several times each summer.
- Even with the best containment efforts, it is difficult to collect all plant fragments, leading to recolonization for some plants.
- Some plants, like waterlilies, which have massive rhizomes, are difficult to remove by hand pulling.
- Pulling weeds and raking stirs up the sediment, making 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.

Permits and Costs

Manual removal of aquatic plants in Washington requires compliance with the Aquatic Plants and Fish pamphlet (WDFW 2015) for control of noxious weeds, or an individual HPA permit for control of native plants in a large area. Hand-pulling, raking, and mechanical cutting are two methods commonly used by residents that do not require an authorization or an individual HPA permit for control of aquatic noxious weeds.

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 to 75 cents per foot).

Other Considerations

The City or community may need to invest money into buying the equipment and operation. 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. This is a large time investment.

Suitability for Green Lake

Diver hand-pulling is not recommended for floating leaved plants, due to difficulties with root (rhizome) removal. It is not cost-effective for control of large areas of submersed plants, due to diver expense and fragment release. At this time, the extent of noxious weeds in Green Lake is too large for this method to be cost and time effective. In the future, once plant communities are under better control, this method may be more appropriate.

Raking can be used to control noxious weeds, especially in early summer when it begins to reach the water. Nuisance submersed plants are easily removed by rakes, but raking will generate fragments that may spread to other areas if they are not properly contained. However, all of the noxious weed species in Green Lake are already widespread throughout the lake, so fragmentation is not a huge issue. Prior authorization is needed from WDFW for projects that exceed specified thresholds, which is 50 percent of the littoral zone.

Mechanical Methods

Mechanical methods include mechanical harvesters, mechanical weed cutters, rotovators, and mechanical dredging.

- **Mechanical harvesters** are large machines, which 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.
- **Mechanical weed cutters** cut aquatic plants several feet below the water's surface. Unlike harvesting, cut plants are not collected while the machinery operates.
- **Rotovators** use underwater rototiller-like blades to uproot fragrant waterlily plants. The rotating blades churn 7 to 9 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.

Advantages and Disadvantages

Advantages of mechanical methods include the following:

- Large areas can be treated.
- There will be no chemical residue.
- Harvesters will collect plant fragments.
- Rotovators will negatively impact plant roots.
- Weed cutters have a low operation cost.

Disadvantages of mechanical methods include the following:

- Increased fragment drift and difficulty in plant collection can occur, which can create new plant populations elsewhere in the lake.
- These machines are difficult to navigate around docks and other obstacles.

- It will be difficult to maneuver in shallow water.
- Rotovators can stir up sediments and negatively impact water quality.
- Mechanical methods use fossil fuels to implement the management and to transport harvested plant matter off site.
- The effectiveness is short-term when roots are not removed, because plants will grow back within the same growing season.

Permits and Costs

Mechanical methods may require an individual HPA permit from WDFW.

Mechanical harvesting costs approximately $3,780/acre.

Other Considerations

None.

Suitability for Green Lake

Mechanical harvesting may be suitable for Green Lake for specific crew events; however, it is not a cost-effective method for long-term control of noxious weed species in the lake.

Diver Dredging

Diver dredging (suction dredging, or diver assisted suction dredging (DASH)) 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 fragrant waterlily, 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 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 off shore.

Removal rates vary from approximately 0.25 acre to 1 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, some plants tend to break off, leaving the roots behind and defeating the purpose of diver dredging.

Advantages and Disadvantages

Advantages of diver dredging include the following:

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

Disadvantages of diver dredging include the following:

- Diver dredging is very expensive.
- Dredging stirs up large amounts of sediment. This may lead to the release of nutrients and buried toxic materials into the water column.
- Only the tops of plants growing in rocks 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 and Costs

Permits are required for many types of projects in lakes and streams. Diver dredging requires an HPA permit WDFW. Diver dredging may also require a Section 404 permit from the U.S. Army Corps of Engineers. Depending on the density of the plants, specific equipment used, number of divers and disposal requirements, costs can range from a minimum of $3,500 to $4,500 per day.

Other Considerations

Diver dredging could be useful for spot control in subsequent years (coordinated with diver survey).

Suitability for Green Lake

Diver dredging removes the plant in its entirety. It removes the biomass above the sediment, as well as roots and tubers in the sediment. This alternative is best used for a pioneering infestation of invasive submersed plants in soft sediments. Due to the widespread extent of noxious weeds in Green Lake and the high cost of diver suction dredging, this method is not recommended at this time.

Bottom Screening

A bottom screen or benthic barrier covers the sediment like a blanket, compressing aquatic plants while reducing or blocking light. Materials such as burlap, plastics, perforated black Mylar, AquaScreen, and woven synthetics can all be used as bottom screens. An ideal bottom screen should be durable and heavier than water. It should 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 AquaScreen (plastic-coated glass fiber), will billow due to gas buildup. Therefore, it is very important to anchor the bottom barrier securely to the bottom. Unsecured screens 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 screen, the rate that new sediment is deposited on the barrier, and the durability and longevity of the material. For example, burlap may rot within 2 years, and plants can grow on top of screen and fabric materials. Regular maintenance is essential and can extend the life of most bottom barriers. Bottom screens will control most aquatic plants; however, non-rooted species, such as the bladderworts or coontail, will not be controlled by bottom screens.

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 and Brazilian elodea. Pioneering colonies that are too extensive to be hand pulled can sometimes be covered with bottom screening material.

Bottom screens can be installed 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 screen installation. Research has shown that much more gas is produced under bottom screens that are installed over the top of aquatic plants. The less plant material that is present before installing the screen, the more successful the screen will be in staying in place. Bottom screens 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.

Advantages and Disadvantages

Advantages of bottom barriers include the following:

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

Disadvantages of bottom barriers include the following:

- Because bottom barrier screens reduce habitat by covering the sediment, they are suitable only for localized control.
- For safety and performance reasons, bottom screens must be regularly inspected and maintained.
- Harvesters, Rotovators, fishing gear, or boat anchors may damage or dislodge bottom screens.
- Improperly anchored bottom screens may create safety hazards for boaters and swimmers.
- Swimmers may be injured by poorly maintained anchors used to pin bottom screens to the sediment.
- Some bottom screens are difficult to anchor on deep muck sediments.
- Bottom screens interfere with fish spawning and bottom-dwelling animals.
- Without regular maintenance, aquatic plants may quickly colonize the bottom screen.

Permits and Costs

Bottom screening in Washington requires an HPA, in accordance with restrictions specified in the Aquatic Plants and Fish pamphlet (WDFW 2015) for control of noxious weeds, or an individual HPA permit for control of native plants in a large area. Local jurisdictions may require shoreline permits. 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 $1,700 to have 1,000 square feet of bottom screen installed.

Other Considerations

None.

Suitability for Green Lake

Bottom barriers have been used at the swimming beaches in Green Lake in the past. Without constant upkeep and maintenance, the long-term benefits of bottom barriers are minimal. Currently, infested areas are too widespread to use a bottom barrier without becoming cost prohibitive.

Barriers could be effective in localized areas, such as in swimming areas and around docks, to prevent re-infestation after initial control. Installing a bottom barrier at a dock can provide these benefits.

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Appendix C

Target Species Best Management Practices

HERRERA
Science + Planning + Design

Eurasian Watermilfoil

Myriophyllum spicatum **Class B Non-Regulated Noxious Weed**
Control Recommended

Variable-leaf Milfoil

Myriophyllum heterophyllum **Class A Noxious Weed**
Control Required

Haloragaceae

Legal Status in King County: Variable-leaf milfoil is a Class A Noxious Weed according to Washington State Noxious Weed Law, RCW 17.10 (non-native species that is harmful to environmental and economic resources and that landowners are required to eradicate). In accordance with state law, the King County Noxious Weed Control Board requires property owners to eradicate variable-leaf milfoil from private and public lands throughout the county (eradicate means to eliminate a noxious weed within an area of infestation). Eurasian watermilfoil is a Class B Non-Regulated Noxious Weed (non-native species that can be designated for control based on local priorities). The State Weed Board has not designated this species for control in King County. The King County Weed Control Board recommends control of Eurasian watermilfoil where feasible, but does not require it. State quarantine laws prohibit transporting, buying, selling, or distributing plants, plant parts or seeds of these milfoils.

BACKGROUND INFORMATION

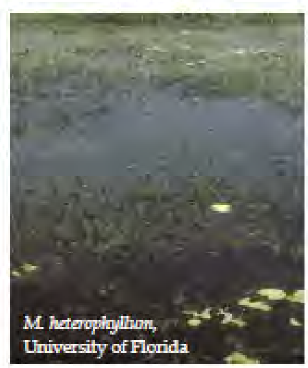
Impacts and History

- Eurasian watermilfoil is native to Eurasia but is widespread in the United States, including Washington. In King County it is present in numerous lakes and slow moving streams and rivers.
- Variable-leaf milfoil is native to the eastern United States. It was introduced to southwestern British Columbia several decades ago and was confirmed in Thurston and Pierce Counties in 2007.
- Both of these plants are very aggressive and can outcompete native aquatic plants, forming dense

M. spicatum, University of Minnesota

M. spicatum, Andrzej Martin Kasinski

M. heterophyllum Dan Tenaglia - missouriplants.com



M. heterophyllum, University of Florida monotypic stands. They can reduce biodiversity, change the predator/prey relationships in a lake and adversely impact the food web.

- These milfoil species impact recreation by eliminating swimming opportunities, fouling boat motors and snagging fishing lines.
- When allowed to grow in dense stands and "top out", the floating mats or emergent flower stems prevent wind mixing, and extensive areas of low oxygen can develop during the summer.
- Stagnant mats create mosquito breeding areas and increase the water temperature underneath by absorbing sunlight.
- These plants die back in the fall, and the resulting decay uses up dissolved oxygen and adds nutrients to the water, potentially increasing algae growth and related water quality problems.

Description, Reproduction and Spread

Milfoil species (*Myriophyllum* spp.) can be very difficult to tell apart, particularly when not in flower. Not only can the vegetative structures look very similar, but Eurasian watermilfoil (M. *spicatum*) is known to cross with the native northern milfoil (*M. sibiricum*), creating an invasive hybrid. Anyone who finds a new, aggressive population of milfoil should consult an expert to get a positive identification before taking action to control it.

Eurasian watermilfoil (*Myriophyllum spicatum*)

- Perennial, rhizomatous plant grows in water to 20 feet (possibly up to 30 feet) deep.
- Forms tangled underwater stands and dense floating mats.
- Leaves are in whorls of four, and are feathery, with generally more than 14 leaflet pairs per leaf. Leaves often appear squared-off at the tip. Leaves usually collapse against the stem when the plant is pulled from the water.
- Stems are long, branched near the surface, and usually reddish.
- Flowers are tiny and borne on reddish spikes above the water surface.
- Spread is generally by plant fragments or rhizomes.

- Can be confused with the native northern milfoil (*Myriophyllum sibiricum*), which generally has fewer than 14 leaflet pairs per leaf. The native milfoils also tend to retain their shape when pulled from the water rather than collapsing against the stem.

Flowering stalk, *M. heterophyllum*

Flowering stalk, *M. spicatum*

Variable-leaf milfoil (*Myriophyllum heterophyllum*)

- Perennial, rhizomatous plant grows in water to 15 feet deep.
- Forms tangled underwater stands and dense floating mats.
- Submersed leaves are in whorls of four to six, and are feathery, with six to 14 leaflet pairs per leaf.
- Flowering spikes emerge up to six inches above the water and have bright green, leaf-like bracts that are in whorls of 4 to 6 with toothed to entire margins.
- Flowers are tiny and borne in the axils of the leaf-like bracts.
- Submersed stems are stout (up to 8 mm in diameter), reddish, often with numerous branches. A cross-section of the stem will reveal "pie-shaped" air chambers.
- Spread is by plant fragments, rhizomes and seed.
- Has the ability to produce terrestrial plants with leaves resistant to drying. These apparently do not colonize new areas, but aid in the survival of the species in years when the water level is unusually low.
- Can be confused with the native western milfoil (*M. hippuroides*), which also has emergent flower stems with leaf-like bracts, and vegetative plants can be confused with the native northern milfoil (*Myriophyllum sibiricum*), which also has fewer than 14 leaflet pairs per leaf.

Habitat

- Milfoils grow in still and slow moving water, generally up to about 20 feet deep for Eurasian watermilfoil, and six to 15 for variable-leaf milfoil, depending on water clarity.
- They tend to cluster at downwind ends of smaller water bodies or in quiet coves where fragments can settle out of the water column and take root.
- Both tolerate a wide range of pH.
- Eurasian watermilfoil can tolerate brackish water.

Local Distribution

- Eurasian watermilfoil is widespread in western Washington and in King County, with established populations in the large lakes (Lakes Washington, Sammamish and Union), the Sammamish River, and a number of smaller lakes (notably Green Lake in Seattle).
- Variable-leaf milfoil was discovered in a lake in Thurston County in 2007, the first confirmed record in Washington State. It has since been found in another lake in Thurston County, as well as in two lakes in Pierce County (Blue and Clear Lakes), all four of which are privately owned. Since it is particularly difficult to distinguish from the native western milfoil (*M. hippuroides*), it may be established in other areas as well. The Washington State Department of Ecology is investigating other potential populations. At this writing, there are no confirmed populations of variable-leaf milfoil in King County.

CONTROL INFORMATION

Integrated Pest Management

- The preferred approach for weed control is Integrated Pest Management (IPM). IPM involves selecting from a range of possible control methods to match the management requirements of each specific site. The goal is to maximize effective control and to minimize negative environmental, economic and social impacts.
- Use a multifaceted and adaptive approach. Select control methods which reflect the available time, funding, and labor of the participants, the land use goals, and the values of the community and landowners. Management will require dedication over a number of years, and should allow for flexibility in method as appropriate.

Planning Considerations

- Survey area for weeds, set priorities and select best control method(s) for the site conditions and regulatory compliance issues (refer to the King County Noxious Weed Regulatory Guidelines).
- Small infestations may be effectively removed using manual methods or hand tools.
- Milfoil spreads by fragmentation, so care must be taken to contain and remove all plant fragments when using manual or mechanical control methods. Otherwise, the infestation will spread.
- Any control actions taken will necessarily affect all landowners adjacent to the water body and will require their approval and participation in order to succeed. In addition, many control options will be expensive and it will be more cost-effective to pool resources.
- Commit to monitoring. Once initial control has been achieved, be sure to conduct follow up monitoring and control in subsequent years in order to catch any overlooked patches or returning infestations before they can spread. Without this, control efforts can be wiped out within a few years. Monitor the site each year for at least three years after last observing any milfoil, and then again after three years.
- Any water body with a public boat launch should be monitored regularly since milfoils can be re-introduced easily from plant fragments on a boat or trailer.

Permitting and Regulatory Requirements

- Permits are required for all weed control work in natural water bodies.
- At minimum, the pamphlet **Aquatic Plants and Fish** is required. This pamphlet is published by the Washington State Department of Fish and Wildlife and acts as a Hydraulic Project Approval (HPA) permit. It is available free of charge online at http://wdfw.wa.gov/hab/aquaplnt/aquaplnt.htm or by calling (360) 902-2534. This "pamphlet HPA" is all you will need for most manual or light mechanical control methods.
- More extensive control, including some bottom barrier placement and all herbicide use, will require additional permits from Washington State. See the sections below for details.
- Permits and licenses are required for all herbicide use in aquatic systems. Minimum requirements include a pesticide applicator's license with an aquatic endorsement from the Washington Department of Agriculture and a permit from the Washington Department of Ecology.
- Some incorporated cities also regulate any work conducted in natural waterbodies. Contact your local jurisdiction for details.
- **Permit requirements can change from year to year. Contact the King County Noxious Weed Control Program for more information on current permitting requirements.**

Early Detection and Prevention

- Look for new plants. Get a positive plant identification from an authority such as King County Noxious Weed Control Program staff.
- Look for plants along lake shorelines and in stagnant or slow-moving water in wetlands and streams. Since these plants are often spread as fragments attached to boat motors and trailers, check especially around boat launches. Also check at the downwind end of the waterbody, and anywhere else where fragments could congregate or settle out of the water column.
- The best time to begin surveys is late spring when plants are visible, and surveys can continue into early fall when the plants senesce (die back).
- Clean all plant material off of boats, motors and trailers, and check bilgewater for plant fragments any time you have been in an infested water body (or a potentially infested water body).
- **Never dispose of unwanted aquarium or water garden plants or animals in a natural water body.** Variable-leaf milfoil in particular is still sold in some areas as an aquarium plant, and may have been introduced to Washington waters by careless dumping of aquariums.

Manual Control

- At minimum, an HPA pamphlet permit is required for all manual control activities in natural waterbodies. In incorporated areas, check with your local jurisdiction for other possible permit requirements.

- Hand pulling and the use of hand mechanical tools is allowable in all critical areas in unincorporated King County.
- Hand pulling can be successful for a very small area but is impractical for large infestations. Be sure to contain and remove all plants and plant fragments from the water.
- Weed rakes and weed cutters can assist in maintaining open water in a discrete area, such as around a dock, but will not eliminate the plants. Be sure to contain and remove all plants and plant fragments from the water.
- All manual control sites should be monitored for several years for signs of plants growing from roots or fragments.
- **DISPOSAL**: Milfoils can be composted on land away from water or placed in yard waste bins. Do not leave any plant parts or fragments in the water or near the water's edge. Variable-leaf milfoil can grow on exposed soil during periods of low water, so extra care should be taken to dispose of it away from the water.

Mechanical Control

- At minimum, an HPA pamphlet permit is required for all mechanical control activities in natural waterbodies. In incorporated areas, check with your local jurisdiction for other possible permit requirements.
- Cutting and harvesting using boat-mounted cutters or in-lake harvesting barges is effective at maintaining open water in water bodies with 100% of the available habitat infested. It must be done on a regular basis to maintain control. However, these methods will quickly spread these plants by creating numerous fragments, so cutting and harvesting are not recommended for small or partial infestations. Neither method will eradicate an infestation. In unincorporated King County, only an HPA pamphlet permit is required for cutting and harvesting noxious weeds.
- Diver dredging using boat or barge mounted suction dredges can be effective for small infestations or as a follow-up to herbicide treatment. Special care must be taken to remove all fragments. This method causes a temporary increase in turbidity and requires specific authorization from the Washington Department of Fish and Wildlife (WDFW).
- Rotovation (underwater rototilling) is not recommended since it causes severe fragmentation of the plants. Rotovation also results in significant short term turbidity and loss of water clarity and quality, as well as destruction of benthic habitat. Rotovation requires an individual HPA permit.

Cultural Methods

- An opaque bottom barrier can be used to suppress growth in small, discrete areas like at a boat launch or around a swimming area. Barriers need to be regularly cleaned because plants will root in the sediment that accumulates on top of them. This is not practical for large-scale infestations. Bottom barriers in Lake Washington and Lake Sammamish are not allowed without prior authorization by the Washington Department of Fish and Wildlife (WDFW) due to potential impact on sockeye salmon spawning areas. A pamphlet HPA at minimum is required for bottom barrier installation. Other permits may also be required.

- Waterbodies with control structures can sometimes use water level drawdown to control submerged weeds. Generally the bottom must be exposed to heat or cold long enough to dry out completely, something that can be difficult to achieve in rainy western Washington. Occasionally drawdowns can backfire and increase subsequent germination of weed seeds, especially with variable-leaf milfoil. Drawdowns can have major impacts on native plants and other aquatic organisms. Carefully weigh the pros and cons before deciding on this option. A drawdown is not covered by the pamphlet HPA. Consult your local WDFW office for permit information.

Chemical Control

- Permits and licenses are required for all chemical control in water.
- Herbicides may be the most reasonable option for eradication of large submerged noxious weed infestations. Professional licensed contractors are available for hire to perform this task.
- Herbicides can only be applied to aquatic systems in Washington State by a licensed pesticide applicator. Aquatic formulations of herbicides are not available for sale over the counter to anyone without an aquatic pesticide license. **NEVER apply non-aquatic herbicide formulations to water since most of them include ingredients that are toxic to aquatic organisms.**
- Multiple years of treatment may be required to eradicate a milfoil infestation. For several years following treatment, monitor areas for new plants germinating from the seed bank. Remove any new growth using one of the manual control methods above.

Specific Herbicide Information

Milfoil species are dicots, and therefore selective herbicides can be used to control them with minimal collateral damage to the primarily monocot native plant communities. 2,4-D, a selective herbicide, and fluridone, a non-selective herbicide, have both been used to control Eurasian watermilfoil to good effect in western Washington lakes. However, 2,4-D cannot be used in waterbodies that support salmonids (salmon and trout species). Triclopyr, another selective herbicide, has been approved for control of submerged plants as of 2008 and shows promise as an alternative herbicide for milfoil control. Endothall and diquat, which are both contact herbicides, will control existing vegetation, but will not kill the roots, so the control is temporary.

The mention of a specific product brand name in this document is not, and should not be construed as an endorsement or as a recommendation for the use of that product. Chemical control options may differ for private, commercial and government agency users. **For questions about herbicide use, contact the King County Noxious Weed Control Program at 206-296-0290.**

Biological

- Triploid grass carp have been tried as a control for milfoil species, but milfoil is not palatable to them, and they will generally eat everything else in the waterbody first. Grass carp are not allowed in water bodies where the inlet and outlet cannot be screened to prevent fish from leaving the waterbody. Grass carp are not allowed anywhere in the Lake Washington and Lake Sammamish system. They are not recommended as a control for milfoil, although they can be used if these species predominate. Care should be taken to evaluate potential impacts on the native plant community before choosing grass carp as a control method.
- In some situations, the native milfoil weevil (*Euhrychiopsis lecontei*) seems to control Eurasian watermilfoil. The weevil appears to prefer Eurasian watermilfoil over its native host, northern watermilfoil (*Myriophyllum sibiricum*), and in lakes where the weevil occurs naturally, Eurasian milfoil has been shown to be less of a problem. Ongoing research is exploring lake conditions in which the weevil may thrive, including water pH and the abundance of insect-eating fish. Although no permits are needed to use native insects as biocontrol, currently the weevils are difficult to obtain in quantities high enough to have an effect on milfoil populations. Even when they have been specially reared and introduced, it can take several years for populations in a waterbody to reach sufficient levels to control milfoil populations. Biocontrols of any type will not eradicate milfoil, but if effective should reduce a milfoil population to below the threshold of significant impact.

SUMMARY OF BEST MANAGEMENT PRACTICES

- At all times at minimum a pamphlet HPA permit is required to do any activity that disturbs a lake bottom or wetland or streambed. For more extensive work, more specific permits will be required.
- Hand pulling or digging is recommended for small populations, with extreme care taken not to let fragments spread.
- Where a population has filled every possible inch of habitat in a waterbody and its connected waterways, cutting or harvesting when done consistently can maintain open water and diminish the adverse affects of these species.
- Bottom barriers can maintain small areas of open water around boat launches, swimming areas or docks, as long as care is taken to keep them free of debris and fragments.
- Diver dredging can be effective for small infestations or as a follow-up to herbicide treatment.
- To eradicate large areas of milfoil, herbicides are probably the best option.
- **Do not apply any herbicide to water without the proper licenses.** Hire a contractor to do the work.

Control in small isolated or man-made ponds

- Permits may be required (see "Permitting and Regulatory Requirements" section above).
- Drawdown can be very effective. Remove all plants and plant fragments. Let the bed dry out completely before refilling. Thoroughly clean pond liners. Examine or discard ornamental plants that may harbor plant fragments before re-introducing them to the pond.
- Manual control will work if the infestation is caught early and all fragments are removed.
- Bottom barriers may be effective over natural pond beds.
- Follow recommendations above for chemical control.

Control in small lakes

- Permits will be required for all control work (see "Permitting and Regulatory Requirements" section above).
- Community involvement will be essential for successful control efforts.
- For small pioneering infestations, manual control or bottom barriers may be effective. Monitor the lake for fragments and additional infestation sites. Maintain bottom barriers to prevent sediment buildup.
- For large or whole-lake infestations, chemical control will be the most effective (see above for chemical recommendations). Mechanical control may be used to manage infestations, but will not eradicate the weeds. Bottom barriers, if properly maintained, will create open water in small areas.

Control in flowing water (rivers, streams, ditches)

- Permits will be required for all control work (see "Permitting and Regulatory Requirements" section above).
- The most effective control will start with the furthest upstream infestation and move downward. If there are any weeds left upstream, any cleared site will likely be re-infested.
- If possible, contain the area being controlled with a boom to catch fragments before they float downstream.
- Manual control may be the most practical. Bottom barriers need to be securely anchored.
- Chemical control in flowing water is difficult. Consult an expert before considering this option.

Control along shores of Lakes Washington and Sammamish

- Permits will be required for all control work (see "Permitting and Regulatory Requirements" section above).
- Eradication of submerged aquatic weeds from these waterbodies is not practical.
- Bottom barriers, if properly maintained, can provide open water around docks, marinas, swimming beaches, and similar areas. Prior authorization by the Washington

Department of Fish and Wildlife (WDFW) is required due to potential impact on sockeye salmon spawning areas.

- Manual control of small patches may be sufficient.
- Mechanical control can be effective for lakeside communities or large marinas. Be sure to remove all fragments from the water.
- Spot control using chemicals can be effective in the right conditions. It is possible that more than one species of submerged noxious weeds may be present (particularly Brazilian elodea, which is increasing in these lakes). If this is the case, be sure to select an herbicide that will control all targeted weeds (consult BMPs for each weed or ask an expert for assistance in selecting herbicides). If there is any significant wave action or current, the chemicals will drift off target or quickly become diluted. Consult with a professional contractor before choosing this option. Neighboring property owners should be advised prior to spot chemical applications.
- Grass carp are not allowed in the Lake Washington and Lake Sammamish system.

Disposal Methods

- Eurasian watermilfoil can be left on land to dry out and/or decompose where it will not move into a waterway.
- Variable-leaf milfoil should not be left on the bank since it may root in damp soil.
- Both milfoils can be composted or placed in yard waste bins.

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Egeria

Egeria densa **Class B Noxious Weed**
Hydrocharitaceae **Control Required except in Selected Areas**

Legal Status in King County: Egeria is a class B noxious weed according to Washington State Noxious Weed Law, RCW 17.10 (non-native species that is harmful to environmental and economic resources and that landowners may be required to control based on distribution in the county and local priorities). The King County Noxious Weed Control Board requires property owners to control Egeria on private and public lands in the county except in Lakes Washington, Sammamish, Union and Fenwick (control, as defined by state law, means to prevent all seed production and to prevent the dispersal of all propagative parts capable of forming new plants). State quarantine laws prohibit transporting, buying, selling, or distributing plants, plant parts or seeds of Egeria.

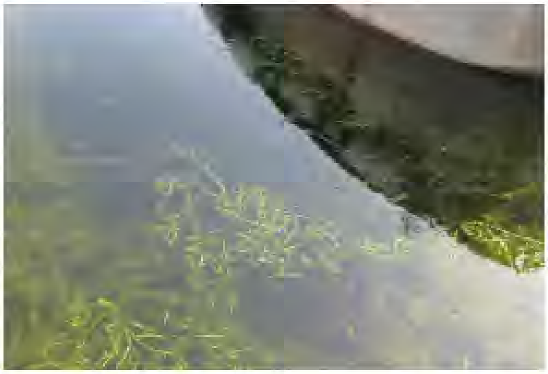
BACKGROUND INFORMATION

Impacts and History

- Native to South America and introduced to the United States through the aquarium trade, it is found scattered throughout western Washington. In King County it is established in Lakes Washington, Sammamish, Union, Fenwick and Dolloff. It is also prolific in the Sammamish River and around Fisherman's Terminal on the Lake Washington Ship Canal.
- Very aggressive and can outcompete native aquatic plants, forming dense monotypic stands. Can reduce biodiversity, change the predator/prey relationships in the lake and adversely impact the food web.

- Impacts recreation by eliminating swimming opportunities, fouling boat motors and snagging fishing lines.
- When allowed to grow in dense stands and "top out", the floating mats prevent wind mixing and extensive areas of low oxygen can develop during the summer.
- Stagnant mats create mosquito breeding areas and increase the water temperature underneath by absorbing sunlight.

- These plants may die back in the fall, and the resulting decay uses up dissolved oxygen and adds nutrients to the water, potentially increasing algae growth and related water quality problems.

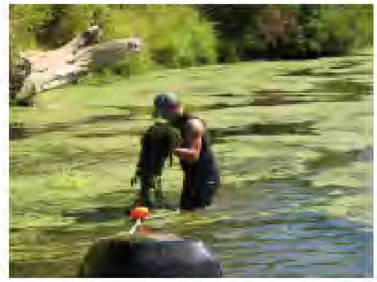


Description, Reproduction and Spread

- Perennial, grows in up to 20 feet of water.
- Generally submergent but can form floating mats.
- Leaves are visibly smooth-edged (teeth are visible with magnification) and densely packed in whorls of four (or up to six).
- Relatively showy white flower has three petals and a yellow center. It is fragrant and floats on the water surface. Flowers are attached on slender stalks to the base of leaf whorls, and there are up to three flowers per whorl. Only male plants are known from the United States.
- Can thrive in relatively low light. High temperatures and high light conditions can cause senescence (die back).
- Often has two major growth periods, one in spring and one in fall. Some plants often persist through the winter.
- Is not known to seed in North America. Spreads by fragmentation.
- Can be confused with the native American waterweed (*Elodea canadensis*), which has a less robust appearance and smooth-edged leaves generally in whorls of three.
- In the nursery trade, also known as Brazilian waterweed, South American waterweed, Common waterweed, Brazilian elodea, and Anacharis.

Native *Elodea canadensis* (left) and *Egeria* (right)

Habitat



- Occurs in still and slow moving water up to about 20 feet deep, depending on water clarity.
- Tend to cluster at downwind ends of smaller water bodies or in quiet coves where fragments can settle out of the water column and take root.
- Tolerates a wide range of pH.

CONTROL INFORMATION

Integrated Pest Management

- The preferred approach for weed control is Integrated Pest Management (IPM). IPM involves selecting from a range of possible control methods to match the management requirements of each specific site. The goal is to maximize effective control and to minimize negative environmental, economic and social impacts.
- Use a multifaceted and adaptive approach. Select control methods that reflect the available time, funding, and labor of the participants, the land use goals, and the values of the community and landowners. Management will require dedication over a number of years, and should allow for flexibility in method as appropriate.

Planning Considerations

- Survey area for weeds, set priorities and select best control method(s) for the site conditions and regulatory compliance issues (refer to the King County Noxious Weed Regulatory Guidelines).
- Small infestations may be effectively removed using manual methods or hand tools.
- Egeria spreads by fragmentation, so extreme care must be taken to contain and remove all plant fragments when using manual or mechanical control methods. Otherwise, the infestation will spread.
- Any control actions taken will necessarily affect all landowners adjacent to the water body and will require their approval and participation in order to succeed. In addition, many control options will be expensive and it will be more cost-effective to pool resources.
- Commit to monitoring. Once initial control has been achieved, be sure to conduct follow up monitoring and control in subsequent years in order to catch any overlooked patches or returning infestations before they can spread. Without this, your control efforts can be wiped out within a few years. Monitor the site each year for at least three years after last observing any Egeria, and then again after three years.

Permitting and Regulatory Requirements

- Permits are required for all weed control work in natural waterbodies.
- At minimum, the pamphlet Aquatic Plants and Fish is required. This pamphlet is published by the Washington State Department of Fish and Wildlife (available free of

charge online at http://wdfw.wa.gov/licensing/aquatic_plant_removal or by calling (360) 902-2534) and acts as a Hydraulic Project Approval (HPA) permit. This "pamphlet HPA" is all you will need for most manual or light mechanical control methods.

- More extensive control, including some bottom barrier placement and all herbicide use, will require additional permits from Washington State. See the sections below for details.
- Permits and licenses are required for all herbicide use in aquatic systems. Minimum requirements include a pesticide applicator's license with an aquatic endorsement from the Washington Department of Agriculture and a permit from the Washington Department of Ecology.
- Some incorporated cities also regulate any work conducted in natural waterbodies. Contact your local jurisdiction for details.
- **Permit requirements can change from year to year. Contact the King County Noxious Weed Control Program for more information on current permitting requirements.**

Early Detection and Prevention

- Look for new plants. Get a positive plant identification from an authority such as King County Noxious Weed Control Program staff.
- Look for plants along lake shorelines and in stagnant or slow-moving water in wetlands and streams. Since these plants are often spread as fragments attached to boat motors and trailers, check especially around boat launches. Also check at the downwind end of the waterbody, and anywhere else where fragments could congregate or settle out of the water column.
- The best time to begin surveys is late spring when plants are visible, and surveys can continue into fall when the plants begin to senesce (die back).
- Clean all plant material off of boats, motors and trailers, and check bilgewater for plant fragments any time you have been in an infested waterbody (or a potentially infested waterbody).
- **Never dump unwanted aquarium or water garden plants or animals into a natural waterbody.** Egeria is still sold in some areas as an aquarium plant, and it was probably introduced to Washington waters by careless dumping of aquariums. It has several other common names, including Brazilian waterweed, Brazilian elodea, South American waterweed, and Anacharis.

Manual Control

- At minimum, an HPA pamphlet permit is required for all manual control activities in natural waterbodies. In incorporated areas, check with your local jurisdiction for other possible permit requirements.
- Hand pulling and the use of hand mechanical tools is allowable in all critical areas in unincorporated King County.
- Hand-pulling can be successful for a very small area but is impractical for large infestations. Be sure to contain and remove all plants and plant fragments from the water.

- Weed rakes and weed cutters can assist in maintaining open water in a discrete area, such as around a dock, but will not eliminate the plants. Be sure to contain and remove all plants and plant fragments from the water.
- All manual control sites should be monitored for several years for signs of plants growing from roots or fragments.
- **DISPOSAL**: Egeria can be composted on land away from water or placed in yard waste bins. Do not leave any plant parts or fragments in the water or near the water's edge.

Mechanical Control

- At minimum, an HPA pamphlet permit is required for all mechanical control activities in natural waterbodies. In incorporated areas, check with your local jurisdiction for other possible permit requirements.
- Cutting and harvesting using boat-mounted cutters or in-lake harvesting barges is effective at maintaining open water in waterbodies with 100% of the available habitat infested. It must be done on a regular basis to maintain control. However, these methods will quickly spread these plants by creating numerous fragments, so cutting and harvesting are not recommended for small or partial infestations. Neither method will eradicate an infestation. In unincorporated King County, only an HPA pamphlet permit is required for cutting and harvesting noxious weeds.
- Diver dredging using boat or barge mounted suction dredges can be effective for small infestations or as a follow-up to herbicide treatment. Thurston County successfully controlled Egeria in the Chehalis River using this method. Special care must be taken to remove all fragments. This method causes a temporary increase in turbidity and requires specific authorization from the Washington Department of Fish and Wildlife (WDFW).
- Rotovation (underwater rototilling) is not recommended since it causes severe fragmentation of the plants. Rotovation also results in significant short-term turbidity and loss of water clarity and quality. Rotovation requires an individual HPA permit.

Cultural Methods

- An opaque bottom barrier can be used to suppress growth in small, discrete areas like at a boat launch or around a swimming area. Barriers need to be regularly cleaned because plants, including Egeria fragments, will root in the sediment that accumulates on top of them. This is not practical for large-scale infestations. Bottom barriers in Lake Washington and Lake Sammamish are not allowed without prior authorization by the Washington Department of Fish and Wildlife (WDFW) due to potential impact on sockeye salmon spawning areas. A pamphlet HPA at minimum is required for bottom barrier installation. Other permits may also be required.
- Waterbodies with control structures can sometimes use water level drawdown to control submerged weeds. Generally, the bottom must be exposed to heat or cold long enough to dry out completely, something that can be difficult to achieve in rainy western Washington. Consecutive drawdowns may be more effective than a single attempt. Drawdowns can have major impacts on native plants and other aquatic organisms.

Carefully weigh the pros and cons before deciding on this option. A drawdown is not covered by the pamphlet HPA. Consult your local WDFW office for permit information.

Chemical Control

- Permits and licenses are required for all chemical control in water.
- Herbicides may be the most reasonable option for eradication of large submerged noxious weed infestations. Professional licensed contractors are available for hire to perform this task.
- Herbicides can only be applied to aquatic systems in Washington State by a licensed pesticide applicator. Aquatic formulations of herbicides are not available for sale over the counter to anyone without an aquatic pesticide license. **NEVER apply non-aquatic herbicide formulations to water since most of them include ingredients that are toxic to aquatic organisms.**
- Multiple years of treatment may be required to eradicate a Egeria infestation. For several years following treatment, monitor areas for new plants. Remove any new growth using one of the manual control methods above.

Specific Herbicide Information

The only herbicide allowed in Washington waters that has been shown to be successful against Egeria is fluridone (e.g., brand name Sonar®). Endothall and diquat have proven successful in combination with copper compounds, but the use of copper is illegal in most Washington State waters due to its demonstrated toxicity to juvenile salmonids.

The mention of a specific product brand name in this document is not, and should not be construed as an endorsement or as a recommendation for the use of that product. Chemical control options may differ for private, commercial and government agency users. **For questions about herbicide use, contact the King County Noxious Weed Control Program at 206-477-9333.**

Biological

- Triploid grass carp can be an option for controlling Egeria. Tests have shown that the carp prefer Egeria to native species. However, in practice, grass carp may remove the entire plant community. Grass carp are not allowed in water bodies where the inlet and outlet cannot be screened. Care should be taken to evaluate potential impacts on the native plant community before choosing grass carp to control Egeria.
- Although research is being done on a variety of invertebrates and pathogens, there are currently no accepted biocontrol agents for Egeria other than grass carp.

SUMMARY OF BEST MANAGEMENT PRACTICES

- At all times a minimum of a pamphlet HPA permit is required to do any activity that disturbs a lake bottom, wetland or streambed. For more extensive work, more specific permits will be required.
- Hand-pulling is recommended for small populations, with extreme care taken to remove all plants and fragments from the water.
- Where the plant has filled every possible inch of habitat in a water body and its connected waterways, cutting or harvesting can keep a large population under control when done consistently.
- Bottom barriers can maintain small areas of open water around boat launches, swimming areas or docks, as long as care is taken to keep them free of debris and fragments.
- Diver dredging has been effective in the Chehalis River and can be a good option in moving water.
- To eradicate large areas of Egeria, herbicides are probably the best option.
- **Do not apply any herbicide to water without the proper licenses.** Hire a contractor to do the work.

Control in small isolated or man-made ponds

- Permits may be required (see "Permitting and Regulatory Requirements" section above).
- Drawdowns can be very effective. Remove all plants and plant fragments. Let the bed dry out completely before refilling. Thoroughly clean pond liners. Examine or discard ornamental plants that may harbor plant fragments before re-introducing them to the pond.
- Manual control will work if the infestation is caught early and all fragments are removed.
- Bottom barriers may be effective over natural pond beds.
- Follow recommendations above for chemical control.
- Triploid grass carp may be an option if eradication is not desired.

Control in small lakes

- Permits will be required for all control work (see "Permitting and Regulatory Requirements" section above).
- Community involvement will be essential for successful control efforts.
- For small pioneering infestations, manual control or bottom barriers may be effective. Monitor the lake for fragments and additional infestation sites. Maintain bottom barriers to prevent sediment buildup.
- For large or whole-lake infestations, chemical control will be the most effective (see above for chemical recommendations). Mechanical control, or grass carp where allowed and appropriate, may be used to manage infestations, but will not eradicate the weeds. Bottom barriers, if properly maintained, will create open water in small areas.

Control in flowing water (rivers, streams, ditches)

- Permits will be required for all control work (see "Permitting and Regulatory Requirements" section above).
- The most effective control will start with the furthest upstream infestation and move downstream. If there are any weeds left upstream, any cleared site will likely be re-infested.
- If possible, contain the area being controlled with a boom to catch fragments before they float downstream.
- Diver dredging has proven effective in flowing water.
- Manual control may be the most practical for small infestations. Bottom barriers need to be securely anchored.
- Chemical control in flowing water is difficult. Consult an expert before considering this option.
- Grass carp will not be allowed in flowing water.

Control along shores of Lakes Washington and Sammamish

- Permits will be required for all control work (see "Permitting and Regulatory Requirements" section above).
- Eradication of submerged aquatic weeds from these water bodies is not practical.
- Bottom barriers, if properly maintained, can provide open water around docks, marinas, swimming beaches, and similar areas. Prior authorization by the Washington Department of Fish and Wildlife (WDFW) is required in these lakes due to potential impact on sockeye salmon spawning areas.
- Manual control of small patches may be sufficient.
- Mechanical control can be effective for lakeside communities or large marinas. Be sure to remove all fragments from the water.
- Spot control using chemicals can be effective in the right conditions. It is possible that more than one species of submerged noxious weeds may be present (particularly Eurasian watermilfoil, which is widespread in these lakes). If this is the case, be sure to select an herbicide that will control all targeted weeds (consult BMPs for each weed or ask an expert for assistance in selecting herbicides). If there is any significant wave action or current, the chemicals will drift off target or quickly become diluted. Consult with a professional contractor before choosing this option. Neighboring property owners should be advised prior to spot chemical applications.
- Grass carp are not allowed in the Lake Washington and Lake Sammamish system.

Disposal Methods

- Egeria can be left on land to dry out and/or decompose where it will not move into a waterway.
- Egeria can be composted away from water or placed in yard waste bins.
- Never dispose of Egeria into waterways, wetlands, or other wet sites where it might grow and spread.

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Fragrant Water Lily

Nymphaea odorata
Nymphaeaceae

Class C Noxious Weed
Control Recommended

Legal Status in King County: Fragrant water lily is a Class C noxious weed (non-native species that can be designated for control based on local priorities) according to Washington State Noxious Weed Law, RCW 17.10. The State Weed Board has not designated this species for control in King County. The King County Weed Control Board recommends control of this species where feasible, but does not require it.

BACKGROUND INFORMATION

History and Impacts

- *Nymphaea odorata* is native to the eastern half of North America, including southern Canada. It has been introduced as an ornamental in many parts of the world and is now found throughout North America. Although found throughout Washington, fragrant water lily is especially prevalent in western Washington lakes where it has been intentionally planted by property owners who admired the showy flowers.
- It is believed that fragrant water lily was originally introduced into Washington during the Alaska Pacific Yukon Exposition held in Seattle in the late 1800s.
- Left unmanaged, water lilies can restrict lake-front access and hinder recreation.
- Drownings in King County have been attributed to swimmers getting tangled in dense water lily stems.
- Water lilies foul boat motors and restrict passage for non-motorized boats.
- When allowed to grow in dense stands, the floating leaves prevent wind mixing and extensive areas of low oxygen can develop under water lily beds during the summer.
- Aggressive water lily mats can outcompete native plants, reduce biodiversity, change the predator/prey relationships in the lake and adversely impact the food web.
- Stagnant mats create mosquito breeding areas and increase the water temperature underneath by absorbing sunlight.
- Water lilies die back in the fall, and the resulting decay uses up dissolved oxygen and adds nutrients to the water, potentially increasing algal growth and related water quality problems.

Description

- Perennial floating leaved rooted aquatic plant, growing in about three to six feet of water. Blooms June to October.
- **Round, green leathery leaves** up to 10 inches across have a basal slit. The flexible leaf stalk is attached at the base of the slit. The leaves float on the surface of the water, rarely sticking up above it as water level drops.
- **Many-petaled Flowers** are showy and range from white to pink (rarely yellow). They are borne on an individual stalk which curls like a corkscrew after the flower has been fertilized and pulls the flower under water. Seeds are leathery capsules with numerous small seeds.
- Both flower and leaf stalks arise from **thick fleshy rhizomes**.
- Adventitious roots attach the horizontal creeping and branching rhizomes.

Habitat

- Fragrant water lily occurs in shallow freshwater ponds and lake margins 3-6 feet deep.
- It will also grow in slow moving water.
- It can tolerate a wide range of pH, and it prefers substrates from mucky to silty.

Reproduction and Spread

- Spreads by floating seed and by rhizomes.
- Seeds disperse through the water by wind and wave action.
- Rhizome pieces can also break off and move through the water before establishing in a new location.
- A planted rhizome will spread to cover about a 15-foot diameter circle in five years.
- Primary source of distribution to new water bodies is deliberate planting. Many cultivars of *Nymphaea odorata* are available in the nursery trade. However, waterfowl can also spread the plant between water bodies.

Local Distribution

- While fragrant water lily is widely present in western Washington, it is less so in eastern Washington and uncommon to absent in western Oregon lakes.
- *Nymphaea odorata* was found in 27 of 36 surveyed lakes in the developed areas of King County in 1996. The number of ponds and smaller wetlands containing the plant is considerably larger.
- Requests for water lily control represent a high percentage of the herbicide permit requests received by the Washington State Department of Ecology.

CONTROL INFORMATION

Integrated Pest Management

- The preferred approach for weed control is Integrated Pest Management (IPM). IPM involves selecting from a range of possible control methods to match the management requirements of each specific site. The goal is to maximize effective control and to minimize negative environmental, economic and social impacts.
- Use a multifaceted and adaptive approach. Select control methods which reflect the available time, funding, and labor of the participants, the land use goals, and the values of the community and landowners. Management will require dedication over a number of years, and should allow for flexibility in method as appropriate.

Planning Considerations

- Survey area for weeds, set priorities and select best control method(s) for the site conditions and regulatory compliance issues (**refer to the King County Noxious Weed Regulatory Guidelines**).
- Small infestations may be effectively removed using manual methods or hand tools.
- For many lake and wetland infestations, the whole community will need to be engaged. Any control actions taken will necessarily affect all landowners adjacent to the water body and will require their approval and participation in order to succeed. In addition, many control options will be expensive.
- Commit to monitoring. Once initial control has been achieved, be sure to conduct follow up monitoring in subsequent years in order to catch any overlooked patches or returning infestations before they can spread. Without this, your control efforts can be wiped out within a few years.

Early Detection and Prevention

- Look for new plants. Get a positive plant identification from an authority such as King County Noxious Weed Control Program staff.
- Look for plants along lake shorelines and in stagnant or slow-moving water in wetlands and streams.
- The best time to begin surveys is late spring when new leaves arise, and they can continue into early fall when the plants senesce.
- Dig up small isolated patches.
- Don't plant fragrant water lily in natural water bodies. It is legal to buy and plant water lilies, but their use as an ornamental should be restricted to small self-contained ponds and other man-made water features with no hydrologic connection to any natural body of water.

Manual

- Hand pulling or cutting can be successful for a small area if repeated on a regular basis. Impractical for large infestations. Must remove all pulled or cut plants and plant parts from the water. HPA pamphlet permit required.
- Carbohydrate depletion is a technique whereby during each growing season, all emerging leaves are consistently removed. Reports indicate that it takes about two to three seasons to kill the plants. This method is difficult to sustain and impractical for large infestations.
- To completely remove plants by hand you must dig up the entire rhizome. HPA pamphlet permit required.
- All manual control sites should be monitored for several years for signs of plants growing from root fragments and from the seed bank.
- Hand pulling and the use of hand mechanical tools is allowable in all critical areas.
- Fragrant water lily can be composted on land or placed in yard waste bins.

Mechanical

- Permits are required for all mechanical control methods.
- An opaque bottom barrier can be used to suppress growth in small, discrete areas like at a boat launch or around a swimming area. Barriers need to be regularly cleaned because plants will root in the sediment that accumulates on top of them. Not practical for large-scale infestations.
- Cutting and Harvesting using boat-mounted cutters or in-lake harvesting barges is a reasonable long-term control solution. These must be done on a regular basis to maintain control. Neither method will eradicate an infestation.
- Rotovation (underwater rototilling) dislodges the large, fleshy waterlily rhizomes which can then be removed from the water. This process results in the permanent removal of waterlily rhizomes. Rotovation results in significant short term turbidity and loss of water clarity and quality.
- Other mechanical solutions that have been tried include mounting a backhoe to a barge and digging the plants out.

Chemical

- Herbicides may be the most reasonable option for eradication of large fragrant water lily infestations. Professional licensed contractors are available for hire to perform this task.
- Herbicides can only be applied to aquatic systems in Washington State by a licensed pesticide applicator. Aquatic formulations of herbicides are not available for sale over the counter to anyone without an aquatic pesticide license. **NEVER apply non-aquatic herbicide formulations to water since most of them include ingredients that are toxic to aquatic organisms.**
- For several years following treatment, monitor areas for new plants germinating from the seed bank. Eradicate any new growth using one of the manual control methods above.

Specific Herbicide Information

Glyphosate (e.g. Rodeo™ or Aquamaster™) Apply to actively growing foliage. Avoid runoff. Caution: Glyphosate is non-selective: it will injure or kill other vegetation contacted by the spray. NEVER substitute Round-up™ or other landscape formulations of Glyphosate: these have additives that can devastate aquatic systems.

Imazapyr (Habitat®) Apply to actively growing foliage. Caution: Imazapyr is non-selective: it will injure or kill other vegetation contacted by the spray.

Triclopyr (Renovate†3). Apply to actively growing foliage. Triclopyr is selective: it will injure other broadleaved plants but not grasses or other monocots such as cattails, rushes, or most native aquatic plants.

All the above listed herbicides require the addition of an approved surfactant. Follow label directions for selecting the correct type of surfactant. Be sure that the selected surfactant is approved for aquatic use.

The mention of a specific product brand name in this document is not, and should not be construed as an endorsement or as a recommendation for the use of that product. Chemical control options may differ for private, commercial and government agency users. **For questions about herbicide use, contact the King County Noxious Weed Control Program at 206-296-0290.**

Biological

- There is currently no biological control approved for fragrant water lily.
- Although a number of organisms have been studied in the past, there is no current plan to pursue biological control for fragrant water lily due to the widespread use of the plant as an ornamental in private, isolated water features.

SUMMARY OF BEST MANAGEMENT PRACTICES

- At all times at minimum a pamphlet HPA permit is required to do any activity that disturbs a lake bottom or wetland or streambed. For more extensive work, more specific permits will be required.
- Hand pulling, cutting or digging is recommended for small populations.
- Where this is not practical, cutting or harvesting can keep a large population under control when done consistently.
- Bottom barriers can maintain small areas of open water around boat launches, swimming areas or docks.
- To remove large areas of water lilies, mechanical methods (such as rotovation) or herbicides can be used.
- **Do not apply any herbicide to water without the proper licenses.** Hire a contractor to complete the work.

Disposal Methods

- Fragrant water lily can be left on land to dry out and/or decompose in an area where it will not move into a waterway.
- Fragrant water lily can also be composted away from water or placed in yard waste bins.
- Never dispose of fragrant water lily into waterways, wetlands, or other wet sites where it might grow and spread.

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