2008 AQUATIC PLANT SURVEY REPORT

Chester Morse Lake - Delta Plant Community Monitoring Study

Prepared for

Seattle Public Utilities
Watershed Services Division

December 2008

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Watershed Services Division
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December 22, 2008

Contents

Tables

Figures

Introduction

This report presents the results of an aquatic plant survey conducted in 2007 at Chester Morse Lake, the City of Seattle municipal water supply reservoir located in the Cedar River Municipal Watershed, east of Seattle, Washington. Since 1987, Seattle Public Utilities (SPU) has been monitoring plant communities in the vicinity of the confluence of the two major tributaries to Chester Morse Lake, the Cedar and Rex rivers (Raedeke 1991, 1997). One purpose of the monitoring is to evaluate the response of plant communities in these areas to long-term lake surface elevation fluctuations that result from reservoir management.

The current delta plant community monitoring study is a commitment under the Cedar River Watershed Habitat Conservation Plan (HCP) (City of Seattle 2000), which is intended to protect and restore habitats for species that are protected under the federal Endangered Species Act (ESA) and selected species that may become listed in the next few decades. The delta areas provide habitat for bull trout, which is listed as threatened by U.S. Fish and Wildlife Service, as well as pygmy whitefish, which is a primary prey source for bull trout.

As part of the delta plant community monitoring program, SPU contracted with Herrera Environmental Consultants, Inc. (Herrera) to characterize submergent aquatic plant species composition, distribution, and biomass in the vicinity of the Cedar River and Rex River deltas, and in selected portions of Young's Cove and Masonry Pool. These four areas are shown in Figure 1 and referred to as *study areas* in this report. Collectively, they are referred to as the *project area* for this aquatic plant mapping effort.

The overall goals of the delta aquatic plant community studies are:

- To document and understand changes in delta aquatic plant communities in response to reservoir operations; and
- To identify species, plant communities, and their distribution in time and space.

The objectives of the aquatic plant survey described in this report are to provide maps showing the distribution of submerged plant species, and to estimate the total submerged plant cover and biovolume within the study areas. Data collected for this survey will be used by SPU to evaluate current conditions in delta aquatic plant communities, and to provide baseline data for estimating the effects on aquatic plant communities from any future changes in the lake level management regime.

This report begins with background information about previous plant monitoring studies of Chester Morse Lake. Methods of data collection and analysis are described. Results of submerged plant cover and bioviolume, and emergent plant distribution are presented and discussed. In addition, factors affecting the distribution of submerged plants are discussed. This report concludes with a discussion of some limitations of the 2007 survey methods and provides options for improving future survey methodology.

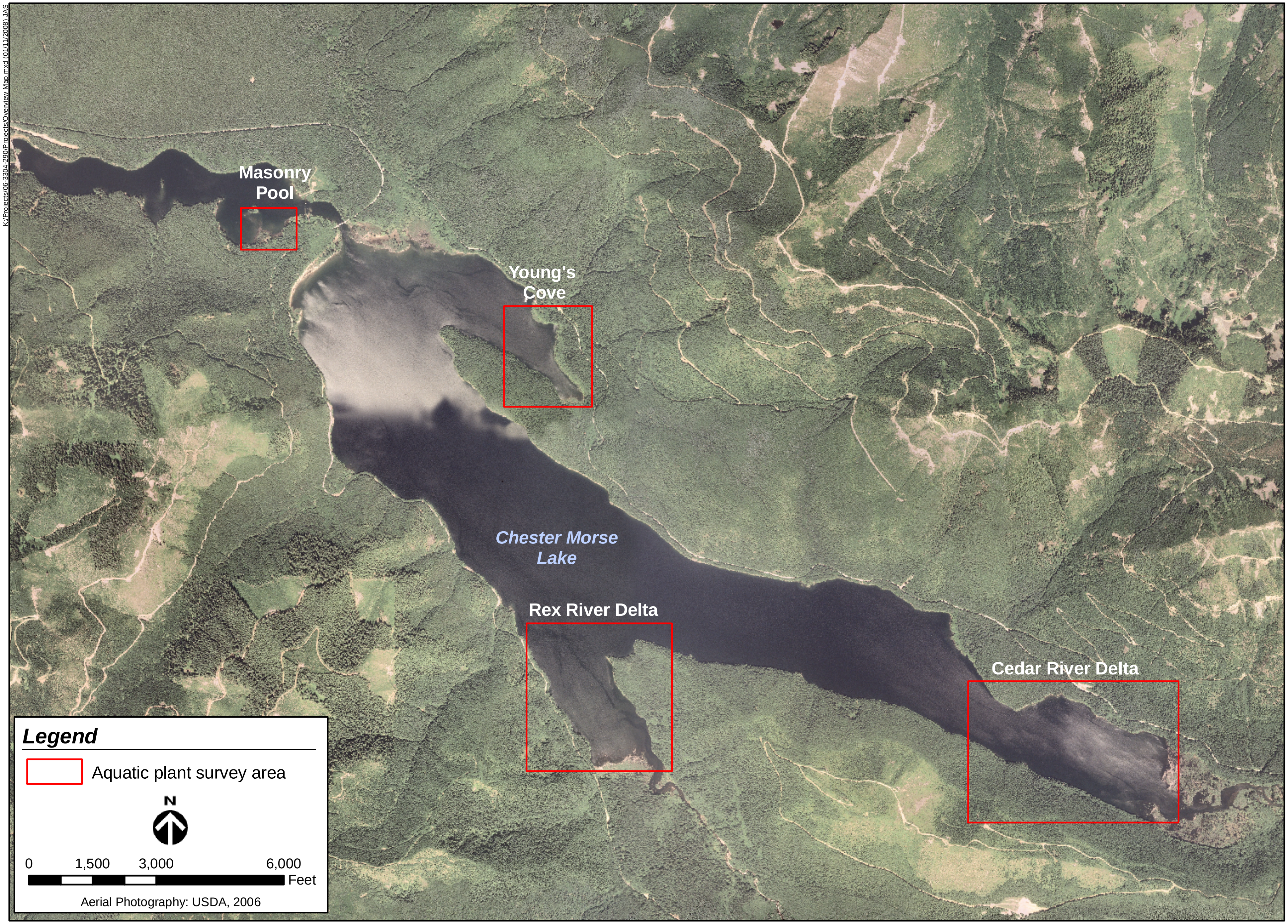

Figure 1. Aquatic plant survey areas at Chester Morse Lake in 2007.

Previous Studies

From 1987 to 1996, SPU conducted a monitoring study of the Rex and Cedar river deltas, coincident with a change in the configuration of the Chester Morse Lake dam structures and a new water management program (Raedeke 1997). Chester Morse Lake levels are managed to provide adequate water in the Cedar River for drinking water supplies and in-stream flows for fish species, and secondarily to attenuate downstream flooding. During the study, the water management program changed to higher and longer peak lake levels, and lower drawdown levels than prior to the 1987-1996 monitoring period.

In the Raedeke (1997) study, a combination of vegetation sampling transects and aerial photograph interpretation was used to estimate the extent and types of emergent and upland vegetation that occurred in the delta areas. Submerged plants were not surveyed for this study. In 1989 (the first year in which acreages were calculated), the Cedar and Rex river deltas were characterized by extensive sedge (*Carex* spp.) meadows, totaling 59.3 acres (24 hectares) and 37.8 acres (15.3 hectares), respectively. By 1996, the extent of sedge meadows decreased to 25.7 acres (10.4 hectares) and 22.1 acres (9 hectares), respectively, presumably due to deeper and longer inundation during the summer. As a result, sedge areas transitioned to mudflats and areas with submerged vegetation (Raedeke 1997).

SPU conducted a cursory survey of submerged aquatic plants in the river deltas and other reservoir locations on September 9 and 10, 1999 (Joubert 2007 personal communication). The reservoir surface elevation was 1,551 feet (Seattle datum) during the survey, which was within 1 foot of the historical mean reservoir surface elevation for the month of September (i.e., 1,550 feet from 1995 through 2005). Three types of aquatic plants were observed at the following depths and locations:

- Plants identified as “rushes” (probably *Eleocharis* sp.) in less than 5 feet of water depth (greater than 1,546 feet elevation) in an area south of Masonry Pool, but not in the river deltas or other survey locations.

- Pondweed (*Potamogeton* sp.) between 13 and 21 feet of water depth (1,530 and 1,538 feet elevation) in both river deltas, in Young’s Cove, and in the outlet channel located immediately upstream of the overflow dike and Masonry Pool.

- Muskgrass (*Chara* sp.) in 20 to 30 feet of water depth (1,521 and 1,531 feet elevation) in the Rex River delta only.

Methods

In this study, submerged plant cover was mapped using data obtained from boat and ground surveys. The total survey area covered approximately 344 acres (139 hectares), 95 percent of which was located in the Cedar River and Rex river deltas (see Figure 1). The remaining area was located in the vicinity of the Bridge Creek delta in Young's Cove and in the southeast portion of the Masonry Pool. Information collected during these field events was compiled and compared to aerial photographs and bathymetry data to develop maps of plant community areas. The data collection and analysis methods are described in more detail in the following sections.

Data Collection

The distribution of submerged plants in the study areas was determined using a combination of boat surveys conducted in early August 2007, and ground surveys conducted in September and October 2007 when the reservoir surface elevation had lowered. The boat and ground survey methods are described separately below. Methods are also described for plant specimen collection and herbarium collection preparation.

Boat surveys provided most of the data used to develop plant distribution maps and calculate plant cover and biovolume in the Cedar River delta, Rex River delta, and Young's Cove. Ground surveys were used to define the upper boundary of submerged vegetation where it abuts emergent vegetation, to collect additional submerged species cover data in shoreline areas, and to collect mature plant specimens to confirm species identification and prepare an herbarium collection. In addition, ground surveys were used to map the plant distribution in the Masonry Pool study area, due to the dominance of very low-growing, predominantly emergent species in this area that are difficult to detect by boat survey.

Boat Survey Method

Boat surveys were conducted on August 6 through 8, 2007 by Herrera and SPU staff. The elevation of the lake surface ranged from 1,555.46 to 1,555.67 feet during the survey. The timing of the survey was optimized to provide ideal survey conditions which are: 1) suitable water depth to allow boat passage over the entire study area, and 2) maximal submerged plant growth in the study areas.

The survey was conducted using SPU's boat (16-foot whaler) equipped with a global positioning system (GPS), echo sounder system, and underwater video equipment to locate, identify, map, and estimate cover and biovolume of submersed aquatic plants by species or species group. The GPS and echo sounder equipment was provided by BioSonics, Inc., located in Seattle, Washington. The GPS equipment included a JRC differential GPS sensor for acquiring horizontal positions with an accuracy of ±3 feet. The BioSonics DT-X echo sounder equipment included a high frequency (420 kHz), narrow–beam (6 degrees split-beam) digital transducer. BioSonics data acquisition software (EcoSAVE) and a laptop computer were used to record horizontal positions, depth to the lake bed, the presence/absence of aquatic plants, depth to the top of aquatic plants, and average percent coverage and biovolume of aquatic plants.

An underwater video camera was towed behind the boat to allow for plant species identification during the boat survey. SPU provided the underwater video equipment, which included components primarily used by the Water Quality Division for aquatic plant surveys and other components primarily used by the Watershed Services Division for fish surveys. The Water Quality Division video equipment was used for the first two surveys days, and consisted of a SeaViewer Sea-Drop™ camera having a 3-inch diameter lens attached to a weighted tailfin, LED light, 100-foot-long cable, and a 5-inch black and white monitor. The camera cable was damaged on August 7 during a collision with underwater wood debris and was replaced on August 8 with the underwater digital color video camera used by the Watershed Services Division, which consisted of a Splash-Cam™ "Deep Blue" analog underwater video camera (Ocean Systems, Everett, WA) with input to a Canon Optura-Pi digital video camcorder. Because the color camera did not include a tailfin, the tailfin from the original equipment was attached to the color camera to orient the camera in the direction of boat travel while being towed. The color camera and tailfin equipment combination proved to be the most useful because aquatic plant identification was easier in color, and the color video camera provided a permanent record of the observations, which was not available with the Water Quality Division equipment.

The boat followed a network of transects to systematically cover each survey area (see Figures 2 through 4). The survey network included a set of longitudinal and transverse transects. The longitudinal transects in the Cedar River and Rex River study areas were parallel to those established for the 1989 through 1997 vegetation survey of the river deltas (Raedeke 1991, 1997) and extended into submerged aquatic plant habitat. The longitudinal survey transects extended out from the river deltas and Young's Cove to the lower depth limits of aquatic plant species in the lake. The transverse transects were perpendicular to the longitudinal transects and were spaced approximately 300 feet apart.

The split-beam recording echo sounder and integrated GPS equipment simultaneously collected location, water depth, plant presence, plant height, and plant cover data as the boat moved along the transects at a speed of approximately 3 knots. The echo sounder signal (ping) rate was set at 7 pings/second and the GPS update rate was set at 1 position/second. The echo sounder and GPS data were recorded directly on a laptop computer. Plant species were identified using an underwater video camera (described above), underwater viewer, and/or rake sampling in combination, as needed. The underwater viewer was used in shallow waters, generally less than 12 feet (4 meters) deep. The rake sampler was used in deep waters, and consisted of a weighted bow rake attached to a rope and equipped with a 0.5-inch (1 cm) mesh for entangling plants. Plant species composition was recorded in a field notebook for each time of observation, which was based on the echo sounder and GPS clock.

Ground Survey Method

Ground surveys were conducted on September 21, 2007 (Masonry Pool) and October 15, 2007 (Cedar River and Rex River deltas) to coincide with near-minimum water surface elevations in Masonry Pool and Chester Morse Lake. Water level drawdown allowed for foot access to areas that were inaccessible during the boat survey (i.e., less than 3 feet deep). The lake elevation was approximately 1,550 feet during ground surveys, which was 5 feet lower than the elevation during the boat surveys and near the annual minimum elevation of 1,548.7 feet observed on October 19, 2007. Ground surveys provided an opportunity to more accurately map the near-shore limits of submerged vegetation and to confirm identification of species that were too small or immature for identification during boat surveys.

Within the Masonry Pool area, a preliminary reconnaissance was conducted by boat, and then a ground survey was used to collect data and map plant communities because the predominantly low-growing species present in this area was difficult to detect by boat survey. The water level in Masonry Pool is typically lowered operationally when reservoir surface elevation drops to 1,550 feet. This can be accomplished because the elevation of the Overflow Dike, which separates Masonry Pool from the main body of the lake, is at an elevation of 1,550 feet (with dam boards installed). Once the lake level reaches 1,550 feet, the water bodies can be separated, and Masonry Pool generally drops 3 to 4 feet of elevation per day to an operational pool level of 1,530 feet or below and aquatic vegetation areas become fully exposed. Masonry Pool was ground surveyed on September 21, 2007 when the lake level was approximately 1,550 feet and the Masonry Pool elevation was approximately 1,530 feet.

Plant Collection Methods

Herrera biologists collected samples of each of the species of submerged aquatic plants that were identified during the boat and ground surveys. The samples were stored in plastic bags in a cooler during the survey. Within 24 hours of collection, the plants were arranged on sheets of acid-free cotton bond paper, per specifications provided by the University of Washington (UW) Herbarium (Gilpin 2007), and arranged in a plant press. Samples were separated from each other with layers of cardboard. The samples were dried for at least 1 month. The samples were labeled with scientific names and collection location and date, and added to the UW Herbarium collection on January 11, 2008.

Base Maps

The base maps used for the 2007 survey consisted of aerial photographs from 2006 and 2007, and bathymetric data from 2000 that had been used to develop elevation contours. The 2007 aerial photos were flown on October 16, 2007 at a water elevation of approximately 1,549 feet, which allowed detection of underwater plants down to an elevation of about 1,544 feet (plants are visible in 5 feet of water or less) and the accurate determination of aquatic plant growth boundaries in areas upgradient of the survey transects. Color aerial photography was taken at a nominal scale of 1:7,200 (1 inch to 600 feet) from which orthophotographs with a pixel size of 0.5 feet were produced. Aero-metric, Inc. (Tukwila, WA) acquired the color aerial photography and produced the orthophotographs. The digital orthophotographs were used for mapping of submerged and emergent vegetation.

The bathymetric data collected in 2000 contained significant noise and in many areas did not agree with bathymetric data collected by the echo sounding equipment during the 2007 survey.

Bathymetric data were used as a general tool, but were not accurate enough to be used for extrapolating plant community boundaries between survey transects.

Data Analysis

Upon completion of the echo sounder and GPS data acquisition conducted during the boat surveys, the data were post-processed by the equipment supplier (Biosonics, Inc.) to compile data into one Excel spreadsheet for each survey area. Each survey point was given a "report" number, which was numbered consecutively beginning with the number 1 for each transect and included the following data:

- Latitude
- Longitude
- Time in universal time coordinated (UTC)
- Time in local time
- Day
- Month
- Year
- Middle ping number (in series of 10 pings/point)
- Bottom depth (water depth in meters)
- Plant canopy height (meters)
- Plant cover (percent of area)
- Plant biovolume (percent of water column volume)
- Number of pings with follow condition:
    - Bare pings (no plants)
    - Plant pings (plants present)
    - Out of water (e.g., transducer out of water, surface noise, or too shallow)
    - Noisy (e.g., gas bubbles)
    - Unclassified (unknown objects in this study, which were primarily submerged stumps and logs in this study)
    - Too deep (greater than 15 meters).
- Quality rank of GPS data where:
    - 0 = no differential correction available, accuracy: ± 5 meters
    - 1 = differentially corrected, accuracy: ± 1 meter.

Percent plant cover was calculated as the number of plant pings (echo sounder signals indicating aquatic plants) by the total number of pings (approximately 10) and multiplied by 100. Out of water, noisy, and unclassified pings (< 0.01% of total pings) were excluded from the total number of pings.

Plant biovolume is the percentage of the water volume occupied by plant biomass and was calculated by Biosonics in units of percent water column volume according the following equation:

$$\text{Biovolume}\,(\%) = \text{Plant cover}\,(\%) \times \frac{\text{plant height (m)}}{\text{water depth (m)}}$$

Plant areal biovolume was calculated by Herrera in units of plant volume per survey area to remove the influence of water depth and provide an estimate of plant biovolume on an areal basis according to the following equation:

$$\text{Areal Biovolume}\,(\text{m}^3/\text{m}^2) = \text{Plant height (m)} \times \frac{\text{plant cover}\,(\%)}{100\%}$$

Assuming:

$$\text{Plant cover}\,(\%) = \frac{\text{plant area}\,(\text{m}^2)}{\text{survey area}\,(\text{m}^2)} \times 100\%$$

Thus, areal biovolume is a measure of the volume of water occupied on an areal basis by aquatic plants within the area surveyed for each survey data point.

The survey point data were added to a geographic information system (GIS) database, in which aerial photographs, bathymetry, and other base maps were overlain. Survey points were compared to plant species presence and cover data collected during boat surveys, including underwater video, surface visual observations, and raw echo sounding data. Each survey point was assigned to one of the following plant community groups:

- Potamogen gramineus
- Nitella
- Potamogeton gramineus mixed with Nitella.

Each survey point was assigned to one of the following relative cover groups:

- High (>30%)
- Medium (9-30%)
- Low (<9%).

These break points in percent cover were based on natural groupings of plant coverages that were present in the data.

The groups of data points were compared to 2007 aerial photographs, bathymetry data, and ground survey observations to delineate polygons on a map for areas having the same species composition and relative plant cover within each study area. In areas with conflicting data, a priority ranking for data sources was used to determine final plant mapping contours. Direct observations of plants (from boat or ground) were given priority over data collected from remote sensing techniques (echosounding and aerial photography), which were given priority above extrapolation based on bathymetric contours.

Percent cover and areal biovolume values for all data points within each mapped plant polygon were compiled, and mean values were applied to the plant polygon area to estimate the average percent cover and areal biovolume for each polygon, and to estimate the total plant cover, area-weighted mean plant cover (the sum of mean plant cover multiplied by the respective polygon area divided by the total polygon area), and biovolume within each study area.

The elevations of plant communities were derived from echosounding data, which was more consistent and accurate than the historical bathymetric data from 2000.

Results and Discussion

A total of 344 acres (139 hectares) were mapped in the project area, including:

- 188 acres (76 hectares) in the Cedar River delta study area
- 112 acres (45 hectares) in the Rex River delta study area
- 37 acres (15 hectares) in the Young's Cove study area
- 7 acres (2.8 hectares) in the Masonry Pool study area.

The 344 acres (139 hectares) of mapped area included:

- 141 acres (57 hectares) (39 percent of mapped area) of submerged vegetation
- 57 acres (23 hectares) (16 percent of mapped area) of emergent vegetation
- 146 acres (59 hectares) (45 percent of mapped area) of no vegetation.

The majority of the mapped area with no vegetation is within the depth limits of aquatic plants and is considered to be potential habitat for submerged or emergent vegetation. One exception is the large offshore area in Young's Cove that is too deep to support submerged vegetation. Detailed analysis of bathymetric data would be required to identify the portion of mapped area that was too deep to support submerged vegetation.

The distribution of plant species in each study area is presented in Figures 2 through 4. A summary of the results for each study area is presented in Tables 1 through 3. These aquatic plant maps show the coverage of submerged and emergent plant groups on a recent (2007) aerial photograph of the study areas. Each plant species group is depicted by a separate color. Fill patterns are used to depict the following three cover classes for the submerged plant species: low (less than 9 percent cover), medium (9 to 30 percent cover), and high (greater than 30 percent cover). These cover classes were based on natural groupings observed in the data set. The polygon area of each plant species/cover group is labeled with a unique polygon number.

The aquatic plant species identification, cover, and biovolume data are compiled for each polygon in Tables 1 through 3. The total aquatic plant mapping area is presented for each plant type and survey area in Table 4. Submerged plant cover and biovolume data are also summarized for each survey area in Table 4. Table 5 presents a summary of the echosounding data for each boat survey area

The results are discussed separately below for submerged plants and emergent plants, followed by a brief discussion on environmental factors affecting the distribution of submerged and emergent plants. Estimates of plant cover and biovolume are calculated and discussed only for submerged plant communities. A more comprehensive emergent plant community characterization is being conducted by SPU staff. A complete list of plants identified during the survey, including the submerged plants that were collected for the Herbarium is presented in Table 6.

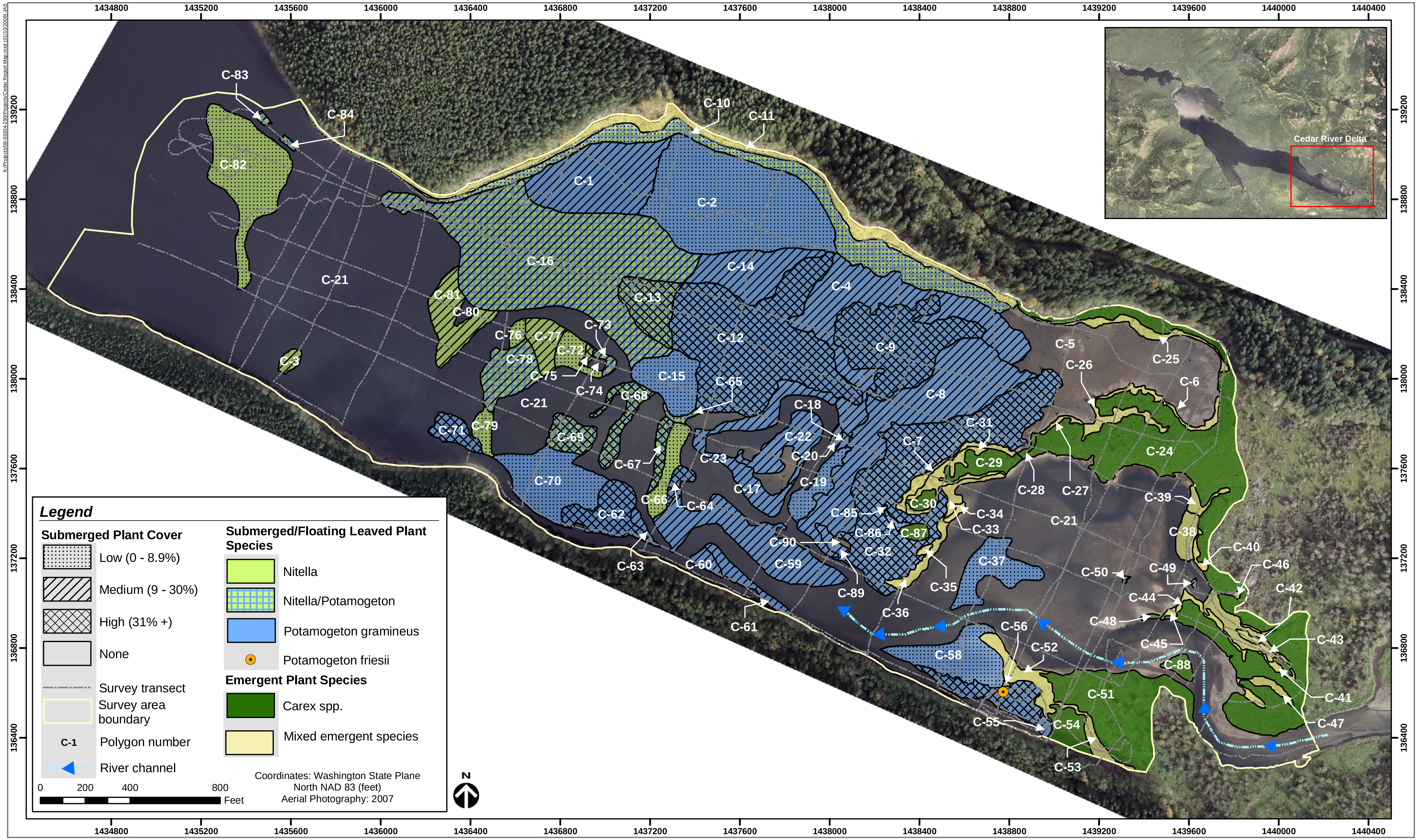

Figure 2. Aquatic plant distribution in 2007 in the Cedar River delta study area, Chester Morse Lake, August 2007

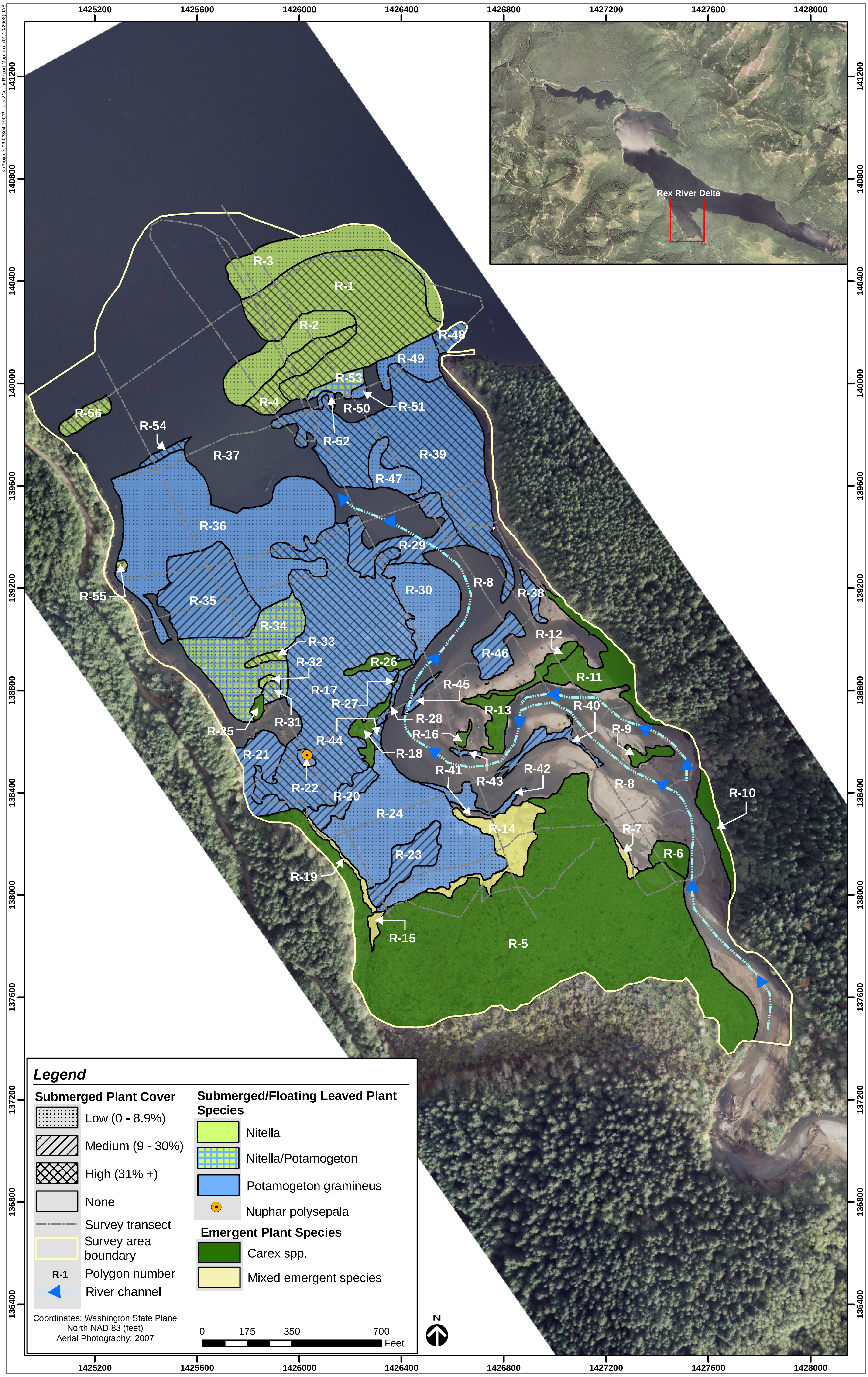

Figure 3. Aquatic plant distribution in 2007 in the Rex River delta study area, Chester Morse Lake, August 2007.

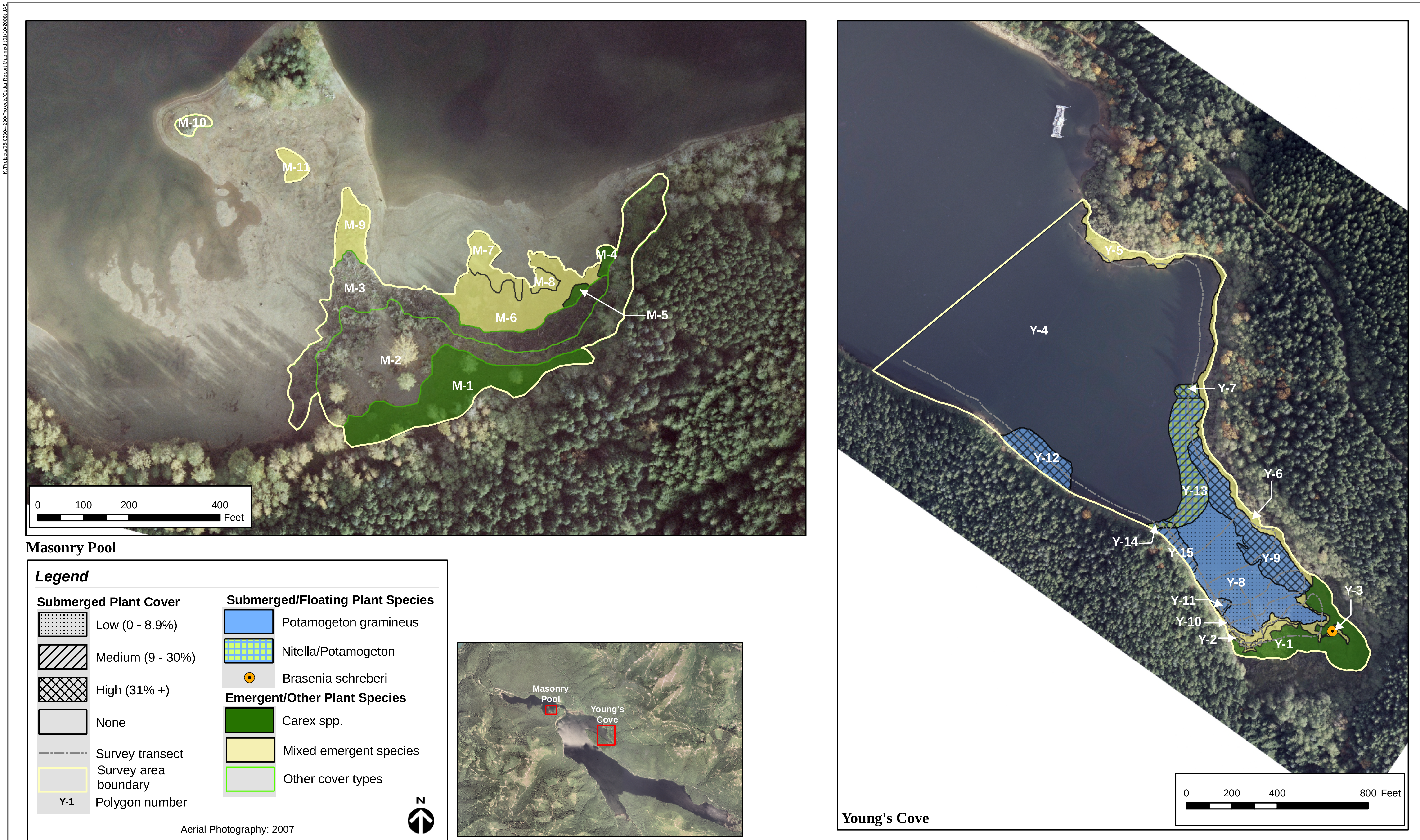

Figure 4. Aquatic plant distribution in 2007 in the Young's Cove and Masonry Pool study areas, Chester Morse Lake, August - September 2007.

Table 1. Aquatic plant species and cover data for polygons mapped in 2007 in the Cedar River delta survey area of Chester Morse Lake.

Polygon Number	Plant Community Type	Cover Class (L/M/H)	Dominant Species	Other Species	Polygon Area (acres)	Polygon Area (hectares)	Cover and Biovolume Calculated from Echo Sounder (Y/N)	Mean Cover (%)	Submerged Plant Cover (acres)	Mean Submerged Plant Biovolume (%)	Areal Submerged Plant Biovolume (m^3/m^2)	Submerge d Plant Biovolume (m^3)
C-1	Submerged	M	*P. gramineus*	None	3.5	1.4	Yes	19.3	0.7	2.6	0.05	653.9
C-2	Submerged	L	*P. gramineus*	None	7.1	2.9	Yes	7.1	0.5	0.8	0.00	125.6
C-3	Submerged	M	*Nitella flexilis*	None	0.2	0.1	Yes	28.4	0.0	2.5	0.09	65.1
C-4	Submerged	M	*P. gramineus*	None	4.5	1.8	Yes	14.5	0.7	1.5	0.02	282.9
C-5	Not Vegetated	–	None	None	6.7	2.7	No	–	–	–	–	–
C-6	Emergent	H	*Carex* spp.	*E. fluviatile*	0.3	0.1	No	–	–	–	–	–
C-7	Emergent	L	*R. flamula*	*P. gramineus, J. filiformis*	0.3	0.1	No	–	–	–	–	–
C-8	Submerged	M	*P. gramineus*	None	5.3	2.1	Yes	14.2	0.7	1.7	0.02	478.8
C-9	Submerged	H	*P. gramineus*	None	3.8	1.5	Yes	59.9	2.2	7.6	0.20	3,078.8
C-10	Submerged	L	*P. gramineus*	*Nitella flexilis*	3.8	1.5	Yes	7.3	.2	0.9	0.01	81.0
C-11	Emergent	H	*Carex* spp.	*E. fluviatile*, *Sparganium* spp.	2.3	0.9	No	–	–	–	–	
C-12	Submerged	H	*P. gramineus*	None	7.7	3.1	Yes	39.1	3.0	5.5	0.13	3,880.6
C-13	Submerged	H	*P. gramineus*	*Nitella flexilis*	1.2	0.5	Yes	50.1	0.7	7.2	0.19	942.5
C-14	Submerged	M	*P. gramineus*	None	1.9	0.8	Yes	15.4	0.2	1.6	0.03	230.6
C-15	Submerged	L	*P. gramineus*	None	1.3	0.5	Yes	6.4	0.0	0.5	0.01	27.9
C-16	Submerged	M	*P. gramineus*	*Nitella flexilis*	11.2	4.5	Yes	16.2	1.7	1.6	0.03	1,336.3
C-17	Submerged	M	*P. gramineus*	None	1.6	0.7	Yes	15.6	0.2	1.1	0.02	155.2
C-18	Submerged	M	*P. gramineus*	None	0.1	0.0	Yes	15.9	0.0	2.3	0.02	5.3
C-19	Submerged	L	*P. gramineus*	None	0.6	0.3	Yes	6.6	0.0	0.5	0.01	15.6
C-20	Submerged	M	*P. gramineus*	None	0.1	0.0	Yes	12.5	0.0	0.7	0.01	5.1
C-21	Not Vegetated	–	None	None	80.0	32.4	No	–	–	–	–	–
C-22	Submerged	M	*P. gramineus*	None	1.1	0.5	Yes	20.4	0.2	2.4	0.04	172.3
C-23	Not Vegetated	–	None	None	0.4	0.2	No	–	–	–	–	–
C-24	Emergent	H	*Carex* spp.	None	10.9	4.4	No	–	–	–	–	–

Table 1 (continued). Aquatic plant species and cover data for polygons mapped in 2007 in the Cedar River delta survey area of Chester Morse Lake.

Polygon Number	Plant Community Type	Cover Class (L/M/H)	Dominant Species	Other Species	Polygon Area (acres)	Polygon Area (hectares)	Cover and Biovolume Calculated from Echo Sounder (Y/N)	Mean Cover (%)	Submerged Plant Cover (acres)	Mean Submerged Plant Biovolume (%)	Areal Submerged Plant Biovolume (m^3/m^2)	Submerge d Plant Biovolume (m^3)
C-25	Emergent	M	*Carex* spp.	*E. fluviatile*, *Sparganium* spp.	0.5	0.2	No	–	–	–	–	–
C-26	Emergent	M	*Carex* spp.	*R. flamula*	0.4	0.2	No	–	–	–	–	–
C-27	Emergent	M	*Carex* spp.	*J. filiformis*	0.1	0.0	No	–	–	–	–	–
C-28	Emergent	M	*Carex* spp.	None	0.1	0.0	No	–	–	–	–	–
C-29	Emergent	H	*Carex* spp.	None	0.6	0.2	No	–	–	–	–	–
C-30	Emergent	H	*Carex* spp.	None	0.2	0.1	No	–	–	–	–	–
C-31	Emergent	M	*Carex* spp.	*P. gramineus*, *J. filiformis*	0.5	0.2	No	–	–	–	–	–
C-32	Submerged	H	*P. gramineus*	None	6.7	2.7	Yes	69.6	4.7	14.7	0.27	7,250.8
C-33	Submerged	L	*P. gramineus*	*Ruppia maritima*	0.3	0.1	Yes	1.1	0.0	0.1	0.00	0.4
C-34	Emergent	H	*R. flamula*	None	0.1	0.0	No	–	–	–	–	–
C-35	Emergent	L	*Carex* spp.	*J. filiformis*	0.0	0.0	No	–	–	–	–	–
C-36	Submerged	L	*P. gramineus*	*J. filiformis*	0.4	0.1	Yes	1.7	0.0	0.3	0.00	0.4
C-37	Submerged	L	*P. gramineus*	None	1.3	0.5	Yes	7.8	0.0	0.9	0.01	44.3
C-38	Submerged	L	*P. gramineus*	*Sparganium* spp.	0.4	0.2	Yes	7.4	0.0	1.0	0.01	10.0
C-39	Emergent	H	*Sparganium* spp	*P. gramineus*, *R. flamula*	0.2	0.1	No	–	–	–	–	–
C-40	Emergent	L	*Carex* spp.	*R. flamula*, *Sparganium* spp.	0.1	0.0	No	–	–	–	–	–
C-41	Submerged	L	*P. gramineus*	*Sparganium* spp.	0.1	0.0	No	8.7	0.0	2.8	0.02	9.0
C-42	Emergent	L	*Carex* spp.	*Sparganium* spp., *P. gramineus*	0.2	0.1	No	–	–	–	–	–
C-43	Submerged	M	*P. gramineus*	*Sparganium* spp., *Ruppia maritima*	0.6	0.2	Yes	20.9	0.0	3.2	0.04	85.9
C-44	Emergent	M	*Carex* spp.	*P. gramineus*, *Sparganium* spp.	0.2	0.1	No	–	–	–	–	–
C-45	Emergent	L	*Carex* spp.	*E. fluviatile*	0.0	0.0	No	–	–	–	–	–
C-46	Emergent	L	*Sparganium* spp.	*Carex* spp.	0.0	0.0	No	–	–	–	–	–
C-47	Emergent	L	*Carex* spp.	*E. fluviatile*, *Sparganium* spp.	0.3	0.1	No	–	–	–	–	–
C-48	Emergent	M	*Carex* spp.	None	0.0	0.0	No	–	–	–	–	–

Table 1 (continued). Aquatic plant species and cover data for polygons mapped in 2007 in the Cedar River delta survey area of Chester Morse Lake.

Polygon Number	Plant Community Type	Cover Class (L/M/H)	Dominant Species	Other Species	Polygon Area (acres)	Polygon Area (hectares)	Cover and Biovolume Calculated from Echo Sounder (Y/N)	Mean Cover (%)	Submerged Plant Cover (acres)	Mean Submerged Plant Biovolume (%)	Areal Submerged Plant Biovolume (m^3/m^2)	Submerge d Plant Biovolume (m^3)
C-49	Submerged	M	*P. gramineus*	None	0.0	0.0	Yes	20.0	0.0	1.3	0.03	1.9
C-50	Submerged	M	*P. gramineus*	None	0.0	0.0	Yes	18.3	0.0	2.9	0.06	3.8
C-51	Emergent	H	*Carex* spp.	None	3.4	1.4	No	–	–	–	–	–
C-52	Emergent	M	*Carex* spp.	*P. gramineus, Sparganium* spp.	0.8	0.3	No	–	–	–	–	–
C-53	Emergent	M	*Sparganium* spp.	*Fontinalis*	0.3	0.1	No	–	–	–	–	–
C-54	Emergent	H	*Carex* spp.	None	0.6	0.2	No	–	–	–	–	–
C-55	Submerged	M	*P. gramineus*	None	0.1	0.0	Yes	25.4	0.0	8.5	0.06	28.3
C-56	Submerged	L	*P. gramineus*	*Sparganium* spp.	0.0	0.0	Yes	6.7	0.0	1.8	0.01	0.6
C-57	Submerged	H	*P. gramineus*	None	1.1	0.5	Yes	43.9	0.5	9.8	0.12	557.9
C-58	Submerged	L	*P. gramineus*	None	1.7	0.7	Yes	6.7	0.0	0.7	0.00	21.6
C-59	Submerged	M	*P. gramineus*	None	2.8	1.1	Yes	12.5	0.2	1.2	0.02	193.0
C-60	Submerged	M	*P. gramineus*	None	0.2	0.1	Yes	26.1	0.0	4.6	0.07	63.2
C-61	Submerged	M	*P. gramineus*	None	0.5	0.2	Yes	19.9	0.0	2.2	0.04	72.0
C-62	Submerged	H	*P. gramineus*	None	1.3	0.5	Yes	49.3	0.7	6.8	0.19	970.2
C-63	Submerged	M	*P. gramineus*	None	0.1	0.1	Yes	15.5	0.0	1.4	0.03	17.1
C-64	Submerged	H	*P. gramineus*	None	0.2	0.1	Yes	40.5	0.0	3.7	0.09	89.2
C-65	Submerged	L	*P. gramineus*	*Nitella flexilis*	0.1	0.0	No Data	–	–	–	–	–
C-66	Submerged	L	*Nitella flexilis*	None	0.7	0.3	Yes	7.9	0.0	0.4	0.01	15.1
C-67	Submerged	H	*Nitella flexilis*	*P. gramineus*	0.3	0.1	Yes	61.0	0.2	4.3	0.19	264.1
C-68	Submerged	H	*Nitella flexilis*	*P. gramineus*	0.8	0.3	Yes	52.6	0.5	4.0	0.18	553.6
C-69	Submerged	H	*P. gramineus*	*Nitella flexilis*	0.7	0.3	Yes	45.1	0.2	5.7	0.17	463.6
C-70	Submerged	L	*P. gramineus*	None	2.3	0.9	Yes	4.7	0.0	0.5	0.00	32.1
C-71	Submerged	H	*P. gramineus*	None	0.5	0.2	Yes	62.2	0.2	5.1	0.20	416.4
C-72	Submerged	L	*Nitella flexilis*	None	0.5	0.2	Yes	8.9	0.0	0.7	0.01	18.2

Table 1 (continued). Aquatic plant species and cover data for polygons mapped in 2007 in the Cedar River delta survey area of Chester Morse Lake.

Polygon Number	Plant Community Type	Cover Class (L/M/H)	Dominant Species	Other Species	Polygon Area (acres)	Polygon Area (hectares)	Cover and Biovolume Calculated from Echo Sounder (Y/N)	Mean Cover (%)	Submerged Plant Cover (acres)	Mean Submerged Plant Biovolume (%)	Areal Submerged Plant Biovolume (m^3/m^2)	Submerged Plant Biovolume (m^3)
C-73	Submerged	M	*Nitella flexilis*	*P. gramineus*	0.1	0.1	Yes	16.2	0.0	1.1	0.04	17.6
C-74	Not Vegetated	–	None	None	0.1	0.0	No	–	–	–	–	–
C-75	Submerged	H	*Nitella flexilis*	None	0.1	0.0	Yes	32.0	0.0	3.7	0.13	43.2
C-76	Submerged	L	*Nitella flexilis*	None	0.2	0.1	Yes	0.9	0.0	0.1	0.00	0.2
C-77	Submerged	M	*Nitella flexilis*	None	0.7	0.3	Yes	21.2	0.2	2.2	0.05	140.1
C-78	Submerged	M	*P. gramineus*	*Nitella flexilis*	1.2	0.5	Yes	9.0	0.0	0.9	0.01	52.3
C-79	Submerged	L	*Nitella flexilis*	None	0.3	0.1	Yes	4.2	0.0	0.3	0.00	2.0
C-80	Not Vegetated	–	None	None	0.1	0.1	No	–	–	–	–	–
C-81	Submerged	M	*Nitella flexilis*	None	1.3	0.5	Yes	9.6	0.2	1.0	0.02	92.7
C-82	Submerged	L	*Nitella flexilis*	None	3.2	1.3	Yes	8.8	0.2	0.8	0.01	131.8
C-83	Submerged	M	*P. gramineus*	*Nitella flexilis*	0.1	0.0	Yes	25.0	0.0	1.6	0.11	25.1
C-84	Submerged	L	*P. gramineus*	*Nitella flexilis*	0.1	0.0	Yes	7.5	0.0	0.4	0.01	2.9
C-85	Submerged	H	*P. gramineus*	None	0.0	0.0	Yes	69.6	0.0	14.7	–	–
C-86	Submerged	L	*P. gramineus*	None	0.1	0.0	Yes	6.6	0.0	0.5	–	–
C-87	Emergent	H	*Carex* spp.	None	0.2	0.1	No	–	–	–	–	–
C-88	Emergent	H	*Carex* spp.	None	0.2	0.1	No	–	–	–	–	–
C-89	Submerged	M	*P. gramineus*	None	0.2	0.1	Yes	15.7	0.0	2.1	0.02	18.7
C-90	Not Vegetated	–	None	None	0.0	0.0	No	–	–	–	–	–

Table 2. Aquatic plant species and cover data for polygons mapped in 2007 in the Rex River delta survey area of Chester Morse Lake.

Polygon Number	Plant Community Type	Cover Class (L/M/H)	Dominant Species	Other Species	Polygon Area (acres)	Polygon Area (hectares)	Cover and Biovolume Calculated from Echo Sounder (Y/N)	Mean Cover (%)	Submerged Plant Cover (acres)	Mean Submerged Plant Biovolume (%)	Areal Submerged Plant Biovolume (m^3/m^2)	Submerged Plant Biovolume (m^3)
R-1	Submerged	H	*Nitella flexilis*	None	5.3	2.1	Yes	69.8	3.7	5.1	0.31	6,725.0
R-2	Submerged	L	*Nitella flexilis*	None	1.4	0.6	Yes	5.8	0.0	0.5	0.01	49.9
R-3	Submerged	L	*Nitella flexilis*	None	1.9	0.8	Yes	2.3	0.0	0.1	0.00	4.7
R-4	Submerged	H	*Nitella flexilis*	None	0.9	0.4	Yes	40.1	0.2	3.5	0.15	546.0
R-5	Emergent	H	*Carex* spp.	None	18.0	7.3	No	–	–	–	–	–
R-6	Emergent	L	*Carex* spp.	None	0.4	0.1	No	–	–	–	–	–
R-7	Emergent	L	*Sparganium* spp.	None	0.1	0.0	No	–	–	–	–	–
R-8	Not Vegetated	–	None	None	19.8	8.0	No	–	–	–	–	–
R-9	Emergent	H	*Carex* spp.	None	0.2	0.1	No	–	–	–	–	–
R-10	Emergent	H	*Carex* spp.	None	0.5	0.2	No	–	–	–	–	–
R-11	Emergent	H	*Carex* spp.	None	1.3	0.5	No	–	–	–	–	–
R-12	Emergent	L	*Carex* spp.	None	0.3	0.1	No	–	–	–	–	–
R-13	Emergent	H	*Carex* spp.	None	0.5	0.2	No	–	–	–	–	–
R-14	Emergent	L	*Carex* spp.	*P. gramineus, E. fluviatile, Sparganium* spp.	1.2	0.5	No	–	–	–	–	–
R-15	Emergent	L	*Sparganium* spp.	None	0.1	0.0	No	–	–	–	–	–
R-16	Emergent	L	*Carex* spp.	None	0.1	0.0	No	–	–	–	–	
R-17	Submerged	H	*P. gramineus*	None	8.2	3.3	Yes	48.8	4.0	7.7	0.16	5,411.9
R-18	Emergent	H	*Carex* spp.	None	0.3	0.1	No	–	–	–	–	–
R-19	Emergent	M	*Sparganium* spp.	*E. fluviatile, P. gramineus*	0.2	0.1	No	–	–	–	–	–
R-20	Submerged	M	*P. gramineus*	None	0.5	0.2	Yes	22.1	0.0	2.2	0.04	78.4
R-21	Submerged	M	*P. gramineus*	None	0.9	0.3	Yes	31.0	0.2	4.2	0.08	291.6
R-22	Submerged	M	*Nuphar polysepala*	*P. gramineus*	0.1	0.0	Yes	13.6	0.0	3.4	0.02	8.0
R-23	Submerged	M	*P. gramineus*	None	0.8	0.3	Yes	18.0	0.2	2.0	0.02	71.7
R-24	Submerged	L	*P. gramineus*	None	4.4	1.8	Yes	5.5	0.2	0.7	0.00	56.8

Table 2 (continued). Aquatic plant species and cover data for polygons mapped in 2007 in the Rex River delta survey area of Chester Morse Lake.

Polygon Number	Plant Community Type	Cover Class (L/M/H)	Dominant Species	Other Species	Polygon Area (acres)	Polygon Area (hectares)	Cover and Biovolume Calculated from Echo Sounder (Y/N)	Mean Cover (%)	Submerged Plant Cover (acres)	Mean Submerged Plant Biovolume (%)	Areal Submerged Plant Biovolume (m^3/m^2)	Submerged Plant Biovolume (m^3)
R-25	Emergent	H	*Carex* spp.	None	0.1	0.0	No	–	–	–	–	–
R-26	Emergent	H	*Carex* spp.	None	0.2	0.1	No	–	–	–	–	–
R-27	Emergent	L	*Carex* spp.	None	0.0	0.0	No	–	–	–	–	–
R-28	Submerged	H	*P. gramineus*	None	0.1	0.0	Yes	78.0	0.0	4.8	0.26	127.0
R-29	Submerged	M	*P. gramineus*	None	1.2	0.5	Yes	12.0	0.2	1.0	0.02	79.2
R-30	Submerged	L	*P. gramineus*	None	1.5	0.6	Yes	8.0	0.0	1.3	0.01	49.6
R-31	Submerged	H	*Nitella flexilis*	*P. gramineus*	0.1	0.0	Yes	42.8	0.0	6.7	0.12	58.7
R-32	Submerged	L	*Nitella flexilis*	None	0.0	0.0	Yes	5.0	0.0	0.3	0.01	0.9
R-33	Submerged	H	*Nitella flexilis*	None	0.1	0.1	Yes	34.2	0.0	6.4	0.11	56.3
R-34	Submerged	L	*Nitella flexilis*	*P. gramineus*	2.4	1.0	Yes	6.7	0.2	0.7	0.00	38.7
R-35	Submerged	M	*P. gramineus*	None	2.5	1.0	Yes	16.9	0.5	1.5	0.03	290.9
R-36	Submerged	L	*P. gramineus*	None	6.8	2.7	Yes	3.4	0.2	0.3	0.00	47.5
R-37	Not Vegetated	–	None	None	19.6	7.9	No	–	–	–	–	–
R-38	Submerged	M	*P. gramineus*	None	0.2	0.1	Yes	14.3	0.0	2.9	0.02	14.9
R-39	Submerged	H	*P. gramineus*	None	6.1	2.5	Yes	57.9	3.5	6.8	0.20	5,089.4
R-40	Submerged	M	*P. gramineus*	None	0.3	0.1	Yes	25.8	0.0	2.0	0.05	63.0
R-41	Not Vegetated	–	None	None	0.1	0.0	No	–	–	–	–	–
R-42	Submerged	L	*P. gramineus*	None	0.3	0.1	Yes	6.4	0.0	1.1	0.01	13.5
R-43	Submerged	M	*P. gramineus*	None	0.1	0.0	Yes	27.1	0.0	5.6	0.07	16.3
R-44	Submerged	H	*P. gramineus*	None	0.1	0.0	Yes	70.0	0.0	2.7	0.15	46.8
R-45	Submerged	M	*P. gramineus*	None	0.1	0.0	Yes	18.9	0.0	1.4	0.04	15.9
R-46	Submerged	M	*P. gramineus*	None	0.6	0.2	Yes	10.7	0.0	2.5	0.03	60.3
R-47	Submerged	L	*P. gramineus*	None	0.5	0.2	Yes	5.9	0.0	0.6	0.00	9.6
R-48	Submerged	H	*P. gramineus*	None	0.2	0.1	Yes	53.4	0.0	4.0	0.20	170.4

Table 2 (continued). Aquatic plant species and cover data for polygons mapped in 2007 in the Rex River delta survey area of Chester Morse Lake.

Polygon Number	Plant Community Type	Cover Class (L/M/H)	Dominant Species	Other Species	Polygon Area (acres)	Polygon Area (hectares)	Cover and Biovolume Calculated from Echo Sounder (Y/N)	Mean Cover (%)	Submerged Plant Cover (acres)	Mean Submerged Plant Biovolume (%)	Areal Submerged Plant Biovolume (m^3/m^2)	Submerged Plant Biovolume (m^3)
R-49	Submerged	L	*P. gramineus*	None	0.6	0.3	Yes	6.3	0.0	0.9	0.01	32.1
R-50	Not Vegetated	–	None	None	0.6	0.2	No	–	–	–		–
R-51	Submerged	L	*P. gramineus*	None	0.1	0.0	Yes	5.0	0.0	0.4	0.01	1.7
R-52	Submerged	M	*P. gramineus*	None	0.1	0.0	Yes	16.3	0.0	1.3	0.05	13.1
R-53	Submerged	M	*Nitella flexilis*	*P. gramineus*	0.3	0.1	Yes	26.0	0.0	3.7	0.11	126.4
R-54	Submerged	H	*P. gramineus*	None	0.1	0.1	Yes	41.3	0.0	1.7	0.09	48.0
R-55	Submerged	M	*Nitella flexilis*	None	0.0	0.0	Yes	30.0	0.0	2.5	0.06	9.7
R-56	Submerged	H	*Nitella flexilis*	None	0.3	0.1	Yes	54.0	0.2	3.0	0.17	225.4

Table 3. Aquatic plant species and cover data for polygons mapped in 2007 in the Young's Cove and Masonry Pool survey areas of Chester Morse Lake.

Polygon Number	Plant Community Type	Cover Class (L/M/H)	Dominant Species	Other Species	Polygon Area (acres)	Polygon Area (hectares)	Cover and Biovolume Calculated from Echo Eounder (Y/N)	Mean Cover (%)	Submerged Plant Cover (acres)	Mean Submerged Plant Biovolume (%)	Areal Submerged Plant Biovolume (m^3/m^2)	Submerged Plant Biovolume (m^3)
Young's Cove												
Y-1	Emergent	H	*Carex* spp.	None	2.0	0.8	No	–	–	–	–	–
Y-2	Emergent	M	*Carex* spp.	*J. filiformis, Sparganium* spp.	0.2	0.1	No	–	–	–	–	–
Y-3	Submerged	L	*P. gramineus*	*Brasenia schreberi*	0.1	0.0	No	No Data	–	No Data	–	–
Y-4	Not Vegetated		None	None	25.1	10.2	No	62.0	15.6	4.3	–	–
Y-5	Emergent	L	*Carex* spp.	*J. filiformis, R. flamula*	0.6	0.2	No	–	–	–	–	–
Y-6	Emergent	L	*Carex* spp.	*J. filiformis, R. flamula, E. fluviatile*	0.9	0.3	No	–	–	–	–	–
Y-7	Submerged	H	*P. gramineus*	*Nitella flexilis*	0.1	0.1	Yes	44.0	0.0	3.1	0.12	73.7
Y-8	Submerged	L	*P. gramineus*	None	3.4	1.4	Yes	5.2	0.2	0.7	0.00	40.2
Y-9	Submerged	H	*P. gramineus*	None	1.8	0.7	Yes	41.7	0.7	5.5	0.11	791.6
Y-10	Emergent	L	*Carex* spp.	*J. filiformis, R. flamula, E. fluviatile*	0.4	0.2	No	–	–	–	–	–
Y-11	Submerged	M	*P. gramineus*	None	0.1	0.0	Yes	17.8	0.0	2.4	0.03	7.5
Y-12	Submerged	H	*P. gramineus*	None	0.8	0.3	Yes	76.4	0.7	4.8	0.34	1,125.7
Y-13	Submerged	M	*P. gramineus*	*Nitella flexilis*	1.4	0.6	Yes	10.7	0.2	0.7	0.01	71.7
Y-14	Submerged	H	*P. gramineus*	*Nitella flexilis*	0.1	0.0	Yes	61.0	0.0	4.0	0.23	71.8
Y-15	Submerged	M	*P. gramineus*	None	0.3	0.1	Yes	27.4	0.0	1.5	0.06	57.6
Masonry Pool												
M-1	Emergent	H	*Carex* spp.	None	0.9	0.4	No	–	–	–	–	–
M-2	Other (Shrubs)	H	*Salix* spp.	None	2.0	0.8	No	–	–	–	–	–

Table 3 (continued). Aquatic plant species and cover data for polygons mapped in 2007 in the Young's Cove and Masonry Pool survey areas of Chester Morse Lake.

Polygon Number	Plant Community Type	Cover Class (L/M/H)	Dominant Species	Other Species	Polygon Area (acres)	Polygon Area (hectares)	Cover and Biovolume Calculated from Echo Eounder (Y/N)	Mean Cover (%)	Submerged Plant Cover (acres)	Mean Submerged Plant Biovolume (%)	Areal Submerged Plant Biovolume (m^3/m^2)	Submerged Plant Biovolume (m^3)
M-3	Not Vegetated		Driftwood	None	1.1	0.4	No	–	–	–	–	–
M-4	Emergent	H	*Carex* spp.	None	0.0	0.0	No	–	–	–	–	–
M-5	Emergent	H	*Carex* spp.	None	0.0	0.0	No	–	–	–	–	–
M-6	Emergent	L	*R. flamula*	*Carex* spp.	0.6	0.3	No	–	–	–	–	–
M-7	Emergent	L	*R. flamula*	*Carex* spp.	0.2	0.1	No	–	–	–	–	–
M-8	Emergent	L	*R. flamula*	None	0.0	0.0	No	–	–	–	–	–
M-9	Emergent	L	*Carex* spp.	*Mentha piperita*, *Myosotis laxa*	0.2	0.1	No	–	–	–	–	–
M-10	Other (Shrubs)	H	*Salix* sp.	*Mentha piperita*	0.1	0.0	No	–	–	–	–	–
M-11	Emergent	L	*Carex* spp.	*Mentha*	0.1	0.0	No	–	–	–	–	–

Table 4. Aquatic plant mapping area, cover, and biovolume in 2007 at four survey areas in Chester Morse Lake.

	Cedar River Delta	Rex River Delta	Young's Cove	Masonry Pool	Project Total
Mapping area (acres)					
P. graminius only	59	36.3	6.4	0.0	101.8
P. graminius + Nitella	18.3	2.7	1.7	0.0	22.7
Nitella only	7.2	10.1	0.0	0.0	9.9
Total submergent plant area	84	49.4	7.4	0.0	140.79
Total emergent plant area	24.7	23.5	4.0	4.2	56.8
Total unvegetated area	79	39.5	24.7	2.7	145.7
Total mapping area	187.7	112.4	36.1	6.9	343.3
Submerged plant cover (acres) [a]					
P. graminius only	15.8	9.9	1.7	0.0	27.4
P. graminius + Nitella	3.7	0.2	0.2	0.0	4.2
Nitella only	0.7	4.4	0.0	0.0	5.2
Total Submerged Plant Cover	20.2	14.5	1.9	0.0	36.8
Submerged plant biovolume (m^3) [b]					
P. graminius only	19,000	12,107	2,022	0.0	33,129
P. graminius + Nitella	2,904	224	217	0.0	3,345
Nitella only	508	7,168	0.0	0.0	8,126
Total submerged plant biovolume	22,412	19,949	2,239	0.0	44,600

[a] Submerged plant cover = mapping area * mean percent cover/100.
[b] Submerged plant biovolume = submerged plant cover * plant height.

Table 5. Number and type of echo sounder signals (pings) for each aquatic plant study area in Chester Morse Lake.

	Cedar River Delta	Rex River Delta	Young's Cove
Number of records (reports)	16,130	5,049	1,180
Number of pings	161,357	50,469	11,808
Bare pings (percent)	81	68	70
Plant pings (percent)	15	18	27
Out-of-water pings (percent)	0	1	1
Noisy pings (percent)	1	1	1
Unclassified pings (percent)	0	0	0
Too deep pings (percent)	2	12	1

Table 6. Plant species observed during the 2007 aquatic plant survey of Chester Morse Lake.

Scientific Name	Common Name	Location Observed	Habitat Type
Brasenia schreberi	Water shield	Youngs Cove	Open-water pockets within emergent zone
Carex spp.	Sedges	Cedar and Rex River Deltas, Youngs Cove, Masonry Pool	Dominates the emergent zones
Eleocharis acicularis	Needle spike-rush	Cedar and Rex River Deltas, Youngs Cove, Masonry Pool	Emergent zones
Equisetum fluviatile	Water horsetail	Cedar and Rex River Deltas, Youngs Cove, Masonry Pool	Emergent and mixed emergent/submerged areas.
Fontinalis antipyretica [a]	Water moss	Rex River Delta	Along southwest shoreline in deep shade
Juncus filiformis	Thread rush	Cedar River Delta	Emergent zones
Juncus supiniformis	Spreading rush	Cedar and Rex River Deltas	Emergent zones
Mentha piperita	peppermint	Masonry Pool	Emergent zones and scrub/shrub edges, and out to areas with up to 12 feet of inundation
Myosotis laxa	Small-flowered forget-me-not	Cedar and Rex River Deltas, Youngs Cove, Masonry Pool	Emergent zones
Nitella flexilis [a]	Nitella	Cedar and Rex River Deltas, Youngs Cove	Submerged areas in 3 to 22 feet of water.
Nuphar polysepala	Yellow pond lily	Rex River Delta	Submerged areas in 5 to 6 feet of water.
Phalaris arundinacea	Reed canary grass	Cedar and Rex River Deltas, Youngs Cove, Masonry Pool	Emergent zones
Potamogeton friesii [a]	Flat-stalked pondweed	Cedar River Delta	Submerged areas in 5 to 6 feet of water.
Potamogeton gramineus [a]	Grass-leaved pondweed	Cedar and Rex River Deltas, Youngs Cove, Masonry Pool	Mixed emergent/submerged areas and submerged areas out to 18 feet of water.
Ranunculus flammula	Creeping spearwort	Cedar and Rex River Deltas, Youngs Cove, Masonry Pool	Emergent and mixed emergent/submerged areas, especially areas with evidence of scour or disturbance
Ruppia maritima	Widgeongrass	Cedar and Rex River Deltas, Youngs Cove	Mixed emergent and submerged areas
Sparganium angustifolium	Narrow-leaved burreed	Cedar and Rex River Deltas, Youngs Cove, Masonry Pool	Emergent and mixed emergent/submerged areas
Veronica scutellata	Skullcap speedwell	Cedar and Rex River Deltas, Youngs Cove, Masonry Pool	Emergent zones

[a] Specimen preserved and archived at University of Washington Herbarium.

For the purposes of this survey project, the boundary between emergent and submerged plant communities was determined by the approximate line separating areas dominated by either growth form. Water elevations observed during the survey period were not used to determine plant boundaries because emergent plant community areas can be submerged throughout a large portion of the growing season in reservoirs such as Chester Morse Lake. This condition was observed during the boat survey, in which most emergent areas were submerged under 3 or more feet of water. However, water level drawdown in late summer and fall exposes these areas, providing conditions that favor emergent rather than aquatic plants.

Submerged Plant Coverage and Biovolume

The submerged plant community in all sampled areas in Chester Morse Lake is dominated by two species: grass-leaved pondweed (*Potamogeton gramineus*) and Nitella (*Nitella flexilis*). The submerged or floating-leaved aquatic plants that were observed in the project area were:

- Grass-leaved pondweed (*Potamogeton gramineus*) (primarily submerged)
- Nitella (*Nitella flexilis*) (submerged)
- Flat-stalked pondweed (*Potamogeton friesii*) (submerged)
- Widgeongrass (*Ruppia maritima*) (submerged)
- Yellow pond lily (*Nuphar polysepala*) (floating-leaved)
- Water moss (*Fontinalis antipyretica*) (submerged)
- Water shield (*Brasenia schreberi*) (floating-leaved).

At elevations below 1,535 feet, submerged aquatic plant growth was extremely limited or non-existent. This is the approximate elevation of the rivers' alluvial shelves, immediately upgradient from where the water depth increases rapidly in the main body of the lake. Submerged aquatic plants were generally present at elevations ranging from 1,552 to 1,535 feet, which is equivalent to water depths ranging from 4 to 21 feet during the survey. Nitella, a macroalgae, was the only species present in the deep water habitat from 1,535 to 1,538 feet elevation (18 to 21 feet depth). Grass-leaved pondweed, a vascular plant, was the dominant submerged plant in the shallow water habitat from 1,538 to 1,552 feet elevation (4 to 18 feet depth). Nitella was also present at some locations in the shallow water habitat from 1,538 to 1,552 feet elevation. In some areas, grass-leaved pondweed grew up to the lower edge of sedge meadows in open-water pockets within the meadows, but rarely grew among emergent plant species (primarily *Carex* spp.) in the sedge meadows. The distribution of these submerged plant species is described by study area in the sections below.

Cedar River Delta

The distribution of submerged plant species in the Cedar River delta is presented in Figure 2. The mapped submerged plant community covered a total of 76 acres (34 hectares) in the Cedar River delta study area. An additional 87 acres (32 hectares) of the mapped area was unvegetated and generally considered to be of suitable water depth for submerged plant growth. Thus, submerged plants occupied approximately 52 percent of the available habitat. A large portion of the unvegetated area was located in shallow waters adjacent to the river mouth and the emergent plant community (see Figure 2). Deep portions of the survey area were also unvegetated. Grass-leaved pondweed was the dominant submerged plant, occupying 92 percent of the total submerged plant area. Nitella was the second most abundant submerged plant, occupying 30 percent of the total submerged plant area (see Table 4). Grass-leaved pondweed cover extended from the upper limit of the submerged plant community (elevation 1,553 feet) down to an elevation of 1,538 feet. Nitella cover typically extended from this lower limit of grass-leaved pondweed down to a lower limit of 1,535 feet, except for an isolated, low-density patch extending down to an elevation of 1,530 feet. Sparse Nitella growth was also observed among the pondweed in some areas above 1,540 feet. Widgeongrass grew in association with grass-leaved pondweed in the shallowest portions of the submerged plant community. An isolated patch of flat-stalked pondweed was observed at an elevation of 1,550 feet.

The area-weighted mean plant cover was 24 percent within mapped submerged plant areas in the Cedar River delta study area, resulting in a total cover of 20 acres (8.2 hectares). Total submerged plant biovolume was 29,314 yd^3 (22,412 m^3) in this area.

Rex River Delta

The distribution of submerged plant species in the Rex River delta is presented in Figure 3. The mapped submerged plant community covered a total of 49 acres (20 hectares) in the Rex River delta study area. An additional 40 acres (16 hectares) of the mapped area was unvegetated and generally considered to be suitable water depth for submerged plant growth. Thus, submerged plants occupied approximately 56 percent of the available habitat. A large portion of the unvegetated area was located in shallow waters adjacent to the river channel and emergent plant community (see Figure 3). Deep portions of the survey area were also unvegetated. Grass-leaved pondweed was the dominant submerged plant, occupying 79 percent of the total submerged plant area. Nitella was the second most abundant submerged plant, occupying 26 percent of the total submerged plant area (see Table 4).

Grass-leaved pondweed cover extended from the upper limit of the submerged plant community (elevation 1,552 feet) down to an elevation of 1,538 feet. Nitella cover typically extended from the lower limit of grass-leaved pondweed down to a lower limit of 1,535 feet, with occurrence in some shallower areas (1543 to 1545 feet), and in other shallow areas where both species occur. Widgeongrass grew in association with grass-leaved pondweed in the shallowest portions of the submerged plant community. An isolated patch of yellow pond lily (floating-leaved) was observed at an elevation of 1,550 feet.

The area-weighted mean plant cover was 30 percent within mapped submerged plant areas in the Rex River delta study area, resulting in a total cover of 15 acres (5.9 hectares). The total submerged plant biovolume was 26,092 yd^3 (19,949 m^3) in this area.

Young's Cove

The distribution of the submerged plant species in Young's Cove is presented in Figure 4. The mapped submerged plant community covered a total of 8 acres (3 hectares) in the Young's Cove study area. An additional 25 acres (10 hectares) of the mapped area was unvegetated. Most of the unvegetated area was located in the offshore portion of the survey area that was likely too deep to be suitable for submerged aquatic plant growth (see Figure 4). Grass-leaved pondweed was the dominant submerged plant, occupying 100 percent of the total submerged plant area. Nitella was the second most abundant plant, occupying 21 percent of the total submerged plant area (see Table 4).

Although bathymetric data were not available for this study area, the distribution of submerged plants appeared to coincide with elevations noted for other study areas. An isolated patch of water shield (floating-leaved) was observed in a deep water area within the sedge meadow.

The area-weighted mean plant cover was 27 percent within mapped submerged plant areas in the Young's Cove study area resulting in a total cover of 2 acres (0.8 hectare). The total submerged plant biovolume was 2,928 yd^3 (2,239 m^3) in this area.

Masonry Pool

The distribution of plant communities is presented in Figure 4. No submerged plants were observed in this study area. However, patches of emergent plants were observed that apparently persist under deep inundation through a majority of the growing season and then grow actively when the water level in the Masonry pool is lowered. The water regime in this area likely does not support the growth of submerged vegetation due to the prolonged drawdown in late summer and fall. The dominant plants observed in this area were small creeping buttercup (*Ranunculus flammula*), peppermint (*Mentha piperita*), and water forget-me-not (*Myosotis laxa*).

Emergent Plant Cover

The mapping of emergent plant cover was undertaken only as a means to characterize the upper boundary of submerged plant communities. As such, the mapped "upper" edge of the emergent zones is for graphical purposes only. The emergent communities actually extend further up-gradient, and become interspersed with scrub-shrub and forested wetland vegetation.

In most areas, there was an ecotone between emergent and submerged plant communities. This "mixed emergent" community contains species typical of both plant growth forms, and represents the overlap between the depth of inundation that the emergent species can tolerate, and the degree of exposure that the submerged plants can endure. The overlapping plant tolerances result in a mixed emergent zone at approximately 1,546 to 1,547 feet elevation in which species from both plant groups have suitable growth conditions over the growing season to persist.

The emergent plant community was divided into two major groups: meadows dominated by sedges (*Carex* spp.); and mixed emergent species areas containing a variety of species including sedges, water horsetail (*Equisetum fluvatile*), narrow-leaved burreed (*Sparganium angustifolium*), small creeping buttercup, thread rush (*Juncus filiformis*), marsh veronica (*Veronica scutellata*), peppermint, and water forget-me-not. Grass-leaved pondweed was the only submerged plant occasionally present in low numbers in some areas mapped as emergent plant communities. Scour holes near stumps and logs and other micro-topographic features provided deep enough water to support this submerged species. Areas scoured by waves or disturbed by floating logs tended to lack sedge cover, and were colonized by small creeping buttercup and spreading rush.

The distribution of the two groups of emergent plants is presented in Figures 2 through 4. The species observed in emergent plant areas are present in Tables 1 through 3.

The mapped emergent plant community covers approximately:

- 24.5 acres (10 hectares) in the Cedar River delta study area
- 23.4 acres (9.5 hectares) in the Rex River delta study area
- 4.0 acres (1.6 hectares) in the Young’s Cove study area
- 4.2 acres (1.7 hectares) in the Masonry Pool study area.

It is important to note that the upper boundary and, hence, total area of emergent plants was not accurately determined for this aquatic plant survey because SPU is gathering that information to separately evaluate effects of water level changes in Chester Morse Lake.

Factors Affecting Plant Distribution

The submerged plant distribution in Chester Morse Lake is determined by a number of environmental factors. The most prominent factors include water depth and water level fluctuation, and water currents, scour and related sediment characteristics. In addition, submerged plant distribution may be affected by less-predictable factors, such as the dispersal of seeds (or other propagules) and herbivory.

Water Depth and Water Level Fluctuation

There are a few features of water depth specific to lake level management that affect submerged plant growth: the depth and duration of inundation, the duration of exposure (no inundation), and the seasonal timing of these variables (Hill et al. 1998; Auble et al 1994; Kozlowski 1984; Raines et al. 2004). Individual plant species have different tolerances for these variables.

Deep inundation limits the sunlight available to submerged plants. Depending on the duration and season of the inundation, this can limit or preclude submerged plant growth. Lake level drawdown to the sediment surface results in unsuitable conditions to support the suspended structure of these plants and exposes submerged plants to desiccation. This exposure generally has less effect, however, than inundation depth and duration (Fraisse 1997). Within these extremes lie a wide range of intermediate conditions that support or retard submerged plant growth.

In many areas, there is sufficient duration of adequate growth conditions to allow a submerged plant to persist or grow, despite unfavorable conditions in other portions of the annual cycle

(Amlin and Rood 2002). Rhizomous species (such as grass-leaved pondweed) can develop a root mat that covers a range of water depths and exposure regimes. The extensive root mat allows the plant to grow, even though different portions of the plant may grow and senesce at different times in the annual water level cycle. At the upper margin of this range, submerged plants are outcompeted by emergent species adapted to shallow inundation and greater duration of exposure. At the lower margin of this range, submerged plant growth is precluded from deep inundation with a long duration. In some areas exposed to wave action, there is evidence of erosion which limits emergent plant coverage or limits sedge growth, resulting in patches dominated by bare soil or small creeping buttercup.

Water level management of Chester Morse Lake in the 1990s tended towards higher lake levels in the spring and lower lake levels in the fall. It is likely that emergent and submerged plant areas gradually changed over time in response to the higher water level and seasonal fluctuation. Continued increase in the spring maximum level and decrease in fall minimum level may initially reduce the cover of the existing submerged and emergent plant communities, until they can re-establish at higher elevations. The reduction in submerged plant cover would be expected to begin immediately once the reservoir operation change is implemented. The reestablishment of plant communities suited to the water regime resulting from the changed reservoir operations is likely to require two to five years to stabilize at a new equilibrium. Emergent areas would likely transition to a submerged plant community and mudflats. Adjacent scrub-shrub and forested wetlands would transition to emergent wetlands. The upgradient extent of these communities would be determined by the topography of the inundated areas. Depending on the extent and duration of the fall drawdown, the submerged plant community cover may be reduced, due to the compounding effects of deeper inundation and longer exposure period.

In the long term, the coverage of grass-leaved pondweed would be expected to stabilize at or near its existing acreage, assuming that the topographic slope of the areas that would be flooded is similar to the slope of the areas currently flooded. This determination is based on the apparent coverage of this species out to a depth threshold (1,538 feet elevation) below which, the species has not spread. If the water level is held at a higher level, then this threshold elevation would move upgradient. Therefore, increasing the pool depth would likely move the location of the population upgradient to a depth range similar to the existing depth range (i.e., 4 to 18 feet at the time of the survey, with the lake level at approximately 1555 feet elevation). Areas containing the deeper portion of the existing population would likely transition to populations of Nitella because of its tolerance for these greater water depths. If the pool depth was held above the current level, then some of the deepest portions of the deltas may become unvegetated, as the greater depths may prevent sufficient light penetration to support Nitella.

Comparison between Study Areas

Each of the four study areas has a unique pattern of submerged plant populations. Masonry Pool has a water regime that is very different than the other three study areas, resulting in distinct plant communities. In this study area, water levels drop precipitously in late summer after water levels in the main body of the lake reach 1,550 feet. Water levels in the pool drop 20 feet over a few days to reach an operational level of 1,530 feet or below. This abrupt drop in water level and extensive exposure of the lake bottom to air result in coverage only by emergent plant species that can tolerate extended inundation, followed by sudden and prolonged exposure.

The three other study areas in Chester Morse Lake (Cedar delta, Rex delta, and Young's Cove) had similar water level regimes and the same dominant species, but the areas differed in the species distribution. These observed differences were likely the result of differences in river flow and bathymetry. The Cedar and Rex River deltas have large rivers flowing through them that resulted in an unvegetated zone where the river current was strongest. However, only a small stream (Bridge Creek) flows into Young's Cove and no stream channel scour was observed in the vegetation pattern. The relatively small size of Bridge Creek also lessens the volume of sediment transported by the stream, resulting in a significantly smaller terrace of sediment than in the Cedar and Rex River deltas. The Cedar delta study area is larger and more gradually sloped (parallel to the river flow direction) than the Rex delta, which explains the lower submerged plant acreage in the Rex (i.e., steeper slopes result in a smaller area of suitable water depths), and the narrow transition zone between pondweed and Nitella. The lower slope of the Cedar delta may also provide habitat for the isolated patch of low-density Nitella that was observed near the outer-most edge of the river terrace. The reason for the absence of vegetation between this patch and the rest of the submerged plant population was not apparent.

Other differences between the study areas that could affect plant growth include directional orientation, surrounding topography, and sediment type. The Cedar delta is oriented ESE/WNW, whereas the Rex delta and Young's Cove are oriented SE/NW. The orientation and height of surrounding topographic features may limit seasonal sunlight exposure, or result in different wind-driven wave energy and direction in the study areas. The different watersheds draining to each study area may also contribute sediment that differs in organic matter content, mineral content, or particle size. They may also differ in stream flow volumes and/or velocities.

There was a large unvegetated area in the northeast portion of the Cedar River delta study area where water depths appeared to be suitable for submerged plant growth. Factors precluding submerged plant growth in this area were not apparent. Some possible factors may include unsuitable substrate type due to historic river flow through this area, exposure of this area to excessive wave action, and/or an insufficient amount of time for submerged plant establishment since the recent die-off of a sedge community in this area.

Comparison to Lake Youngs

The distribution of aquatic plant species and their depth/light level tolerances in Lake Youngs provides a good comparison to conditions within the Chester Morse Lake study areas. Lake Youngs is another reservoir in the City of Seattle's municipal water system. Water discharged from Chester Morse Lake flows down the Cedar River to Landsburg Diversion Dam, where some of the flow is diverted through an aqueduct into Lake Youngs.

The water chemistry and temperature in Lake Youngs is similar to Chester Morse Lake due to a common water source (Cedar River watershed). Also, both lakes are closed to public access, limiting the opportunity for invasive species or other plants to be transported into the lakes by public use. These factors limit the variables that affect plant species presence and distribution.

The lakes differ in their elevation (Lake Youngs at 500 feet above sea level, Chester Morse Lake at 1,500 feet above sea level), bathymetry (Lake Youngs is in a shallow basin, and has a maximum depth of 100 feet, Chester Morse Lake is in a mountain valley and has a maximum depth of 120 feet), sediment type (Lake Youngs does not receive river sediment), and trophic state (Lake Youngs has higher algae biomass than Chester Morse Lake). The most significant difference is that the water level of Lake Youngs is maintained at a relatively constant level year-round, whereas the water level of Chester Morse Lake varies by over 20 feet on an annual basis. Due to these conditions, Lake Youngs provides a good comparison for only select topics, specifically the effects of inundation and water depth on plant communities.

The main effect of water depth on plants is the reduced sunlight available with increased depth. Secchi depth is the depth that a Secchi disk disappears from view as it is lowered in a lake. Thus, Secchi depth varies directly with the amount of light penetration into a lake and the resulting potential maximum depth of submerged plant habitat.

Table 7 presents a comparison of Secchi depth and submerged plant depth for Chester Morse Lake and Lake Youngs (Joubert 2008). The summer mean Secchi depth (and relative amount of light penetration) is less in Chester Morse Lake (26.2 feet) than in Lake Youngs (36.7 feet). Thus, submerged aquatic plants should grow at somewhat deeper depths in Lake Youngs than in Chester Morse Lake. The maximum depth of grass-leaved pondweed was slightly (10 percent) greater in Lake Youngs (20 feet) than Chester Morse Lake (18 feet). However, the maximum depth of Nitella was much greater (60 percent) in Lake Youngs (35 feet) than in Chester Morse Lake (22 feet). The presence of Nitella at much deeper depths in Lake Youngs may be due to less water level fluctuations and wave action at Lake Youngs than Chester Morse Lake. Unlike rooted vascular plants, Nitella loosely attaches to sediment with a holdfast that easily dislodges upon minor disturbance.

Table 7. Comparison of submerged plant depth ranges and Secchi depths for the Chester Morse Lake delta study areas and Lake Youngs in 2007.

	Nitella flexilis Depth Range (feet)	*Potamogeton gramineus* Depth Range (feet)	Summer Mean Secchi Depth (feet) [a]
Cedar River Delta	10-22	1-17	26.2
Rex River Delta	10-20	1-18	26.2
Lake Youngs [a]	7-35	4-20	36.7

[a] Data source: Joubert 2008

Currents, Scour, and Related Sediment Characteristics

The aquatic plant distribution in the Cedar and Rex River delta study areas was clearly affected by river flows. In both river deltas, the main river channel conveying flow through the delta created a zone that did not support submerged plant growth. The absence of submerged plants in this riverine zone was likely due to seasonally strong currents, hydrologic scour, and coarse-grained sediment that prevent plant establishment and growth. There was evidence of erosion in some areas exposed to wave action, which limited emergent plant coverage or sedge growth, and resulted in patches dominated by bare soil or small creeping buttercup.

In some areas exposed to wave action, there is evidence of erosion which limits emergent plant coverage or sedge growth, resulting in patches dominated by bare soil or small creeping buttercup.

Dispersal and Herbivory Characteristics

Pondweeds are propagated by seeds, dislodged root fragments, and the spread of the root mass. The root (rhizome) masses expand into suitable habitat wherever the habitat abuts existing root masses. Until future surveys are conducted, it is impossible to know whether this process is continuing, or if the species has occupied most of the available habitat. However, given the widespread distribution of pondweed observed in 2007, it is likely that the coverage of this species is near its maximum extent under current lake-level regime.

Nitella is propagated by spores and plant fragments. It does not develop a root mass and does not necessarily grow in the same location every year. As such, Nitella may vary in population size and location on an annual basis. It has a greater tolerance for the low light and high pressure conditions of greater water depths than vascular plants (including pondweeds). It is therefore able to populate deeper areas that are not suitable for vascular plants. The lack of a root mass gives Nitella a lower tolerance for currents and less able to populate shallow areas.

The effects of herbivory on aquatic plant communities depend on the type and extent and are the result of herbivore population size, herbivore behavior and feeding locations, and plant species preference. The most likely herbivores in the study area include snails, beaver, and waterfowl. Crayfish are also present in Chester Morse Lake and have exhibited significant effects on Nitella populations in other water bodies. During low lake level periods, elk, deer, and other terrestrial herbivores may also browse on exposed vegetation. Limited information regarding populations and feeding patterns for these herbivore species in the study area make any pattern of effects difficult to detect. However, these processes may be affecting aquatic plant coverage in some areas.

Invasive Species

There were no invasive submerged plant species observed in Chester Morse Lake during this survey. The limited human access to the watershed, limited transfer of in-water equipment into the watershed, and thorough decontamination protocols used by Seattle Public Utilities staff have contributed to this condition. There is always a possibility that an invasive species such as Eurasian watermilfoil (*Myriophyllum spicatum*) could be introduced into the lake by waterfowl, or accidentally by humans. The existing voids in plant coverage and the ability of invasive species to tolerate greater water depths and water level fluctuations than native species would likely contribute to a rapid spread of invasive species if they are introduced into the lake. Routine surveillance of aquatic plant habitat is recommended to allow early detection and potential eradication of an introduced invasive plant in Chester Morse Lake.

Options for Future Surveys

The survey results presented in this report provide baseline information on the distribution of submerged aquatic plants in the study areas. This is the first quantitative survey of the submerged plant community and will provide a useful benchmark for future studies. During the course of the data collection and analysis, some limitations were observed in the techniques and application of the survey methods used in 2007. These limitations were primarily related to the location of survey transects and type of base maps. Limitations of the 2007 survey methodology and options for future aquatic plant surveys are briefly described below.

Survey Transects

The spacing of survey transects, which was targeted to be approximately 300 feet, was a known constraint before survey work was initiated. The planned spacing of the transects was balanced against the level of effort and associated time and cost constraints. This pre-determined spacing was intended to provide a reasonable coverage of the study areas, which was confirmed during the survey data analysis. The number of transects was increased on the Cedar River delta study area because additional time was available to survey more transects than had been planned. The closer transect spacing provided information that enabled more accurate mapping, due to less reliance on aerial photos and bathymetry to extrapolate between transects. In addition, closer spacing of transects also provided more echo sounder data points per unit area, increasing the accuracy of the estimated plant cover and biovolume values.

For comparison with this survey, future surveys should collect data along approximately the same transects as those surveyed in 2007. Surveying the same transects increases the ability to measure temporal variability and detect long-term trends in specific areas of concern by reducing the influence of spatial variability on the analysis of aquatic plant species distributions, which are inherently patchy in natural systems. If more accurate maps are needed for analysis and planning, future aquatic plant surveys should consider adding transects. In particular, the Rex River delta study area would benefit from additional transects in areas where the 2007 transects were spaced greater than 300 feet apart.

The combination of using the same and additional transects during future surveys would allow a detailed analysis of changes in the aquatic plant community distribution, cover, and biovolume.

Base Maps

A more accurate bathymetric map would increase the accuracy of submerged vegetation boundaries and predictions of future water level changes on those boundaries. Submerged plants are heavily influenced by water depth. To determine the effects of water management decisions on submerged plants, the distribution of potential water depth effects must be known, which is dependant on accurate bathymetric maps.

The integrated echo sounding and GPS equipment used in the 2007 survey is a cost effective method for collecting accurate bathymetric and aquatic plant data concurrently. At a rate of seven data points taken per second, resulting in thousands of data points per transect, the bathymetric resolution is quite high. However, overall accuracy is dependent on the number and spacing of transects and the number of transects would need to be increased substantially to obtain sufficient data for an accurate bathymetric map.

Additional Survey Method Options

Annual aquatic plant surveys would provide a more complete picture of changes that are occurring in the study areas. At a minimum, a cluster of annual surveys before, during, and after major changes in the water management program would be needed to understand the effects of the changed water level regimes versus other factors affecting annual variability in plant distribution.

The boundaries of emergent plant growth reported for this survey should be combined with the results of emergent plant sampling and mapping conducted by SPU in 2007. Together, these two surveys in 2007 will provide an accurate estimate of the total emergent plant cover and allow a comparison of the 2007 survey results with the 1987-1996 survey data.

A video camera with digital color format was used to identify plants on the last day of the 2007 boat survey. This system records video footage along transects, and proved to be a better method than the non-recording black and white format used during the first two days of the boat survey. The recorded color format improved real-time plant identification, and allowed for review and confirmation of field observations, and has been archived for potential comparison to video data collected in the future.

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