Warner's Pond Watershed Management Plan

Warner's Pond
Concord, Massachusetts

PREPARED FOR:
Town of Concord
Division of Natural Resources
141 Keyes Road
Concord, Massachusetts 01742

PREPARED BY:
ESS Group, Inc.
100 Fifth Avenue, 5th Floor
Waltham, Massachusetts 02451

Supported in part from Concord Community Preservation Act funds

Revised May 25, 2012

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ESS Project No. C574-000

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1.0 INTRODUCTION

ESS Group, Inc. (ESS) has prepared this Watershed Management Plan for Warner's Pond on behalf of the Town of Concord's Division of Natural Resources (DNR) and the Warner's Pond Stewardship Committee (WPSC). This Plan was supported in part from Concord Community Preservation Act funds. The objective of this Watershed Management Plan is to provide the Town of Concord (Town) with a framework that can be used to guide future management decisions related to Warner's Pond.

This Watershed Management Plan provides background information on existing conditions within Warner's Pond and its watershed, collates previous studies and reports, identifies the key environmental issues that are negatively impacting the pond, prioritizes issues for remediation, and offers recommendations for the pond's future management. ESS worked with Aquatic Control Technologies, Inc. (ACT), a plant control company familiar with the pond, to develop realistic cost estimates for several of the in-pond plant control options considered as part of the recommendations.

1.1 Warner's Pond Description and History

Warner's Pond was created in the 1800s by damming Nashoba Brook less than a mile downstream of its confluence with Fort Pond Brook to operate a saw mill, then a pail factory. In 1895, a fire destroyed the factory, and Ralph Warner sold it to the West End Land Company. The dam has since grown and been rebuilt several times for various purposes, including operation of David Loring's Lead Pipe Works from 1819 to 1854 (WPSC, 2011). Most recently, in 2008, the dam was reconstructed due to safety concerns about aging and failing structural components.

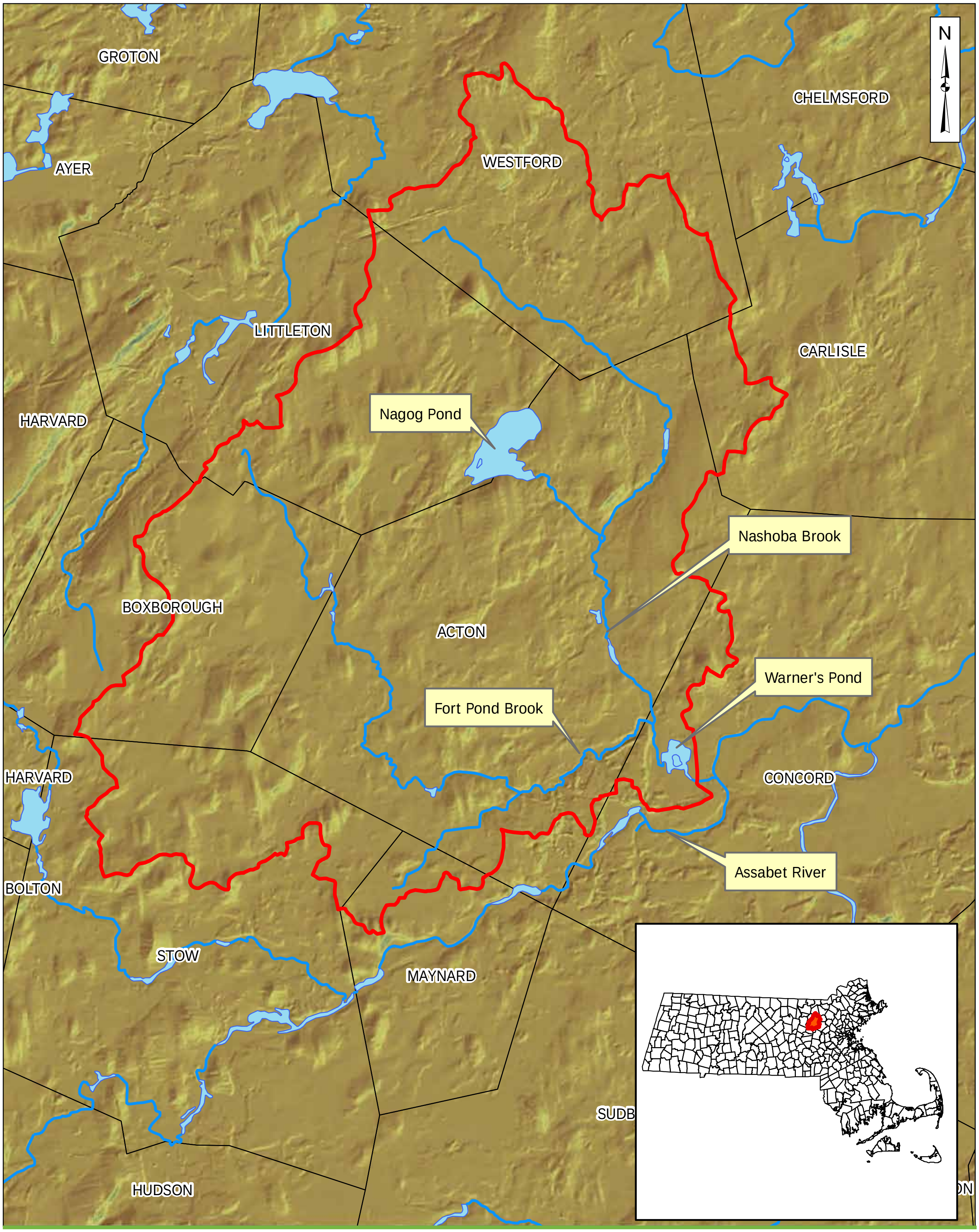
Since the late 1890s, Warner's Pond has been a significant Town natural resource and popular recreation area. Its ecosystem has provided habitat for numerous species of aquatic plants and animals and this continues today.

However, since at least the 1980s, the pond has undergone eutrophication (a process where waterbodies receiving excessive nutrients experience excessive plant growth) and sediment deposition, leading to a decreased use by canoeists, kayakers, and fishermen, as well as diminished ecological value from the establishment of several non-native invasive plants, Exotic, invasive species of plants dominate the pond today, and open water areas are dwindling, Sediments have increased so that some areas are impassable by kayakers and canoeists.

Warner's Pond is relatively shallow and occupies approximately 48 acres (54 acres, if islands are included) fully within the town of Concord, Massachusetts. The pond is fed by an approximately 47-square-mile watershed (Figure 1), which is located primarily outside of Concord and includes portions of the towns of Acton, Boxborough, Carlisle, Littleton, Stow and Westford (Figure 1). The two tributaries that flow into the pond, Nashoba Brook and Fort Pond Brook, merge just upstream of the pond inlet on the western shore (Figure 2). Water discharges into the pond through a broad delta of emergent wetlands on the western shore. Given the size of the pond's watershed and the volume of water contained in the streams feeding the pond, the water entering the pond flushes through the pond relatively rapidly. Water leaves the pond via its outlet at the southeast corner of the pond (Figure 2).

Another consequence of the large watershed to pond ratio is that much of Warner's Pond has filled in with sediments that have made the pond shallower and more susceptible to excessive weed growth, particularly from highly invasive exotic plant species such as variable watermilfoil (*Myriophyllum heterophyllum*), fanwort (*Cabomba caroliniana*), and water chestnut (*Trapa natans*). Sediment and excess nutrients are transported to the pond from its tributaries as well as from the nine stormwater outfalls that discharge directly to the pond or adjacent wetlands around its perimeter. The sediment accumulation, excess nutrients in the water column, and dense growths of exotic aquatic plants have led to a seriously degraded condition in the pond over time. These degraded conditions have diminished the ecological value of the pond with regard to its ability to support fish and wildlife populations typical of

Location: G:/GIS-Projects/Warners-Pond-Concord/00-mxd/Report/watershed.mxd



WARNER'S POND WATERSHED MANAGEMENT PLAN

Warner's Pond Watershed

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Scale: 1" = 8,500' (1.6 miles)

0 8,500 Feet

Watershed boundary

Figure
1

Source: 1) MassGIS, Shaded Relief, 2005
2) MassGIS, Hydrology, 2000

WARNER'S POND WATERSHED MANAGEMENT PLAN

Warner's Pond Locus

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Scale: 1" = 1000'

0 1,000 Feet

Source: 1) MassGIS, USGS Topo Quads

Figure 2

healthier open water habitats. The poor water quality and increased weed growth are also impairing the pond's ability to serve the community with regard to recreational opportunities.

Over the last 13 years, some components of Warner's Pond have been evaluated in an effort to rehabilitate the pond from the effects of excessive sediment and nutrient loading as well as invasive plant growth. This Watershed Management Plan builds on previous studies of Warner's Pond and provides further detail on basic characteristics, the impairments to the pond, and prioritized short- and long-term management recommendations to improve water quality, biological condition, and recreational opportunities.

In 1999, ACT conducted a survey of aquatic plants as well as water and sediment depth and quality (ACT, 1999). The major conclusion from the survey was that excessive sedimentation had facilitated nuisance-level aquatic macrophyte growth in Warner's Pond. In particular, the report noted the establishment of exotic invasive and aggressive native macrophyte beds, particularly at access points in the pond.

Concurrent with the ACT evaluation of Warner's Pond in 1999, New England Environmental, Inc. (NEE) conducted an evaluation of habitat and wildlife use of Warner's Pond. NEE documented that the pond once supported a rainbow trout population, but lost this species as the pond warmed and became a warm-water fishery. No rare or endangered flora or fauna were identified at Warner's Pond during NEE's survey or in any of the documents NEE evaluated from previous surveys. NEE recommended a major restoration effort to improve water quality and habitat in Warner's Pond.

Four years later, ACT conducted a similar study to assess change in Warner's Pond and documented the spread of invasive macrophyte beds throughout the pond (ACT, 2003 and 2004). As a result, aquatic weed harvesting and hydro-raking were implemented to manage water chestnut and fanwort. Following this activity, it was determined that the aquatic weed harvester, or hydrorake, should not be used where variable watermilfoil was also present due to its ability to spread by fragmentation. Volunteer efforts to hand-harvest water chestnut (and thus prevent spreading species that propagate through fragmentation) began in 2004 and continue into the present day.

In June 2007, Geosyntec conducted water quality sampling for the Town in Warner's Pond (Geosyntec, 2007). The motivation for this evaluation was to evaluate two potential sources of pollution inputs to the pond: 1) the area surrounding a 30-inch storm drain outfall to Warner's Pond and 2) water in the vicinity of the old Town dump along Laws Brook Road in West Concord. This study was not able to confirm either source as a definite cause of water quality impairment in Warner's Pond.

Currently, Warner's Pond continues to suffer from high sedimentation and nutrient loading rates, which have accelerated the natural process of pond eutrophication. The excessive growth of exotic and nuisance macrophyte species at the pond impairs recreational uses and both benefits from and contributes to the filling of the pond with sediment in the long term.

2.0 METHODS AND APPROACH

The studies and data collection supporting the current analysis of the Warner's Pond system were conducted between January and December 2011 and included a review of existing data and reports, Geographic Information Systems (GIS) mapping, field data collection, data analysis, and computer modeling. The specific methods and approach that was used to complete each task are described in the following sections.

2.1 Quality Assurance Project Plan Development

ESS developed a Quality Assurance Project Plan (QAPP) for the Warner's Pond Assessment and Restoration Project (Attachment A). A QAPP is a document that is submitted for review by independent authorities to ensure that the data being collected as part of the scientific studies will meet specific data quality objectives and are able to be consistently repeated in future trials. By ensuring that the data collected are valid and repeatable, it ensures that the work performed for this project will be of a quality that will allow the project to qualify for future consideration by state and federal grant programs for pond restoration.

This project's QAPP included plans for the data collection, analysis, and quality control protocols covering all data generating aspects of the project. The QAPP was submitted to the Massachusetts Department of Environmental Protection (MassDEP) and US Environmental Protection Agency (US EPA) for review on February 11, 2011. ESS did not receive comments on the QAPP from MassDEP or US EPA. However, prior correspondence with MassDEP and US EPA indicated that it would be approvable, as long as standard methods were adhered to within the QAPP. Therefore, there is no evidence that the QAPP developed for this project would be considered unacceptable in its draft form.

2.2 Review of Previous Studies

ESS reviewed a number of existing reports and studies, as presented in Table 1 below.

Table 1. Summary of Previous Studies and Reports Reviewed by ESS

Report/Study	Date	Author	Brief Description
Warner's Pond Fisheries Report	July 1983	MA Division Fisheries & Wildlife	Summary of fish population assessment in Warner's Pond
1997 Satellite-Based Monitoring of Massachusetts Lakes & Ponds	December 1997	Organization for the Assabet River	1997 Field data on Warner's Pond; includes aquatic vegetation maps, chlorophyll a data, correlation of lake and pond conditions with satellite imagery
Warner's Pond Management Plan	September 1999	ACT	Provides data on existing conditions and management recommendations for Warner's Pond
Wildlife and Habitat Assessment, Warner's Pond	November 1999	New England Environmental	Attachment to Management Plan; includes biological assessment and management recommendations for Warner's Pond
Updated Aquatic Vegetation Survey and Management Recommendations	October 2003	ACT	Update to 1999 ACT study; includes plant map, water quality results and updated management recommendations.
Project Completion Report for Nuisance Aquatic Plant Management Program at Warner's Pond	January 2005	ACT	Summary of plant surveys and harvesting and hydro-raking efforts to remove invasive weeds during the summer of 2004
Water Quality Sampling Results in Warner's Pond	July 2007	Geosyntec Consultants	Summary report of water quality sampling from stormwater outfall and area near old town dump
Warner's Pond Narrative	Provided to ESS in 2011	Warner's Pond Stewardship Committee	Summary of Warner's Pond characteristics, history, environmental issues and management

ESS conducted its own brief research review to compile additional studies and existing data available on Warner's Pond and its watershed. These sources included the following:

- Massachusetts Year 2010 Integrated List of Waters. April 2010. Prepared by MassDEP, Division of Watershed Management.
- Various presentations and status reports on the Warner's Pond outlet dam rehabilitation project, 2006 to 2008.

In addition to these reports and previous studies, the following digital photographs, GIS shapefiles, maps and figures were also provided by the Town of Concord and WPSC.

- Town of Concord GIS Shapefiles – Provided by Town of Concord Division of Natural Resources in January 2011. Shapefiles used in this study included orthophotos, stormwater outfalls, storm drain lines and catch basins.
- Digital photographs – Provided by Mr. Charlie Simpson, WPSC. Photographs include views of dense floating aquatic vegetation, aerial photo, historic photos of the pond, recreational photos and flooding over the outlet dam during March 2010 floods.
- Concord Board of Health septic system records for homes on streets that border Warner's Pond.

ESS compiled additional information on current watershed and pond features from the most recent USGS topographic maps and Massachusetts Geographic Information System (MassGIS) data.

2.3 Bathymetry and Isopach Survey

A bathymetric (water depth) and isopach (unconsolidated sediment depth) survey was completed at Warner's Pond on January 28, 2011. The purpose of the survey was to collect data to assess the feasibility of pond management options including dredging and drawdown. Prior to conducting the survey, 17 transects were laid out in representative areas throughout the pond as outlined in the QAPP (Figure 3 and Attachment A). Evenly spaced water depth sampling stations were placed along each transect using a GIS in a manner to accurately characterize depth contours across the pond. The sampling stations were uploaded onto a sub-meter accurate Trimble Differential Global Positioning System (DGPS) so that ESS scientists could navigate to each sampling station in the field during the survey.

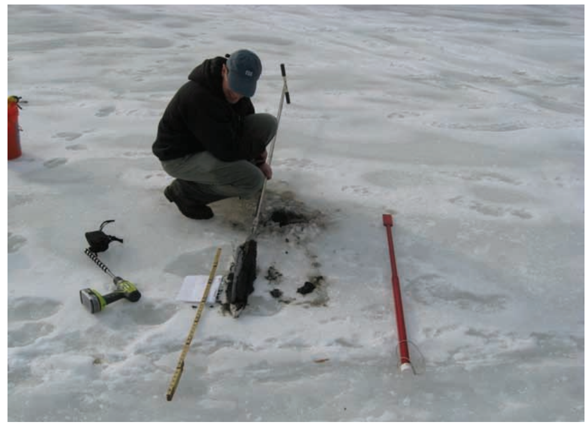
The pond was covered in approximately 16 inches of ice during the time of the survey. A datum measurement was taken at the pond outlet with water surface 5.5 feet below the top of the concrete spillway. Using maps and a DGPS, ESS navigated to each sampling station and used an ice chipper and battery-powered drill to create a hole through the ice. An extendible carbon steel tile probe was extended through the hole to collect two measurements: water depth and total depth. Total depth was obtained by pushing the tile probe into soft sediments until "refusal" at a harder underlying substrate was reached. Data was recorded in field notebooks and used to create figures using a GIS.

Extending tile probe into sediment to measure depth.

2.4 Sediment Sampling

Sediment quality is often used as an indicator of long-term nutrient or contaminant contributions from the watershed to a waterbody. In addition, sediment samples are collected to document physical characteristics and identify levels of potential contaminants that could pose challenges for pond dredging. The characterization of sediments is part of a screening process designed to reveal the severity of sediment contamination, if present, and to aid in the development of future management strategies.

An initial round of sediment sampling at Warner's Pond was completed on February 17, 2011. Prior to collecting sediment, the locations of 12 sediment core locations were plotted using GIS (Figure 4). The coordinates of the 12 sediment core locations were uploaded to a DGPS to navigate to locations in the field. The sediment core locations were selected to characterize the areas of Warner's Pond that are under consideration for dredging and to evaluate any effect of the former landfill at the southwestern corner of the pond on sediment quality. Sample sediment cores were recovered from the pond bottom using an extendible Russian peat corer. ESS photographed each sediment core (Attachment B) and characterized the core color and texture.



View of a sediment core extracted with the peat corer.

A total of four sediment samples (SC1, SC2, SC3, SC4) was composited from three individual sediment cores (SC1-1, SC1-2, SC1-3, etc.) and submitted to the laboratory for analysis. Compositing was accomplished by homogenizing each set of cores with a stainless steel spoon in a stainless steel bowl. Volatile organic compounds (VOCs) were sampled from individual cores prior to compositing, in order to avoid sample loss through volatilization.

Bulk physical and chemical analysis was conducted on the four composite samples. Sediment samples were analyzed for the following parameters: arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), polynuclear aromatic hydrocarbons (PAHs), extractable petroleum hydrocarbons (EPH), percent ash and ASTM grain size analysis per American Society for Testing and Materials (ASTM) standards.

Based on the results of the initial round of sampling, an additional composite sample was collected from the pond at SC-2 on September 2, 2011 to re-test the total chromium and hexavalent chromium levels.

2.5 Sediment Loading and Water Quality Sampling

An initial watershed reconnaissance survey was conducted on March 18, 2011 to identify potential sites to sample to assess sediment and nutrient loading within the Warner's Pond watershed. The reconnaissance was also used to verify that the proposed tributary and point source outfall water quality sampling locations first identified during the development of the QAPP were appropriate for sampling.

Prior to conducting the reconnaissance, maps of land use within the watershed and orthophotos were reviewed to identify areas within the watershed with higher potential to contribute sediment and nutrients to Warner's Pond (Figure 5). After completing the desktop review, targeted areas of the watershed were investigated for potential sediment/nutrient sources and water quality sampling locations (Attachment C). Where obvious pollution sources were observed, the area was described, a GPS position was collected, and photographs taken. These locations included road cuts at bridge crossings, stormwater outfalls, areas with large impervious surfaces, agricultural areas adjacent to pond tributaries, and commercial development along tributary banks (Attachment C). ESS also examined all stormwater outfalls previously identified by the Town around the pond to determine best access for sampling (Figure 6). During the watershed reconnaissance, ESS visited the Town of Acton Planning Department to gather existing data on the locations of catch basins and stormwater outfalls in Acton. According to the Acton Planning Department, comprehensive stormwater infrastructure data for the town is not available in hard-copy or GIS format (March 18, 2011). The Acton Engineering Department was contacted and confirmed that town-wide data is not available though it is currently being developed in an electronic format.

The results of the watershed reconnaissance were used to finalize sediment and nutrient loading point and non-point source sampling locations (Figure 7). Dry and wet weather sampling was completed on September 2 and September 22, 2011, respectively. During dry weather, water quality samples were collected within the pond and at pond tributaries. Samples were not collected from targeted outfalls because no dry weather discharge was observed from these outfalls. During wet weather sampling, water quality samples were collected from pond tributaries and five of the eight targeted outfalls. Samples were not collected from the remaining three outfalls because they were not observed to be flowing during the storm.

2.6 Hydrologic Budget and Nutrient Load Modeling

Data generated during field and desktop assessments was used to develop a hydrologic budget and nutrient load model for Warner's Pond. The nutrient model is a key component of a Watershed Management Plan because nutrient levels influence water quality (e.g., clarity, algal production, etc.) within Warner's Pond. The results of the nutrient model are used to gain an understanding of how the pond is affected by the surrounding watershed and allow management to effectively target those areas of the watershed that will benefit most from restoration efforts and thus be likely to yield the greatest success toward restoring water quality.

Determining a pond's hydrologic budget is the first step toward modeling its nutrient load because all water being delivered to the pond carries some quantity of nutrients. A hydrologic budget models water inflow into the pond, storage capacity within the pond and water outflow from the pond based on the hydrologic cycle. Sources of water inflow include precipitation onto the pond surface, as well as the associated overland runoff, direct stream flow from tributaries, and groundwater seepage along the margins of the pond. Evapotranspiration, groundwater recharge, and direct outflow via a stream outlet all lead to losses of water from the pond. The difference between the sum of the inflows and sum of the outflows determines the storage volume of the pond at a given point in time.

The following sources were used to develop a hydrologic budget for Warner's Pond :. The general pond characteristics, which include acreage, circumference, volume, and watershed size, were calculated using a combination of GIS data and field parameters collected by ESS. Streamflow inputs from the two tributaries to the pond (Nashoba Brook and Fort Pond Brook) were calculated using the online streamflow modeling application, Streamstats[1]. An estimate of the rate of groundwater movement into the pond was based on averages obtained for southern New England ponds of similar morphometry. Data on average precipitation were collected from local weather stations and regional estimates, including the 30-year normals for Boston and Worcester (www.wunderground.com).

The hydrologic model, water quality sampling results (see Attachment A for methods), and sub-watershed land use data were used to model the nutrient load to Warner's Pond. The nutrient budget for a pond models the level of nutrients entering, circulating within, and exiting the pond system. The nutrient level is expressed as a nutrient "load", which is the total mass of the nutrients entering over a given time period (typically expressed as kg/year). A nutrient budget model was developed for Warner's Pond for both phosphorus and nitrogen (Attachment D). Since phosphorus is viewed as the nutrient that controls

[1] Available at: http://water.usgs.gov/osw/streamstats/massachusetts.html

productivity in this freshwater system, greater emphasis was placed on the phosphorus load modeling results.

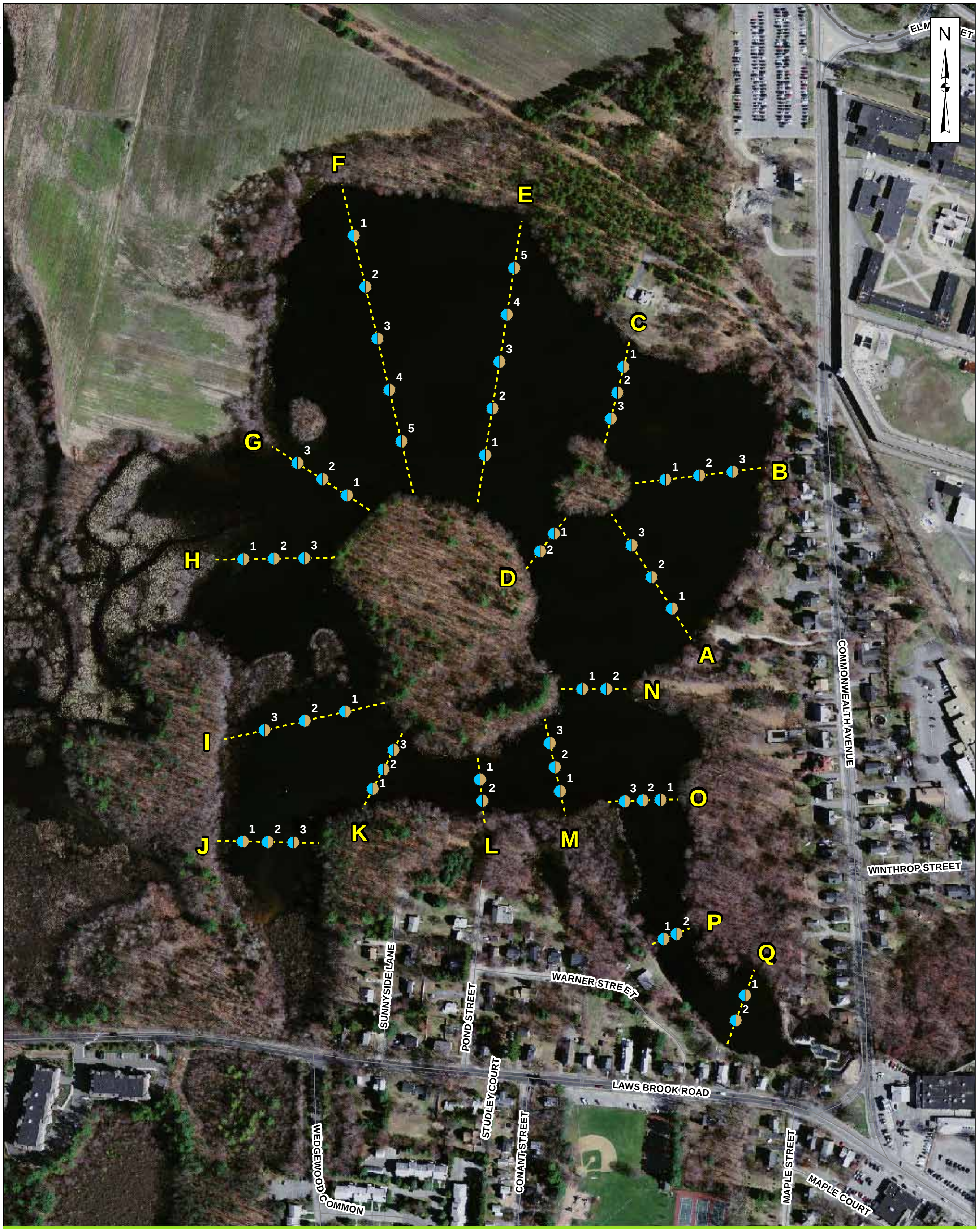
The model approach for this study began with a nutrient load estimate based on the land use export coefficient approach (Reckhow, 1980). This estimate was then calibrated using limnological modeling techniques based on pond features, watershed hydrology, and field data collected at Warner's Pond. The inputs to the nutrient model include data on watershed land use, parameters from the hydrologic model, and the results of water quality sampling.

Existing GIS data was first used to determine the acreage of the various land uses which occur within the three primary sub-watersheds of Warner's Pond, which include the Nashoba Brook sub-watershed, the Fort Pond Brook sub-watershed, and the watershed that immediately surrounds the pond (Attachment D). Each land use contributes a different nutrient load based on its propensity to generate nutrient runoff. Developed areas contribute the highest nutrient loads while forested areas and wetlands contribute the lowest nutrient loads. The total nutrient load contributed from each sub-watershed will depend on the acreage of each land use within the watershed and the nature of the route that runoff from the drainage area must travel to reach the pond.

Hydrologic parameters were used to model characteristics of Warner's Pond that influence how nutrients move through the system. These characteristics include the mean depth (pond volume/pond area), flushing rate (number of times/year that the total volume of water in the pond is renewed), areal water load (volume of water entering a pond in a year divided by the pond surface area) and settling velocity (rate at which a particle drops from the water column) (Attachment D). These metrics are subsequently used to refine the nutrient model for the pond.

Water quality data were used to model the concentration of phosphorus and nitrogen flowing into and out of the pond. These data were also used to calibrate the estimated nutrient load entering from the individual sub-watersheds that was calculated earlier using the GIS land-use based approach. Septic inputs, while potentially present, were not incorporated into the model. According to the Board of Health, most of the homes around Warner's Pond are sewered, with the exception of a few on Wright Road and Laws Brook (see Figure 12). The nutrient load inputs were then used to calculate a phosphorus and nitrogen load entering the pond under several different in-pond models (Dillon and Rigler, 1974; Oglesby and Schaffner, 1978; Jones, Rast and Lee, 1979; Kirchner and Dillon, 1975; Vollenweider, 1968 and 1975; Reckhow, 1977; Larsen-Mercier, 1976; Bachmann, 1980; Jones-Bachmann, 1976) (Attachment D). The individual model results were averaged to obtain a final estimate of the phosphorus and nitrogen load entering Warner's Pond.

Once the nutrient loads for the existing conditions were calculated, the effect these loads have on chlorophyll *a* concentration, total phosphorus concentration, and Secchi depth (water clarity) within the pond was determined. The modeled nutrient inputs were also used to determine the permissible load and critical load for Warner's Pond. Vollenweider (1968) established criteria for calculating the phosphorus load below which no productivity problems were expected (permissible load) and above which productivity problems were almost certain to persist (critical load). Once the nutrient load rises above the permissible load, water quality will begin to deteriorate until nutrient loading increases to a level above the critical load at which point the rate of deterioration will slow since the pond is saturated with nutrients – a state of advanced eutrophication.



WARNER'S POND WATERSHED MANAGEMENT PLAN

Scale: 1" = 400'

0 400 Feet

Source: 1) MassGIS, Orthos, 2008

Legend

Bathymetry/Sediment Sampling Locations

Sampling Transects

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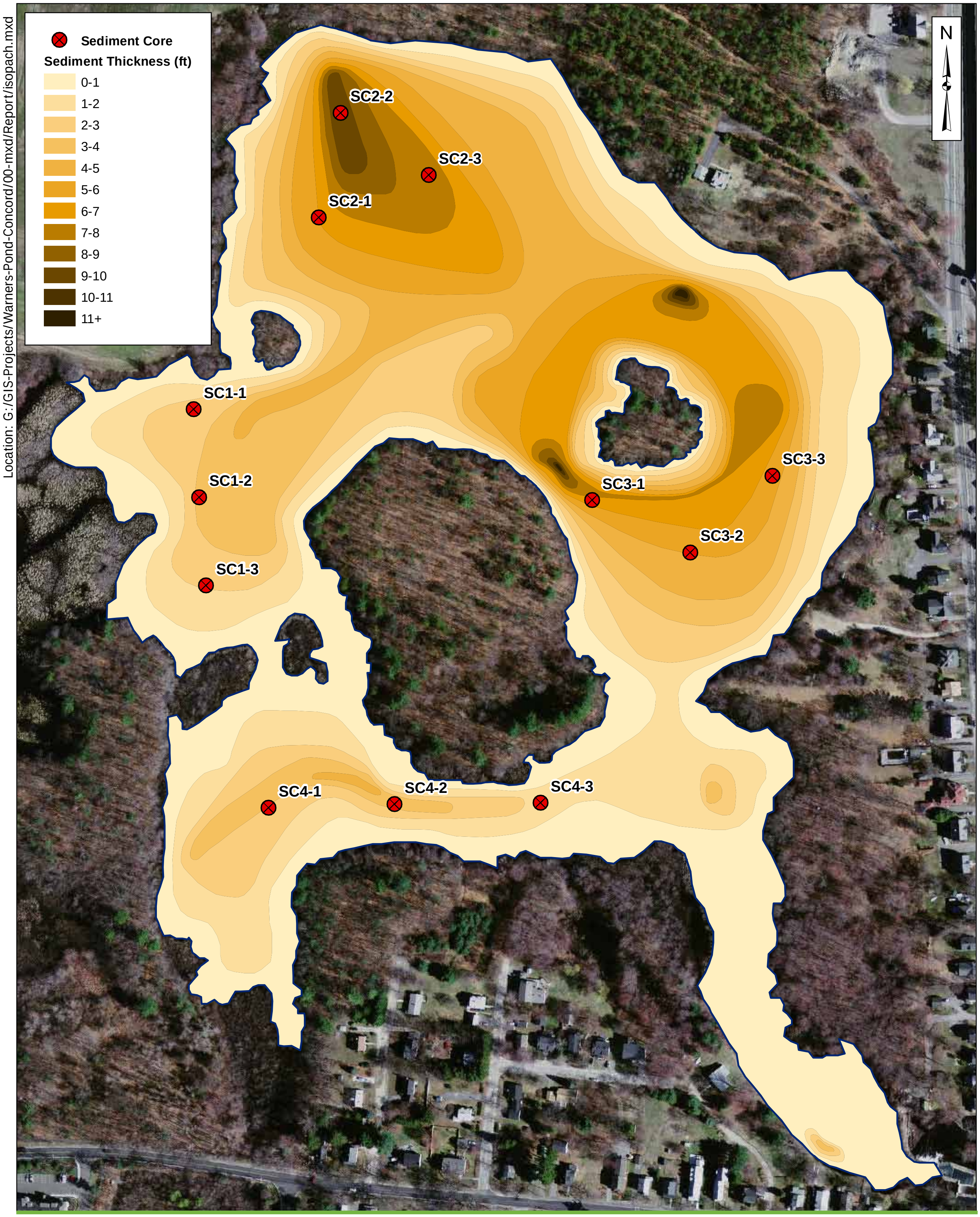
Bathymetry and Sediment Thickness Sampling Transects

Figure 3



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WARNER'S POND WATERSHED MANAGEMENT PLAN

Warner's Pond Isopach Map and Sediment Sampling Locations

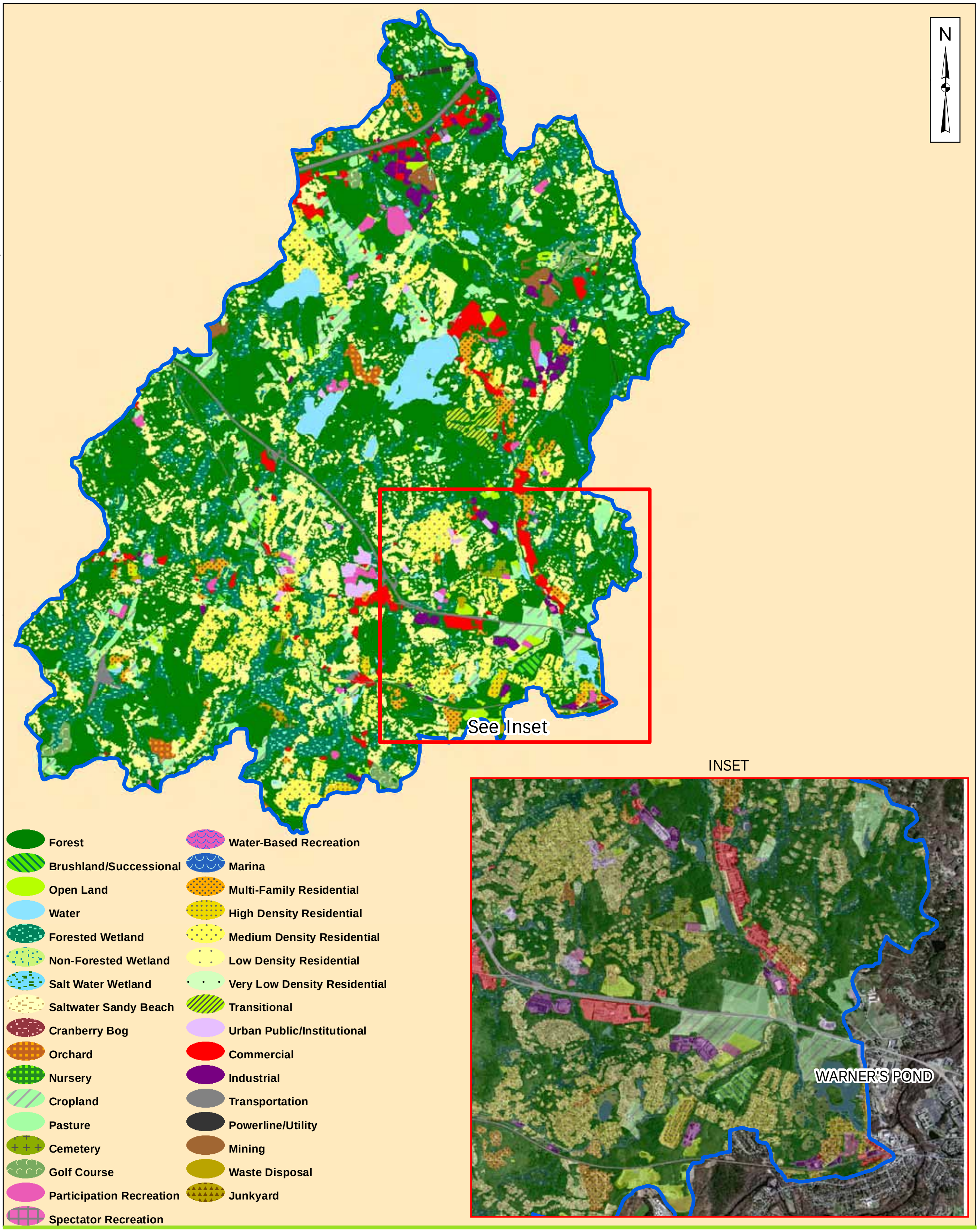
Scale: 1" = 300'

0 300 Feet

Source: 1) MassGIS, Color Orthophotos, 2008

Figure 4

Location: G:/GIS-Projects/Warners-Pond-Concord/00-mxd/Report/LandUse.mxd



WARNER'S POND WATERSHED MANAGEMENT PLAN

Watershed Land Use

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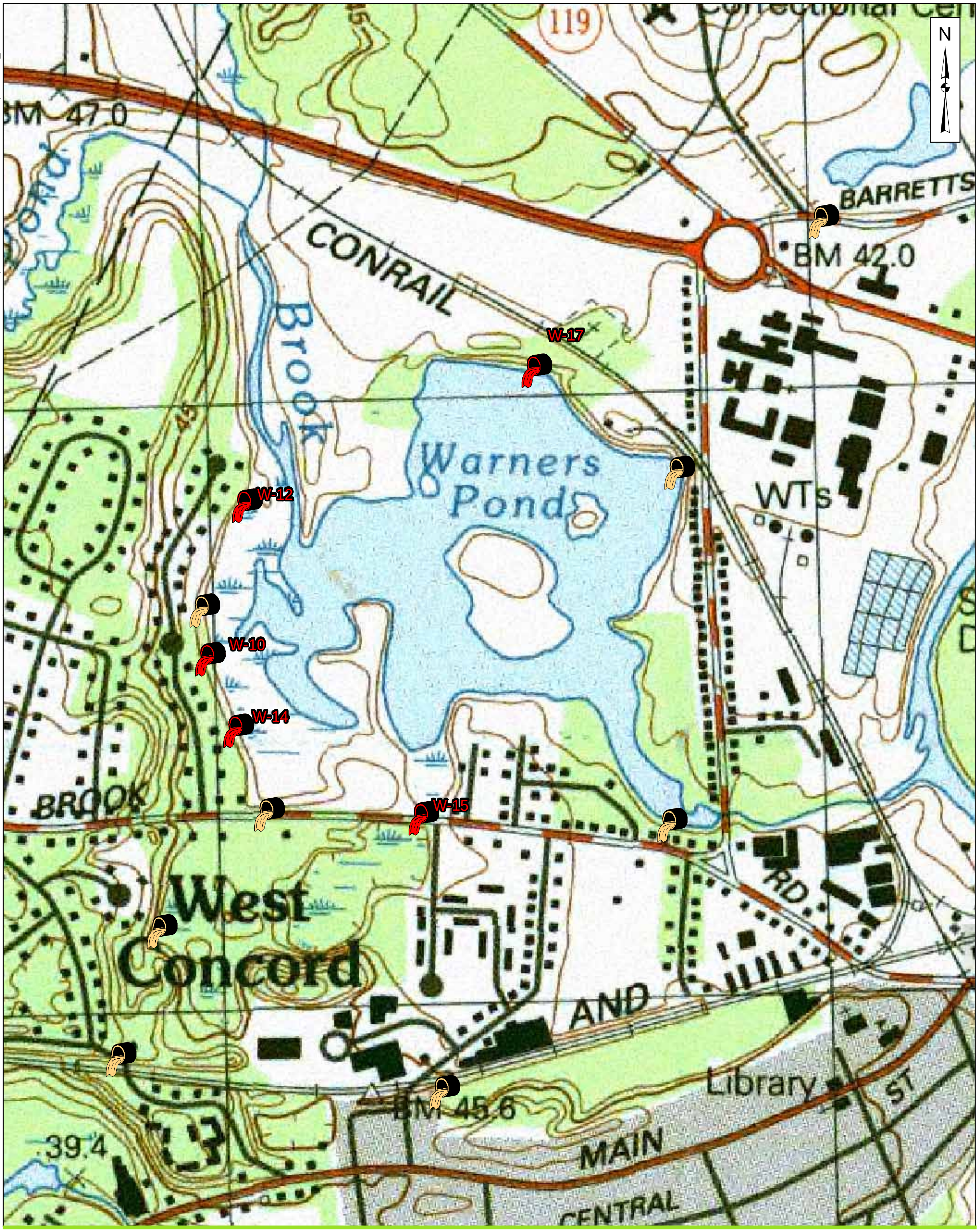
Scale: 1" = 9,000'
0 1 Miles

Source: 1) MassGIS, Color Orthos, 2008
2) MassGIS, Land Use, 2005

Figure 5

Location: G:/GIS-Projects/Warners-Pond-Concord/00-mxd/Report/Point_source.mxd



WARNER'S POND WATERSHED MANAGEMENT PLAN

Point Source Discharge Locations

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Scale: 1" = 750'

0 750 Feet

Source: 1) MassGIS, USGS Topos, 1987-1988
2) Town of Concord, Outfall Locations

Legend

Sampled

Not Sampled

Figure 6

Site ID	Location
WP-1	Nashoba Brook Inlet
WP-2	Fort Pond Brook Inlet
WP-3	Pond Outlet
WP-4	Coles Brook
WP-5	Nashoba Brook
WP-S/B	In-Pond Sample

Outfall ID	Location
W-10	Wright Road
W-12	Wright Road
W-14	Wright Road
W-15	Law's Brook Road
W-17	Route 2

Location: G:/GIS-Projects/Warners-Pond/00-mxd/Report/WQ_Sampling.mxd

WARNER'S POND WATERSHED MANAGEMENT PLAN

Final Water Quality Sampling Locations

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Scale: 1" = 1500'

0 1,500 Feet

Source: 1) MassGIS, USGS Topos, 1987-1988

Legend

Outfall Sample Location

Tributary & In-Pond Samples

Final Location (TSS & Nutrients)

Final Location (Nutrients only)

Figure 7

3.0 RESULTS

The results of each component of the study are presented in the following sections. Results include data collected from previous studies, field collection, desktop review, and limnology modeling.

3.1 Quality Assurance/Quality Control

The project was conducted in substantial compliance with the QAPP developed for the project. All water quality data are deemed valid based on the laboratory's stringent QA/QC procedures (Attachment A). In addition, all of the water quality sample results were inside the normal range of expected values.

The few deviations from the QAPP are described below.

- GeoLabs, Inc. laboratory analysis for total phosphorus for dry weather samples collected on September 1, 2011, did not meet the target detection limit of 0.005 mg/L. The total phosphorus detection used by the laboratory was 0.200 mg/L. ESS requested that the samples be reanalyzed to meet the lower detection limit. The samples were reanalyzed 36 days after collection, which is outside the hold time of 28 days to meet the target detection limit. This option was preferable to using the original results as nearly all of the total phosphorus samples had a "no detect" at the 0.200 mg/L level. The original results were not suitable for use in the nutrient model and instead, the reanalyzed total phosphorus results were used in nutrient modeling calculations.
- The wet weather sampling event captured the first flush of a storm which was forecast to produce greater than 0.25 inches of rain in accordance with the QAPP. The 24-hour storm total of the storm sampled was approximately 0.40 inches. However, according to online weather records (available at www.weatherunderground.com) from the nearest weather station in Bedford, Massachusetts, the majority of the rain in the storm fell the next day, after the samples were collected. There was a period of very light to no precipitation near the end of the time period when ESS was collecting samples. Five of the outfalls that had been targeted for sampling were flowing during the sampling event. However, there was no longer any flow at outfall W-23, which had been targeted for sampling. Therefore, W-23 and the other two remaining outfalls targeted for sampling were not sampled during this event. Despite the lower than anticipated rainfall during the sampling time period, ESS believes the sampled storm still provides reliable data on a smaller storm event and captured the essential first flush period of the storm.
- The laboratory results for hexavalent chromium sediment re-sampling submitted on September 2, 2011, did not meet the target detection limit. The result was that hexavalent chromium was not detected at a detection limit (33.3 mg/kg) that was just above the MCP Method 1 Soil Standard of 30 mg/kg. In accordance with standard methods where laboratory results are above the target detection limit (due to matrix interference or excessive moisture content), the actual value is presumed to be half the laboratory detection limit (in this case, 16.65 mg/kg).

All other field sampling protocols developed for bathymetry, sediment sampling, water quality sampling and biological assessments were completed without deviations from the QAPP.

3.2 Summary of Previous Studies and Existing Conditions

ESS reviewed the previous reports, studies, datasets, and correspondence described in Section 2.2 to develop an understanding of the current conditions in Warner's Pond and how the system has changed through the years. The historic information on Warner's Pond can be used to set realistic restoration goals that are consistent with conditions previously found in the pond.

3.2.1 Biological Resource Assessment

Over the last 12 years, various components of Warner's Pond have been evaluated by the Town to address the effects of excessive sediment and nutrient transport to the pond. Some of the reports presented in Section 2.2 include studies that provide a biological assessment of the pond. These studies were reviewed and provide the baseline for the following biological assessment that ESS conducted during site visits to the pond during the summer of 2011.

The earliest assessment of fisheries within Warner's Pond reviewed was the report prepared by the Massachusetts Division of Fisheries and Wildlife (MassWildlife) in 1983. MassWildlife used gill nets and a shock boat to collect fish within the pond. The fish collected are shown in Table 2).

View of scrub-shrub wetlands that fringe large areas of Warner's Pond. Water willow is dominant.

These results document that warm-water species are dominant within the Warner's Pond fisheries community (except for the stocked rainbow trout). Additionally, red-breasted sunfish (*Lepomis auritus*), pickerel (presumably the redfin pickerel, *Esox americanus americanus*), banded sunfish (*Enneacanthus obesus*), and fallfish (*Semotilus corporalis*) were also observed by MassWildlife in Nashoba Brook and may occur on a transient basis within or at the margins of Warner's Pond. ESS observed bluegill, pumpkinseed, and yellow perch in Warner's Pond in 2011.

Table 2. Fish Species Observed in Warner's Pond

Common Name	Scientific Name
American eel[1]	*Anguilla rostrata*
Golden shiner[1]	*Notemigonus crysoleucas*
White sucker[1]	*Catostomus commersoni*
Rainbow trout[1]	*Oncorhyncus mykiss*
Bluegill[1,2]	*Lepomis macrochirus*
Pumpkinseed[1,2]	*Lepomis gibbosus*
Largemouth bass[1]	*Micropterus salmoides*
Black crappie[1]	*Pomoxis nigromaculatus*
Yellow perch[1,2]	*Perca flavescens*
White perch[1]	*Morone americana*
Yellow bullhead[1]	*Ameiurus natalis*
Brown bullhead[1]	*Ameiurus nebulosus*

†Source: 1. MassWildlife, 1983; 2. ESS, September 2012

The report prepared by the Organization for the Assabet River in 1997 includes plant map results, chlorophyll *a*, and Secchi depth data. The report indicates that the pond was considered eutrophic based on sedimentation levels and excessive aquatic plant growth in the pond.

In 1999, ACT conducted a survey of aquatic plants as well as a study of water and sediment depth/quality (ACT, 1999) (Table 3).The major conclusions from the survey described excess sedimentation facilitating nuisance level aquatic macrophyte growth in Warner's Pond. Additionally, the report noted that exotic and native invasive species were present throughout much of the pond. Exotic aquatic macrophyte species included variable watermilfoil, water chestnut, and fanwort. Additionally, purple loosestrife was observed growing along the margins of Warner's Pond, particularly adjacent to water willow beds on the western side. Four years later, ACT conducted a similar study to document any changes in the condition of Warner's Pond (ACT, 2003 and 2004) (Table 3). The most alarming results indicated that the invasive plants identified in 1999 were spreading rapidly throughout the pond. Fanwort, for example, had increased its cover by 20%, its biomass by 38% and accounted for 54% of all macrophyte growth in the pond (ACT, 2003).

Dense aquatic plant growth just south of Scout Island. Fanwort is visible just below the water surface.

Concurrent with the ACT evaluation of Warner's Pond in 1999, NEE conducted an evaluation of habitat and wildlife use of Warner's Pond (NEE, 1999). The findings in this habitat evaluation are all consistent with the conditions that ESS observed during its assessment of the pond in 2011. NEE described four distinct ecological communities at the pond:

1. Shallow marsh on the western side of the pond
2. A scrub-shrub/emergent marsh (water willow marsh) at the inlet of the pond
3. Open water habitat in the eastern and northern sections of the pond
4. Upland habitat on islands within the pond

The locations and descriptions of these communities in the NEE report are generally consistent with observations made by ESS during the summer field assessment. The most significant observable change is that the scrub-shrub/emergent wetland, which had formerly been limited to the pond inlet and western shoreline, has spread to other areas of the pond. These scrub-shrub/emergent wetlands, which are comprised primarily of water willow (*Decodon verticillatus*), now occur on the southern pond shoreline and areas bordering Scout Island.

Although a fish survey was not conducted as part of this study, ESS believes that, based on the habitat present in Warner's Pond and water quality conditions, the fish community likely remains similar to the community that has been previously documented. The NEE report lists the same warm-water species that were observed during the MassWildlife survey in 1983. NEE noted that the pond once supported a rainbow trout population; however, this species was lost as the pond warmed and warm-water species began to dominate. No rare or endangered flora or fauna were identified at Warner's Pond during NEE's survey or in any documents NEE evaluated from previous surveys.

A major restoration effort was suggested by NEE to restore Warner's Pond water quality. Two approaches (aquatic weed harvesting and hydro-raking) to manage water chestnut and fanwort were implemented in 2004 by the Town at NEE's recommendation. It was later determined that the aquatic weed harvester should not be used where invasive variable watermilfoil was also present, due to its ability to fracture and re-root from cuttings, which is also probably true for fanwort growth as this plant also is known to spread through vegetative fragmentation. Grassroots efforts began in 2004 to hand-harvest water chestnut in areas where variable watermilfoil also occurred, and continues pond-wide.

Currently, Warner's Pond continues to suffer from high sedimentation rates and nutrient inputs due to its large, densely developed watershed. These sediment and nutrient inputs accumulate within the pond and ultimately contribute to the excessive growth of exotic and nuisance macrophyte species, which can degrade open water habitat and impair recreational uses.

The most recent invasive macrophyte treatment program was conducted using the Sonar and Sonar One herbicide formulations during the 2011 growing season. ACT applied these formulations three times in 2011 to control the growth of non-native invasive fanwort and variable watermilfoil (Attachment E). A pre-treatment survey was conducted by ACT on May 20, 2011, which included both plant cover and biovolume mapping from pre-determined sampling locations (Figure 1 in Attachment E). ACT documented numerous macrophyte species in the pond, as well as filamentous green algae and the macroalgal species stonewort (*Nitella sp.*).

ESS and ACT conducted a late season, post-treatment vegetation survey to characterize the aquatic plant community in Warner's Pond and to assess the effects of the Sonar treatment. The Sonar treatment area was limited to the northern and eastern portions of the pond (Figure 2 in Attachment E). A total of 18 different plant species was observed growing within and along the margins of Warner's Pond during the September 2, 2011 post-treatment survey (Table 3).

The two surveys completed in 2011 generated different plant lists as well as somewhat contrasting areas of aquatic macrophyte cover and biovolume. This is due to the effects of seasonality (most aquatic macrophytes do not fully develop until mid- to late summer) and the implementation of a Sonar herbicide treatment between the two surveys.

Table 3. List of Aquatic Plant Species Observed in Warner's Pond[†]

Common Name	Scientific Name
Burreed*[2]	*Sparganium sp.*
Canadian waterweed[1,4,5]	*Elodea canadensis*
Coontail[1,2,3,4,5]	*Ceratophyllum demersum*
Curly-leaf Pondweed[4]	***Potamogeton crispus***
Duckweed[1,2,3,5]	*Lemna sp.*
Eurasian watermilfoil[4]	***Myriophyllum spicatum***
Fanwort[1,2,3,4,5]	***Cabomba caroliniana***
Flatstem pondweed[2,3,4,5]	*Potamogeton zosteriformis*
Floating pondweed[1,2,3,4,5]	*Potamogeton natans*
Humped bladderwort[5]	*Utricularia gibba*
Bladderwort[4]	*Utricularia sp.*
Little floating heart[5]	*Nymphoides cordata*
Mudplantain*[5]	*Heteranthera sp.*
Pickerelweed*[1,2,3,5]	*Pontederia cordata*
Pond water-starwort[1,2,3,4,5]	*Callitriche sp.*
Purple loosestrife*[1,2,3,4,5]	*Lythrum salicaria*
Ribbon-leaf Pondweed[1,2,3]	*Potamogeton epihydrus*

Common Name	Scientific Name
Smartweed[4,5]	*Polygonum sp.*
Thin-leaf Pondweed[2,3]	*Potamogeton pusillus*
Water willow*[1,2,3,4,5]	*Decodon verticillatus*
Variable watermilfoil[1,2,3,4,5]	***Myriophyllum heterophyllum***
Water chestnut[5]	***Trapa natans***
Watermeal[1,2,3]	*Wolffia sp.*
Watershield[1,5]	*Brasenia schreberi*
White water lily[1,2,3,4,5]	*Nymphaea odorata*
Yellow water lily[1,2,3,4,5]	*Nuphar lutea variegata (=N. variegatum)*

†Source: 1. ACT, August 1999; 2. ACT, September 2003; 3. ACT, September 2004; 4. ACT, May 2011; 5. ESS, September 2011
*Emergent species
Exotic invasive species noted in bold

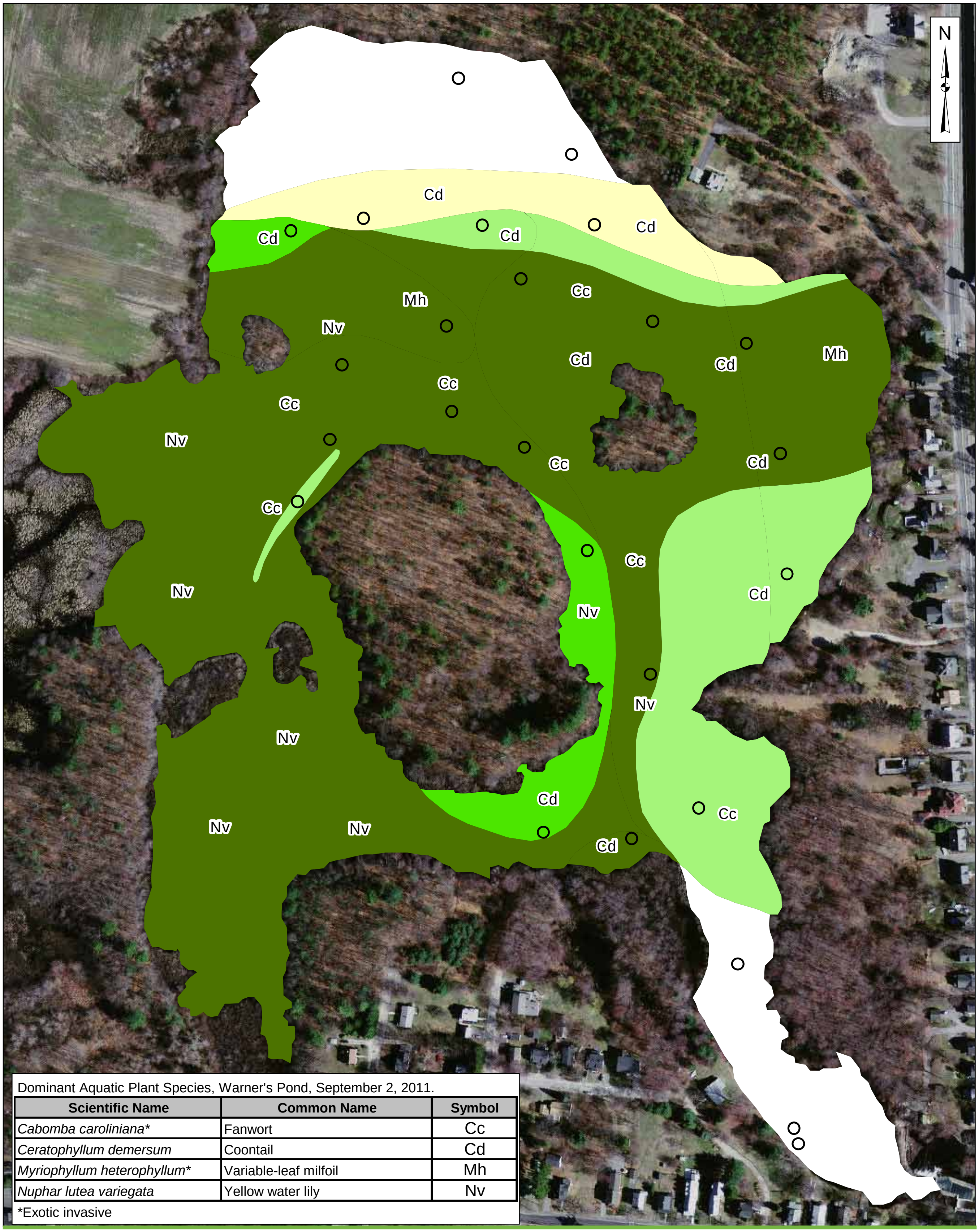
Although the overall number of different plant species observed was relatively high, nearly all of the aquatic plant cover within the pond consisted of fanwort or coontail. This includes southwestern portions of the pond dominated by water lily species, where fanwort and variable watermilfoil were also present as subdominant species. The majority of the other species observed was found at a few limited locations along the shorelines of the southeastern outlet of the pond.

Plant cover, or the percent of an area covered by plants, was highest in the western and southwestern portions of the pond, which had not been targeted by the Sonar treatment (Figure 8). Plant cover was also very high to the north and northeast of Scout Island where swift-moving water through the pond was likely to have limited herbicide contact time and thus appeared to be less effective in these areas. The Sonar treatment was highly effective in the northern and eastern portions of the pond where fanwort, variable watermilfoil and coontail showed signs of chlorosis and had dropped out of the water column due to decay.

Biovolume, or the percentage of the water column occupied by plants, was greatest in the western and southwestern areas of the pond, which were not treated with Sonar (Figure 9). The low biovolume in the northern and eastern portions of the pond reflect the effectiveness of the treatment in some of these areas. The field survey results suggest that there will be a lasting effect of the herbicide treatment going into the 2012 growing season. However, based on the overall densities and coverage of invasive aquatic macrophytes observed during the survey in untreated portions of the pond, these nuisance species will continue to impact the overall ecological integrity of Warner's Pond.

Despite the presence of aquatic invasive species, Warner's Pond provides habitat for birds, warm-water fisheries, reptiles, amphibians, invertebrates and aquatic mammals. The pond is fringed by the extensive scrub-shrub/emergent wetland system near the inlet and along the southern shoreline. These wetlands provide ideal habitat for a variety of waterbirds and likely offer an important feeding area for migratory waterfowl (NEE, 1999). The dense vegetation within the wetlands and shallow water provide foraging, cover, and nesting habitat for avian species. A compilation of bird species observed by NEE and ESS in aquatic, wetland, and upland habitats of the pond and adjacent areas is provided in Table 4.

Location: G:/GIS-Projects/Warners-Pond-Concord/00-mxd/Report/Plant-Cover.mxd



Dominant Aquatic Plant Species, Warner's Pond, September 2, 2011.

Scientific Name	Common Name	Symbol
*Cabomba caroliniana**	Fanwort	Cc
Ceratophyllum demersum	Coontail	Cd
*Myriophyllum heterophyllum**	Variable-leaf milfoil	Mh
Nuphar lutea variegata	Yellow water lily	Nv

*Exotic invasive

WARNER'S POND WATERSHED MANAGEMENT PLAN

Warner's Pond Plant Cover
September 2, 2011

ess group
environmental consulting & engineering services

Scale: 1" = 300'

0 300 Feet

Source: 1) MassGIS, Color Orthophotos, 2008

Note: The symbols on this map represent only the dominant species in each area. Additional species were present and a full species list is provided in the text.

O Plant Cover Sample Location

Plant Cover
- 0%
- 1% - 25%
- 26% - 50%
- 51% - 75%
- Greater than 75%

Figure 8

Location: G:/GIS-Projects/Warners-Pond-Concord/00-mxd/Report/Biovolume.mxd

WARNER'S POND WATERSHED MANAGEMENT PLAN

Warner's Pond Biovolume
September 2, 2011

ess group
environmental consulting
& engineering services

Scale: 1" = 300'

0 300 Feet

Source: 1) MassGIS, Color Orthophotos, 2008

Biovolume Sample Location
0%
1% - 25%
26% - 50%
51% - 75%
Greater than 75%

Figure
9

Table 4. List of Avian Species Observed using Warner's Pond and its Shoreline Habitats

Common Name	Scientific Name
Belted Kingfisher[1]	*Megaceryle alcyon*
Canada Goose[1,2]	*Branta canadensis*
Double-crested Cormorant[1]	*Phalacrocorax auritus*
Chimney Swift[1]	*Chaetura pelagica*
Eastern Kingbird[1]	*Tyrannus tyrannus*
American Goldfinch[1]	*Spinus tristis*
Great Blue Heron[1,2]	*Ardea herodias*
Least Flycatcher[1]	*Empidonax minimus*
Green Heron[1]	*Butorides virescens*
Mallard[1]	*Anas platyrhynchos*
Mute Swan[2]	*Cygnus olor*
Red-tailed Hawk[2]	*Buteo jamaicensis*
Song Sparrow[1]	*Melospiza melodia*
Spotted Sandpiper[1]	*Actitis macularius*
Wood Duck[1]	*Aix sponsa*
Downy Woodpecker[1]	*Picoides pubescens*
Mourning Dove[1]	*Zenaida macroura*
Gray Catbird[1]	*Dumetella carolinensis*
Northern Flicker[1]	*Colaptes auratus*
Cedar Waxwing[1]	*Bombycilla cedrorum*
Black-capped Chickadee[1]	*Poecile atricapillus*

Source: 1. NEE, April to August 1999; 2. ESS, September 2012

Reptiles and amphibians were not directly observed by ESS at Warner's Pond. However, NEE (1999) reported painted turtle (*Chrysemys picta*) and green frog (*Rana clamitans*) observations. Appropriate breeding, foraging, and overwintering habitat is readily available for both species and they are likely to be common at Warner's Pond.

Aquatic macroinvertebrates, including the terrestrial stages of some species, were observed at Warner's Pond by NEE (1999) and ESS. In addition to several dragonfly and damselfly (Odonata) species, other aquatic worms, insects, crustaceans, snails, and native eastern elliptio freshwater mussels (*Elliptio complanata*) are also present and an important part of the pond community. No rare aquatic macroinvertebrate species were observed.

Although not observed during the survey, the scrub-shrub/emergent and shallow marsh wetlands on the eastern and southern sides of the pond may also provide habitat for muskrats (*Ondatra zibethicus*), beavers (*Castor canadensis),* and mink *(Mustela vison)*. Muskrats may forage to some extent on freshwater mussels in Warner's Pond, as evidenced by the presence of empty mussel valves along portions of the pond shoreline.

In sum, Warner's Pond provides valuable wildlife habitat through the diversity of wetland and open water habitats that occur within the pond. The mix of water depths, variety of water flow regimes, and extensive scrub-shrub/emergent wetland system that border the pond are ecological assets. However, the excessive sediment and nutrient load to the pond have fostered the aggressive expansion of aquatic and emergent plant species that will continue to encroach upon areas of open water habitat. Over the long run, the pond will continue to fill in with sediment and gradually transition into a scrub-shrub/emergent wetland through the process of succession. This will limit the pond's future ecological value as open water habitat and its recreational value to the community.

3.2.2 Recreational Resource Assessment

Warner's Pond has provided recreational opportunities to West Concord residents and visitors for over 160 years. In this time, recreational access and activities have taken many forms. Descriptions of activities documented in the Warner's Pond brochure and are summarized in the following paragraphs,


Historic photo of Scout Island. A bridge that once ran to the island is just visible in background.

In the 1890s, a bridge connected the mainland with Scout Island (then the Isle of Pines), the largest island in the pond. At this time, the Isle of Pines was subdivided into 34 lots for summer cottages. In 1944, ownership of the island was transferred to the Boy Scouts Troop 33 of West Concord and, owing to the use of the island by Boy and Girl Scouts for camping, nature study, cooking and sports, it eventually became known as Scout Island.

The Warner's Pond shoreline was historically used for swimming access by town residents and even inmates from the state reformatory on Commonwealth Avenue. At least four separate swimming areas have been established at one time or another at the pond. A picnic area, playground, and rental boats were also available for summer recreation in previous years.

Historic winter recreational activities included ice skating and hockey. Community ice skating parties were sometimes held in the evenings after Christmas. Residents would bring their old Christmas trees down to the pond and burn them in a bonfire. The light of bonfire would provide enough illumination by which to ice skate.

Ice cutting was also popular in the past at Warner's Pond. Each year, cut ice was stored in ice houses near the state reformatory until these houses burnt down. Mink and muskrat trapping and fishing were also historically practiced.

The current trajectory of the pond's condition appears to be threatening some of these recreational activities as the area of open water habitat shrinks and access to the pond has become more limited.

However, restoration plans could enhance these recreational activities at Warner's Pond if implemented in the near future. The primary pond recreational goals include the following:

- Continue to maintain and improve the pond's fishing opportunities.
- Clear select areas of water lilies and dense exotic aquatic vegetation to provide greater access to Scout Island and other areas of the pond.
- Address the excess sediment and nutrients in the pond.
- Improve the existing boat launch access off Commonwealth Avenue so that it can better accommodate recreational activities throughout the year. This could include adding new gravel and maintaining a relatively deep and weed free boating access channel near the launch that would allow boats to more easily access open water areas of the pond.
- Maintain primitive boat landings on Scout Island and Pond Street to allow for easier access.

The primary concern of residents in the area has been the gradual loss of open water habitat to aggressive aquatic plant growth, particularly of invasive exotic species such as fanwort, variable watermilfoil, and water chestnut. Water lilies, although native, have also developed extensive beds in the pond and often grow alongside fanwort and variable watermilfoil. Some of the recreational goals (i.e., access to Scout Island, boat launch improvement) are dependent on maintaining a large portion of the pond as open water habitat. These goals will need to be balanced with interests to maintain the ecological value of the shallow marsh habitat that occurs in significant portions of the pond, particularly on its western margins.

3.3 Bathymetry

Results of water depth surveys were used to create a bathymetric map for the pond (Figure 10). Warner's Pond was found to be shallow (generally less than 4 feet deep) in the western bays near the inlet. The deepest point in Warner's Pond is at a hole in the northern portion of the pond, where the depth is 12 feet. The total volume of water in the pond is estimated to be approximately 7,214,000 cubic feet (or about 54 million gallons) with a mean water depth of 3.4 feet (Attachment D).

Water flows through Warner's Pond relatively rapidly resulting in a high flushing rate for the pond. Field observations indicate that the dominant flow path leads from the inlet, to the north of Scout Island and then down to the outlet (Figure 10). There is less flow in the deeper pools and coves within the pond. The variety of depths and flow regimes provide aquatic habitat diversity.

3.4 Isopach Map and Sediment Quality

The thickness of soft pond sediments was measured along transects throughout Warner's Pond in order to generate a sediment isopach map (Figure 4). The thickest sediments were found in small pockets located around the small island in the northeast section of the pond. Additionally, deep soft sediment layers were also found in the northwestern corner of the pond where sediment thickness reached 9 feet deep. Sediment thickness averaged 2.8 feet across the entire pond. However, soft sediments in the southeast basin of Warner's Pond near the outlet were generally very thin (less than 1 foot). The total volume of soft sediments in Warner's Pond was estimated to be 5,934,000 cubic feet (220,000 cubic yards) which is a volume that is slightly less than that of the overlying water volume.

An assessment of overall sediment quality in Warner's Pond was conducted on February 17, 2011. The purpose of the analysis was to assess the feasibility of incorporating dredging as a management option for the pond. Results of the analysis provide insight into regulatory issues related to dredge spoils, should dredging be pursued as a management action. This study included analysis of bulk physical properties and a quantitative assessment of sediment chemical parameters.

Sediment core sample from Warner's Pond.

The color and texture of each sediment core collected was documented during the sampling effort. In addition, each sediment core was photographed (Attachment B). The majority of the sediment cores collected consisted of a dark brown, organic muck mixed with silt. A few of the sediment cores were dark, brown, organic mucks mixed with greater percentages of sand and clay. Refusal during sediment core collection was reached at either an underlying sand or clay layer.

A summary table of sediment chemistry results is provided (Attachment F). Sediment chemistry data was compared to the Massachusetts Contingency

Plan (MCP) Method 1 Soil Standards (Attachment F). These standards consider the potential risk of harm resulting from direct exposure to the hazardous constituent of the soil. The MCP defines three different soil types (S-1, S-2, & S-3), generally based on the potential for exposure to that soil. To be conservative, the lowest concentration level was used to evaluate the Warner's Pond sediment quality data. It should be noted that the MCP Method 1 standards apply to upland soils and thus are not directly applicable to the pond sediments. However, the MCP Method 1 standards will apply to any sediment dredged from the pond and would be used to determine whether the sediment is safe for beneficial reuse or how the sediment could be disposed.

Sediments collected near the inlet to Warner's Pond (composite sample SC-1 from the western basin) were below MCP Method 1 Soil Standards for all analytes evaluated. Similarly, in the eastern basin (composite sample SC-3) and southern basin (composite sample SC-4), each of the tested analytes were also below MCP Method 1 Soil Standards. This suggests that sediments in these basins are relatively free of contaminants of concern.

Sediments collected from the northern basin (composite sample SC-2) on February 17, 2011 exceeded the MCP Method 1 Soil Standards for chromium. Chromium occurs in two valence states, trivalent and hexavalent. Trivalent chromium is an essential element and is considered much less toxic than hexavalent chromium, both for acute and chronic exposure. Sediments from this area were re-sampled on September 2, 2011 and analyzed for hexavalent chromium to determine whether the observed exceedance was due to this valence state or the less toxic trivalent state. The results of the re-sampling effort indicate that the hexavalent chromium was not detected and that dredging is a feasible option (Attachment F).

Physical testing indicated that pond sediment was primarily fine sand according to the Unified Soil Classification System (Table 5). The north (SC-2), east (SC-3), and southern (SC-4) basins of Warner's Pond had "medium sand" as the dominant grain size in their sediments. The western basin (SC-1) near the pond inlet was primarily "fine sand" according to the Unified Soil Classification System.

Table 5. Unified Soil Classification System for Warner's Pond Sediments

Sample ID	Fines (Clay or Silt)	Fine Sand	Medium Sand	Coarse Sand	Fine Gravel
SC-1	15.9	49.9	26.2	7.7	0.3
SC-2	17.1	29.3	39.7	13.0	0.9
SC-3	14.2	32.9	44.1	8.6	0.2
SC-4	11.1	31.2	40.3	17.1	0.3

The sieve analysis results, which are the basis of the Unified Soil Classification System, are presented in Table 5. Less than 1% of the sediment collected was greater than 4.75mm in diameter (fine gravel) (Passing #4) (Table 4 and 5). The smallest size fraction (fines) (Passing #200), ranged from 11% of the bulk dry-weight at SC-4 to 17% at SC-2.

Table 6. Results of Sieve Analysis for Sediment Sample, Warner's Pond

Sample ID	Sieve Analysis ASTM C 136, ASTM C 117							
	Percent Passing #4 (% by Wt.)	Percent Passing #10 (% by Wt.)	Percent Passing #20 (% by Wt.)	Percent Passing #40 (% by Wt.)	Percent Passing #60 (% by Wt.)	Percent Passing #80 (% by Wt.)	Percent Passing #100 (% by Wt.)	Percent Passing #200 (% by Wt.)
SC-1	99.7	92.0	77.2	65.8	59.1	53.3	49.4	15.9
SC-2	99.1	86.1	62.4	46.4	37.0	31.9	29.8	17.1
SC-3	99.8	91.2	66.8	47.1	36.6	31.0	28.2	14.2
SC-4	99.7	82.6	55.9	42.3	34.1	29.0	26.1	11.1

3.5 Sediment Loading and Water Quality Results

The results of the watershed reconnaissance described in Section 2.5 were used to identify locations with high, medium, and low potential to contribute sediment and nutrients to Warner's Pond (Figure 11 and Attachment C). The tributary and point source sampling locations were relocated as needed to target areas with the greatest potential to contribute sediment and nutrients to Warner's Pond.

Based on the reconnaissance, the primary sediment loading hotspot occurs along the reach of Nashoba Brook from downstream of Concord Road to the point at which Nashoba Brook turns south from Route 119/2A (Figure 11 and Attachment C). Numerous commercial and light industrial businesses line Nashoba Brook along Route 119/2A with little to no vegetative buffer along the banks of the brook. A dam just downstream of Concord Road in Acton impounds Nashoba Brook to form Ice House Pond. Although there are additional sources of sediment and nutrients from commercial development upstream of Ice House Pond, most of these upstream sediments are likely trapped behind the dam and do not reach Warner's Pond. Sampling location WP-5 was relocated downstream of Ice House Pond from its original location further upstream in order to better target the high priority sediment source locations along Route 119/2A (Figure 7).

Development along Fort Pond Brook, the other major tributary to Warner's Pond, is generally lighter. Drainage from commercial and residential development in West Acton and South Acton likely contributes sediment to Fort Pond Brook. Fort Pond Brook runs alongside the large impervious parking area of the Acton MBTA commuter rail parking lot, which is another potential sediment source. Another large impervious area associated with a facility at the corner of Hosmer Road and Route 2 is another potential sediment source to Coles Brook, which discharges to Fort Pond Brook.

ESS consulted the Town for additional information on sediment and nutrient loading sources to Warner's Pond. According to Concord Board of Health records, most of the homes on the streets that border Warner's Pond are on Town sewer. The exceptions are the homes on Wright Road and a small section of Laws Brook Road, which are primarily on septic systems (Figure 12). Failed septic systems may contribute to the nutrient load to the pond.

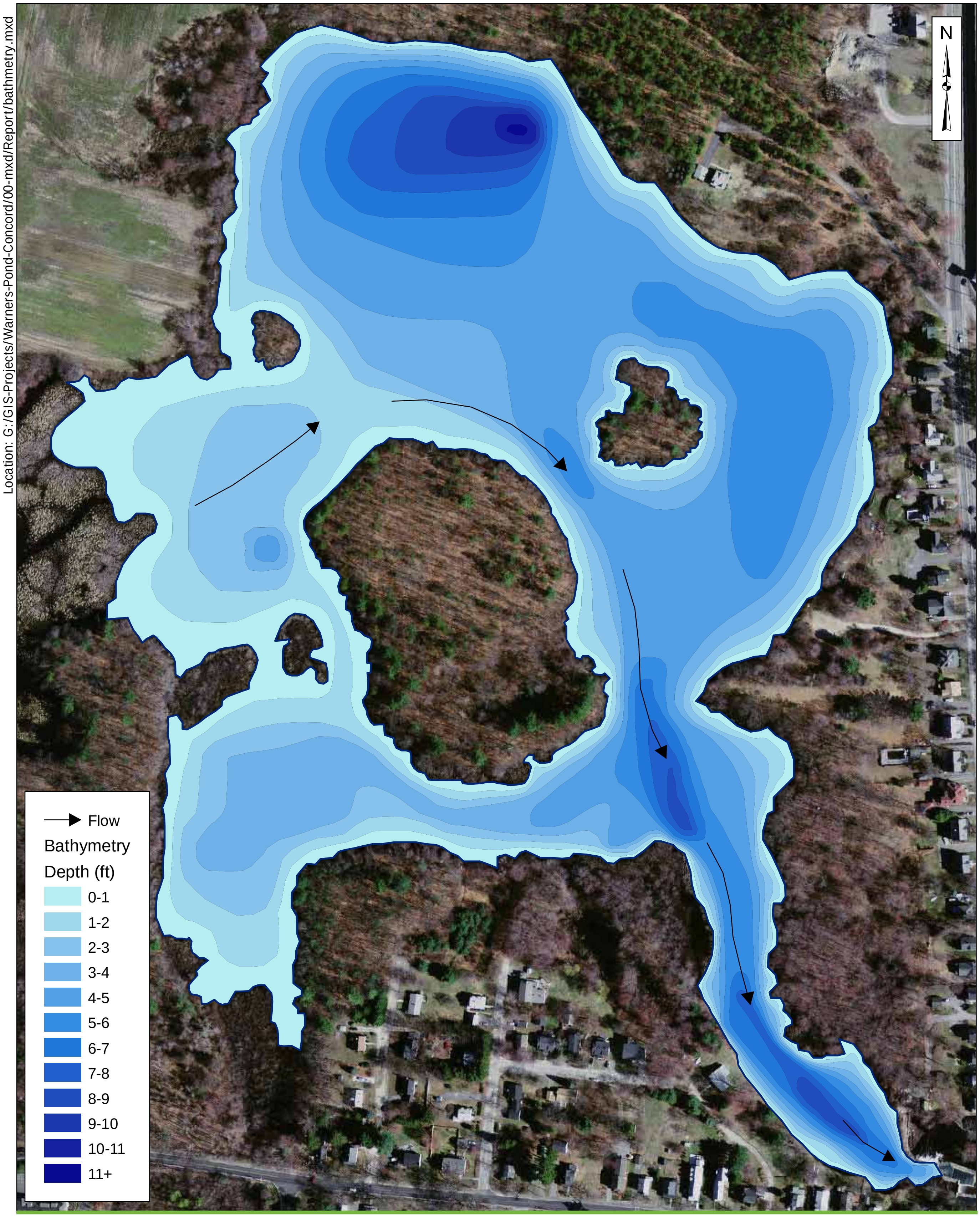
The majority of the stormwater outfalls along the perimeter of Warner's Pond that were examined during the watershed reconnaissance discharge to emergent and scrub-shrub wetlands that ring the western shoreline of the pond. Outfalls W-10, W-11, W-12 and W-14 all drain road runoff from Wright Road; however, bordering wetlands likely trap and attenuate much of the sediment load being discharged from these outfalls (Figure 7). Outfall W-15 drains runoff from Law's Brook Road which also discharges to a bordering wetland within Warner's Pond (Figure 7). Outfall W-17 was a high priority for sampling as it discharges runoff from Route 2 directly to Warner's Pond. One mapped outfall near the state prison could not be located and according to correspondence received from the Town, the outfall is likely buried.

During dry weather sampling, total phosphorus levels were elevated (>0.02 mg/L) at all locations except the Warner's Pond surface site (Table 7). This result indicates that dry weather phosphorus levels contribute significantly to the excess nutrient load in Warner's Pond. The total suspended solid (TSS) levels, which are an indicator of sediment load, were all below the threshold of concern of 10 mg/L. The highest turbidity level was observed at WP-5, which was identified as a sediment loading hotspot during the watershed assessment.

Measuring flow from outfall and stormwater discharging to a catch basin on Wright Road during wet weather sampling.

It should also be noted that flow at the Warner's Pond outlet (WP-3) and Nashoba Brook sites (WP-2 and WP-5) was greater during dry weather than during the wet weather sampling, which may have been due to the timing of dry weather sampling, which occurred soon after Hurricane Irene. Although Irene itself did not produce extreme rainfall amounts over eastern Massachusetts (e.g., less than two inches fell in Boston), it capped off a wetter than average August and extended a period of relatively high stream flows. It is unlikely that this significantly skewed TSS and nutrient values. This is due to the tendency of sediment and nutrient transport to be higher at a given discharge during rising flows than when flows are receding. Given the several days of dry weather between Irene and dry weather sampling, Coles Brook, Nashoba Brook, and Fort Pond Brook were likely receding at the time of sampling. All other parameters fell within the range of expected values for dry weather sampling.

During wet weather sampling, total phosphorus levels were elevated (>0.02 mg/L) at Coles Brook and at all of the outfalls sampled (Table 7). The TSS level at WP-5 was elevated at 9 mg/L; WP-5 was identified as a sediment loading hotspot during the watershed assessment. Turbidity and TSS at two outfalls on Wright Road were also very high. Given the high total phosphorus levels observed during dry weather flow, we would expect to see even higher levels in the tributaries during wet weather flow. However, as described in Section 3.1, the stormwater samples were collected at the beginning of the storm after relatively little rain had fallen. In contrast to streams, water concentrates faster at outfalls, where turbidity and TSS were at levels that are more consistent with what is expected during a storm. Samples collected from tributaries later in the storm would likely have had higher levels of sediment after a greater volume of stormwater discharged to these waterbodies. Although nutrients and TSS were high in the outfalls on Wright Road, their relative contribution to the pollutant load in the pond is very low given the low flows that discharge from these outfalls, which were all well under 1 cubic-foot/second (cfs) (Table 7).



WARNER'S POND MANAGEMENT PLAN

Warner's Pond Bathmetry

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environmental consulting
& engineering services

Scale: 1" = 300'

0 300 Feet

Source: 1) MassGIS, Color Orthophotos, 2008

Figure
10

Location: G:/GIS-Projects/Warners-Pond-Concord/00-mxd/Report/Wtrshd_Assessment.mxd

WARNER'S POND WATERSHED MANAGEMENT PLAN

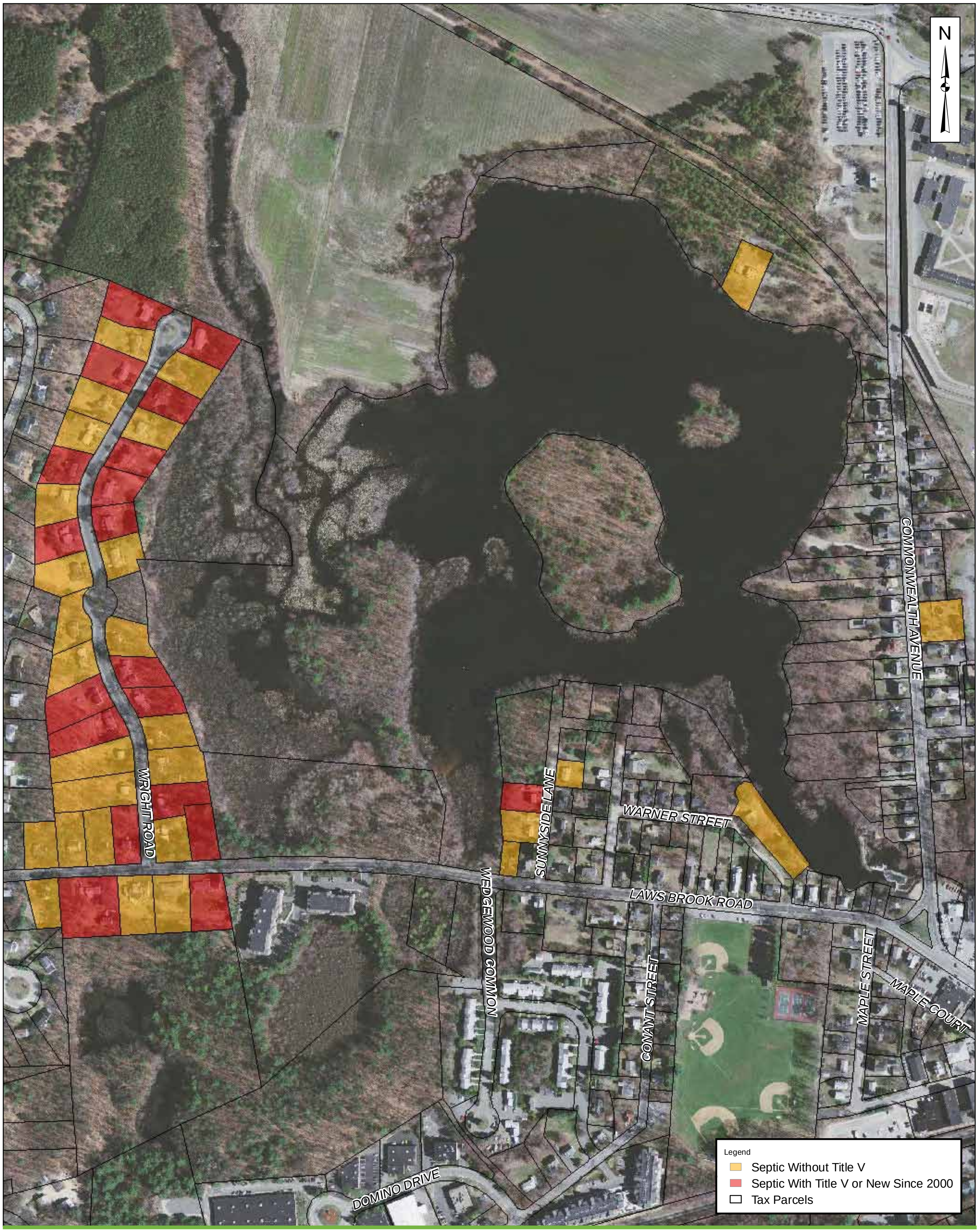
Watershed Assessment Results

Scale: 1" = 3000'

0 3,000 Feet

Source: 1) MassGIS, Orthophotos, 2008

Figure 11



WARNER'S POND WATERSHED MANAGEMENT PLAN

1 inch = 500 feet

0 125 250 500 Feet

Source: 1) MassGIS, Color Orthophotos, 2008
2) MassGIS, L0 Tax Parcel Data, 2008
3) Concord Board of Health, 2012

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Septic System Status in Vicinity of Warner's Pond

Figure 12

Table 7. Results of Dry and Wet Weather Water Quality Sampling (Values of concern are indicated by yellow shading)

Date	Sample ID and Location	Temperature (°C)	pH	Conductivity (µS)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat)	Total Kjeldahl Nitrogen (mg/L)	Nitrate-N (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)	Secchi Depth (meters)	Streamflow (cfs)
Sept. 1, 2011 Dry Weather	WP-1: Fort Pond Brook Inlet	21.8	6.9	279.7	3.11	7.53	86.0	0.866	0.14	0.06	ND[2]	NA	22.0
	WP-2: Nashoba Brook Inlet	21.1	6.8	394.9	1.24	8.24	92.7	0.726	0.47	0.05	ND[2]	NA	20.0
	WP-3: Warner's Pond Outlet	22.0	6.7	286.9	1.15	6.41	73.3	0.956	0.17	0.04	ND[2]	NA	75.0
	WP-4: Coles Brook	18.9	7.0	982.0	2.19	7.57	81.7	0.692	1.00	0.04	ND[2]	NA	4.5
	WP-5: Nashoba Brook off Route 2A	21.2	6.8	387.5	6.44	7.40	82.9	0.855	0.39	0.04	ND[2]	NA	30.0
	WP-S: Warner's Pond surface	20.3	6.7	318.6	1.09	6.50	71.2	0.833	0.23	0.01	NA	1.25	NA
	WP-B: Warner's Pond bottom	19.3	6.4	313.2	1.65	2.29	26.9	1.150	0.24	0.06	NA		NA
Sept. 22, 2011 Wet Weather*	WP-1: Fort Pond Brook Inlet	17.2	6.2	405.3	1.20	5.82	58.3	0.612	0.35	ND[1]	ND[2]	NA	28.1
	WP-2: Nashoba Brook Inlet	17.2	6.2	473.0	2.34	7.21	74.9	0.553	0.88	ND[1]	ND[2]	NA	12.5
	WP-3: Warner's Pond Outlet	17.2	6.1	418.2	1.42	7.66	81.2	0.596	0.47	ND[1]	ND[2]	NA	36.0
	WP-4: Coles Brook	16.5	6.2	1,143.0	4.59	7.62	73.3	0.489	0.93	0.33	ND[2]	NA	5.3
	WP-5: Nashoba Brook off Route 2A	17.2	6.2	472.0	0.91	8.58	89.2	0.665	0.87	ND[1]	9	NA	21.0
	Outfalls												
	W-10: Wright Road	16.9	6.0	130.4	7.30	6.87	71.5	1.480	0.84	0.18	6	NA	0.001
	W-12: Wright Road	16.7	6.1	36.1	11.61	5.48	56.4	1.380	0.37	0.14	51	NA	0.003
	W-14: Wright Road	17.0	5.8	71.5	15.27	7.41	76.5	1.280	2.50	0.22	24	NA	0.025
	W-15: Law's Brook Road	16.0	5.9	764.0	8.67	4.61	45.9	0.910	0.85	0.10	5	NA	0.128
	W-17: Route 2	17.5	6.3	635.0	2.86	7.42	78.1	0.984	5.10	0.03	ND[2]	NA	0.090

ND[1] = Total phosphorus detection limit 0.01 mg/L
ND[2] = TSS detection limit 4.00 mg/L
NA = Not applicable
*Samples collected during first flush of storm, which was of sufficient intensity for wet weather sampling. However, the number of samples collected was limited by the short duration of the first pulse of this storm.

The TSS levels collected during water quality sampling were used to estimate the relative contribution of the main tributaries and nearby outfalls to the overall suspended sediment load to Warner's Pond (Figure 13). Not surprisingly, outfalls (W-10 to W-17) contribute less than 1% of the load, even though their TSS concentrations were higher than the tributaries (Table 7). The total sediment load from the sampled tributaries and outfalls was estimated to be approximately 108 to 162 cubic yards (cy)/year. There is approximately 65 to 98 cy/year of sediment leaving the pond via the pond outlet. This results in net in-pond deposition of approximately 43 to 64 cy/year, or about five ten-ton dump trucks full of sediment per year.

Due to the large watershed of Warner's Pond, much of it outside the Town boundaries, exhaustively documenting sediment and nutrient hotspots was not practical as part of this study. However, it is anticipate that the National Pollutant Discharge Elimination System (NPDES) general permit for Municipal Separate Storm Sewer Systems (MS4s) will provide a systematic process for finding and eliminating hotspots at the municipal level throughout most of the watershed.

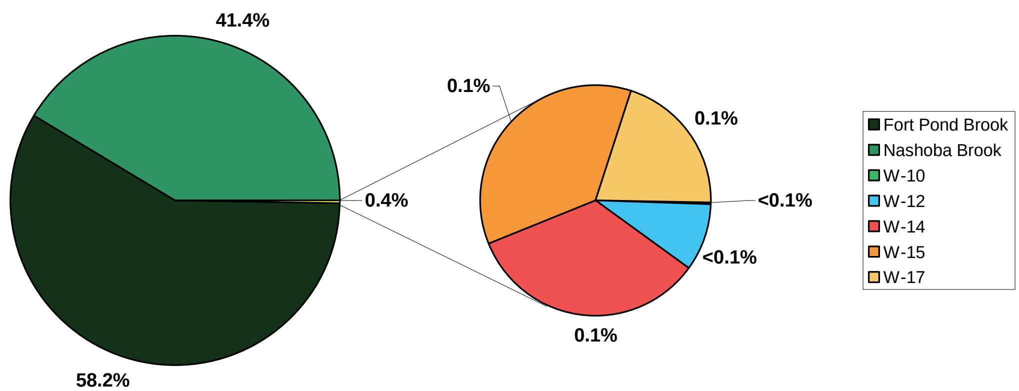


Figure 13. Relative Contribution of Sediment from Tributaries and Storm Water Outfalls

3.6 Hydrologic Budget and Nutrient Load Modeling

The results of the hydrologic budget and nutrient load modeling for Warner's Pond are presented in Attachment D.

The average annual precipitation for Warner's Pond is estimated to be 45.79 inches. This value was used for precipitation inputs during the hydrologic modeling for Warner's Pond. Estimated average water input to Warner's Pond from surface water tributaries, groundwater, and direct precipitation is 86.4, 0.01 and 0.17 cfs, respectively, for a total average annual flow of approximately 86.6 cfs (Attachment D). This average annual value for flow will vary appreciably among seasons and weather conditions. Surface water flow contributes significantly (99%) to the total pond inflow, while groundwater inflow and direct precipitation to the pond surface contribute the remaining 1% combined. The surface water flow can be further divided into dry weather flows (40%) and wet weather flows (60%). A summary of key hydrologic parameters for Warner's Pond is presented in Table 8.

Table 8. Summary of Warner's Pond Hydrology

Element	Value
Watershed Area	29,849 acres
Pond Area	49 acres
Pond Circumference	15,225 feet
Pond Volume	7.21 million cubic feet
Average Groundwater Seepage Inputs	0.012 cfs
Average Direct Precipitation	0.172 cfs
Average Surface Water Inputs	86.433 cfs

Based on total pond volume (7.2 million cubic feet) and the estimated flow through the system, average detention time was calculated to be 0.949 days (0.0026 years). Since detention time represents the duration of time necessary to exchange the volume of water in the pond one time this means that the water entering Warner's Pond is retained for less than a day's time, on average. Flushing rate is the inverse of detention time and represents the number of times per year the pond volume is replaced; for Warner's Pond the flushing rate is nearly 379 times per year. This is an extremely high flushing rate but is not unexpected given the large watershed to pond area ratio (approximately 612:1). The flushing rate indicates that water moves through Warner's Pond very quickly and in many regards, it is more appropriate to view the pond functioning as a large, wide pool within a river system rather than a pond.

A calculation of minimum nutrient load was made by multiplying the volume of the pond by its flushing rate and the average concentration of the nutrient observed during this study. The minimum phosphorus and nitrogen loads delivered to Warner's Pond were determined to be 24.99 g/m^2/yr (4,930 kg/yr) and 504.58 g/m^2/yr (99,547 kg/yr), respectively, based on the in-pond nutrient concentrations observed during the study (Attachment D).

The actual load of phosphorus or nitrogen will exceed the estimated minimum load as a consequence of loss processes that reduce the in-pond concentration over time. A more detailed and realistic estimate of nutrient loading can be obtained by using a combination of actual field data and in-pond modeling theory, e.g., Vollenweider, 1975 and Reckhow, 1977). Nutrient loads are calculated based on nutrient values measured within the pond and hydraulic features of the system. Based on this approach, the predicted phosphorus load necessary to achieve the values found in Warner's Pond ranges between 22.80 g/m2/yr (4,498 kg/yr) using the Vollenweider (1975) model and 27.96 g/m2/yr (5,516 kg/yr) using the Reckhow (1977) model (Table 9). The average predicted phosphorus load for all models was 24.99 g/m2/yr (4,930 kg/yr). The nitrogen load necessary to achieve the observed in-pond concentrations was estimated to be 529.35 g/m2/yr (104,434 kg/yr) (Bachmann 1980) in this manner (Table 9).

As described in Section 2.6, Vollenweider (1968) established criteria for calculating the phosphorus load below which no productivity problems were expected (permissible load) and above which productivity problems were almost certain to persist (critical load). These loading limits are also based on the hydraulic properties of the pond which were calculated from the hydrologic budget. The modeling results indicate that the existing conditions for phosphorus in Warner's Pond greatly exceed the permissible load and critical load. The average of phosphorus loads estimated for the pond through the in-pond models (4,930 kg/yr) is much greater than the permissible level of 393 kg/yr and the critical level of 785 kg/yr. This indicates that the phosphorus levels in Warner's Pond are much higher than desirable and at levels that would likely result in algal blooms and poor water clarity throughout the growing season. Given this understanding, it is actually beneficial that Warner's Pond has an extremely high flushing rate since any significant algal blooms that might otherwise occur are more likely to be rapidly flushed through the system.

Similar loading limits for nitrogen have not been established, owing to the less predictable relationship between nitrogen, pond hydrology, and primary productivity. Although nitrogen data are very useful in understanding in-pond conditions and processes, phosphorus is the logical target of management actions aimed at maintaining water quality conditions in Warner's Pond.

Table 9. Summary of Warner's Pond Nutrient Loading Models

Nutrient	Model Output	Value
Phosphorus	Minimum Load	4,486 kg/yr
	Model Average Load	4,930 kg/yr
	Permissible Load	393 kg/yr
	Critical Load	785 kg/yr
Nitrogen	Minimum Load	99,547 kg/yr
	Bachmann (1980) Load	104,434 kg/yr

The land use based model developed for the three major sub-basins in the Warner's Pond watershed included Fort Pond Brook, Nashoba Brook, and the area immediately surrounding Warner's Pond (Table 10). This modeling demonstrates that the portion of the watershed located primarily in Concord contributes only approximately 5% of the total phosphorus load and 3% of the nitrogen load to Warner's Pond. When considered in light of the in-pond nutrient load modeling results, which indicate that more than an 80% reduction in phosphorus loading is necessary, even eliminating all sources of phosphorus in Town would not be nearly enough to bring Warner's Pond phosphorus back below the critical load.

The nutrient model results guided the management recommendations to focus on in-pond techniques as opposed to watershed-wide techniques as described in Section 4.0 and Section 5.0. The modeling results demonstrate that even an 80% reduction in the phosphorus load to Warner's Pond will still mean in-pond levels will be well above the critical load and the water quality issues associated with these high levels. Therefore, constructing stormwater BMPs throughout the watershed, developing vegetated buffers, and implementing other phosphorus-load reducing techniques within the watershed are likely to be important but of low value. Given the size of the watershed and the fact that the watershed spans multiple towns, in-pond techniques for management are likely to provide a more economical and meaningful approach than a watershed-wide approach that would require watershed-wide agreement.

Table 10. Average Annual Nutrient Load by Land Use within the Warner's Pond Watershed Sub-basins*

Sub-basin	Land Use Classification	Acres	Percentage of Phosphorus Load	Percentage of Nitrogen Load
Fort Pond Brook	Cropland and Pasture	653.1	6%	6%
	Currently Developed (Residential/Commercial)	4363.2	76%	38%
	Forest	7562.7	10%	40%
	Open/Cleared Land	210.0	0%	1%
	Transportation	195.2	3%	2%
	Water	282.5	0%	0%
	Wetland	2656.7	5%	14%
	Sub-basin Contribution (%)		**52%**	**53%**

Sub-basin	Land Use Classification	Acres	Percentage of Phosphorus Load	Percentage of Nitrogen Load
Nashoba Brook	Cropland and Pasture	574.3	6%	6%
	Currently Developed (Residential/Commercial)	3633.2	77%	38%
	Forest	6777.3	11%	43%
	Open/Cleared Land	414.9	1%	3%
	Transportation	97.3	2%	1%
	Water	386.9	0%	0%
	Wetland	1575.0	3%	10%
	Sub-basin Contribution (%)		**43%**	**44%**
Warner's Pond	Cropland and Pasture	54.1	14%	16%
	Currently Developed (Residential/Commercial)	145.9	73%	43%
	Forest	151.6	6%	27%
	Open/Cleared Land	3.1	0%	1%
	Transportation	10.0	5%	3%
	Water	46.3	0%	0%
	Wetland	55.6	3%	10%
	Sub-basin Contribution (%)		**5%**	**3%**

*Export coefficients based on median value predicted by Reckhow (1980), Lin (2004), Rast and Lee (1978)

4.0 MANAGEMENT GOALS

The Town is seeking ways to improve the pond's overall ecological value and management actions means to implement recreational improvements that will not decrease the ecological values that currently exist at the pond. The Town has expressed an interest in the following:

- Maintaining or improving water quality
- Controlling exotic/invasive species
- Preserving native plant species within the pond and its adjacent wetlands to the greatest extent feasible
- Maintaining high quality wildlife habitat value

Given the number of issues currently affecting Warner's Pond, including excessive aquatic weed growth, excessive sediment accumulation, and excessive nutrient and sediment loading, a wide range of management options need to be considered and evaluated to maintain or improve in-pond conditions.

A review of each of the management options with regard to their ability to achieve the defined management objectives, as defined above, is presented below.

5.0 SHORT AND LONG-TERM MANAGEMENT OPTIONS AND RECOMMENDATIONS

This section presents the range of options for improving water quality and/or reducing aquatic weed growth within Warner's Pond based on the goals stated in Section 4.0. Prioritized recommendation summaries are provided in Table 11 the reasoning behind these recommendations is provided in greater detail within the sub-sections.

Approval from the Natural Resources Commission will be required in order to implement any approach in Warner's Pond. If two or more approaches are combined into one filing, the required permitting efforts should be easily combined at little additional cost. Any management recommendations involving manipulation of the water level in Warner's Pond would need to be approved by and coordinated with the dam owner (Concord Public Works).

Table 11. Management Options Assessed and Listed by Priority for Action

Priority	Approaches	Issue(s) Addressed	Primary Pros	Primary Cons	Cross-reference
Recommended Short-term Actions					
1	Herbicide (Fluridone)	Fanwort control	Works quickly and provides control for two or more seasons	Limited effectiveness in Warner's Pond due to high flushing rate and extent of fine sediments– will likely require reapplications	Section 5.1.1
2	Herbicide (2,4-D)	Variable watermilfoil control	Works quickly and provides control for two or more seasons	• May require setbacks to prevent migration into adjacent wells • Requires less contact time to be effective than fluridone but can still be affected by flushing rate	Section 5.1.1
3	Mechanical Control (Hand Harvesting)	Water chestnut control	Effective and can be done by volunteers	Infestations can quickly re-emerge if not diligent. Annual removal of water chestnut prior to seed set is required	Section 5.1.2
		Control of small or shoreline infestations of other species			
4	Biological Control (Loosestrife Beetles)	Purple loosestrife control	Inexpensive with no anticipated collateral damage to desirable native species	• Population requires time and contiguous areas of purple loosestrife to become established. May need to reintroduce if population flags • Eradication not feasible through biological control alone	Section 5.1.3
5	Bottom Sealing	Local macrophyte control	Immediately effective in eliminating macrophyte growth	Numerous drawbacks, most notably the high cost. Best over very small areas (<1 acre).	Section 5.1.4
6	Drawdown	Shallow-water macrophyte control	May achieve good control in shallow waters at minimal operating cost	• Effectiveness limited by weather • Reduces or eliminates winter recreation activities and fish habitat • May impact downstream waters	Section 5.1.5
7	Hydroraking or Rotovation	Water lily control	Best way to quickly control water lilies and create open water habitat	• Encourages spread of vegetatively reproducing species (less of a problem in Warner's Pond due to nearly pond-wide establishment of invasive exotics) • Expensive	Section 5.1.6

Priority	Approaches	Issue(s) Addressed	Primary Pros	Primary Cons	Cross-reference
Recommended Long-term Actions					
1	Control Nutrient and Sediment Loading	Water quality	Addresses underlying problems at the source (i.e., in the watershed)	• Does not address internal (in-pond) recycling of nutrients • Warner's Pond watershed is so large, with so many nutrient and sediment sources that sensible improvements in water quality will require lots of time, expense, and regional coordination to achieve	Section 5.2.1
2	Dredging	Shallow water depth	Addresses multiple in-pond problems and lasts for decades	• Expensive • Lengthy permitting process • Reduces or eliminates access to the pond during dredging	Section 5.2.2
		Thick sediment deposits			
		Overall macrophyte control			
Options Assessed but not Currently Recommended					
	Aeration and/or Destratification				Section 5.3.1
	Plant Competition				Section 5.3.2
	Chemical Sediment Treatment				Section 5.3.3
	Dilution and/or Flushing				Section 5.3.4
	Shading Dye		See text for details		Section 5.3.5
	Herbicides (Excluding Fluridone and 2,4-D)				Section 5.1.1
	Biological Controls (Excluding loosestrife beetles)				Section 5.1.3
	Nutrient Inactivation				Section 5.3.6

5.1 Short-term Management Recommendations

5.1.1 Chemical Treatment (Herbicides) – Selected formulations recommended only as short-term or interim approach

Herbicides remain a controversial aquatic weed control measure in many communities because of their association with pesticides, which is generally perceived to be negative. However, as we learn more about the various negative impacts that can be associated with alternative physical and biological management options, chemical control measures continue to be used as part of many balanced pond management plans.

Although no herbicide is completely safe or harmless, a premise of federal pesticide regulation is that the potential benefits derived from use outweigh the risks when registered herbicides are applied according to label recommendations and restrictions. Current herbicide registration procedures are far more rigorous than in the past and the ability of qualified and licensed applicators to target applications of herbicides further improves the relative safety of using these chemicals for nuisance aquatic plant control. Each of the herbicides evaluated in this Plan present some degree of risk with regard to potential toxicity to non-target organisms and temporary recreation restrictions would be needed for herbicide applications at Warner's Pond.

Where exotic aquatic plants infestations have become extensive and well-established (as with fanwort in Warner's Pond), pondwide herbicide treatment is usually the most effective initial control option. Chemical treatment will also be the most cost effective means by which to immediately achieve the goal of reducing aquatic weed biomass.

As herbicides can only be applied by state licensed herbicide applicators, this is not an option that pond residents can undertake themselves. It should also be noted that herbicide treatment alone would not provide for long term, sustainable control of nuisance aquatic plant growth. However, when integrated with other management strategies as part of a comprehensive plan which includes watershed and in-pond level approaches, herbicides can play a valuable role in managing nuisance growth.

Costs for permitting an herbicide treatment are typically low but could be somewhat high if there is significant opposition to this management approach. Permits could be denied, appealed, or rigorously conditioned, the last of which could add cost both through constraints on the treatment process and monitoring expenses.

Herbicide Control of Fanwort

Fluridone – Systemic Herbicide: In Warner's Pond, fanwort is the dominant species of concern and the only herbicides which are effective on fanwort are fluridone (tradename Sonar) and the more recently available flumioxazin (tradename Clipper). Fluridone was applied in the pond as a slow-release pellet formulation during the summer of 2011. Although the results of this treatment did show effective control in many areas, the high flushing rate of Warner's Pond make the use of fluridone extremely challenging since it is imperative to maintain a target concentration throughout the treatment area for a minimum of a three week period to achieve the desired level of control. Fine sediments also make pelletized treatment difficult, since pellets in mucky areas may sink below the sediment-water interface thereby precluding the maintenance of effective in-water fluridone levels. It may be possible to re-apply fluridone pellets to the targeted management zone (Figure 14) to control fanwort as needed going forward if this approach is still desired. Costs for this approach are likely to be on the order of $1,000 per acre or about $8,000 for controlling fanwort within the targeted management zone between Scout Island and the public access point (allowing for some overtreatment beyond the 6.1 acre targeted zone to occur to get the desired results within the target zone). Although the effectiveness of fluridone treatments could last as long as five years under ideal conditions, treatments in Warner's Pond would likely need to be repeated more frequently – every other year or at least every third year.

Flumioxazin – Contact Herbicide The herbicide, flumioxazin is a much faster acting contact herbicide that can achieve results in less than 24 hours. This would theoretically allow for it to be applied selectively to specific larger beds of fanwort (or variable watermilfoil) while avoiding areas of the pond where weed control may not be desired. Flumioxazin is currently approved for use by the US EPA and registered in 46 states including five of the six New England states; unfortunately, Massachusetts is not yet one of these states. Therefore, flumioxazin cannot currently be recommended for Warner's Pond.

Herbicide Control of Variable Watermilfoil

Variable watermilfoil could be effectively managed through the use of herbicides. The three most effective herbicides for targeting variable leaf milfoil in Warner's Pond are presented below.

Diquat dibromide – Contact Herbicide**:** For Warner's Pond one of the most immediate approaches for controlling variable watermilfoil growth would be with the contact herbicide known as diquat (trade name Reward). As a contact herbicide, diquat can clear large areas of weeds in a very short time. Treatment of the milfoil beds throughout the entire pond (in excess of 20 acres of treatment) could be performed at a cost of approximately $8,000 to $10,000 per treatment (including permitting) and would clear the pond of most milfoil. Because diquat is a contact herbicide, it does not typically kill rooted portions of aquatic vegetation and follow-up applications would be needed to control growth each year. Additionally, diquat is not selective and would also likely reduce the biovolume of native plants. A pond-wide diquat program would likely need to be phased in at least three partial-pond treatments in order to avoid excessive nutrient release and oxygen demand due to the decaying plant material.

The use of the contact herbicide diquat is not ideal, particularly since the costs would not decrease significantly on an annual basis. This approach would not be recommended as anything more than a very short-term solution to the problem at hand. If other techniques to control the milfoil on a pond-wide basis prove to be ineffective or difficult to permit, a diquat treatment program targeting the 6.1-acre targeted management area (Figure 14) could be performed at an annual cost of about $3,000.

Triclopyr – Systemic Herbicide**:** The dicot selective systemic herbicide known as triclopyr (Renovate OTF) is a growth regulating herbicide that would be an option for achieving longer term control of the variable leaf milfoil problem because systemic herbicides are able to kill the roots of the plants as well. A joint study by the U.S. Army Corps of Engineers (USACE) and the state of New Hampshire showed triclopyr to be very effective in controlling variable leaf milfoil when the targeted dose was maintained for a period of at least 12 hrs (Getsinger et al., 2003). One of the most recent and comprehensive investigations on the effects of triclopyr on variable leaf milfoil showed that it provided "good" control across a broad range of concentrations (Netherland and Glomski, 2008). However, in a recent Rhode Island application in Lake Mishnock in 2007 and 2008 (Aquatic Control Technology, 2008), triclopyr did not prove to be as effective at lower doses and although control at higher doses was achieved, the additional cost to attain these higher concentration levels resulted in a treatment program that was not cost effective.

One of the major benefits of using an herbicide such as triclopyr as compared to diquat is the ability to be selective for dicots such as milfoil while having much less to no impact on most natives such as lilies and pond weed (*Potamogeton*) species. This represents a much more sustainable solution and is protective of the necessary native plant species and habitat they afford to pond biota.

One drawback of triclopyr is the longer (two to four days is ideal) contact period required for maximum effect. A poorly planned or executed treatment might not achieve appreciable improvement over large areas of the pond given the high flushing rates observed for Warner's Pond. This may be countered by drawing the pond down slightly in advance of the treatment and this may result in better control.

Additionally, triclopyr treatments are comparatively expensive. Costs to treat Warner's Pond with triclopyr are likely to be on the order of $1,000 per acre. A treatment program targeting variable milfoil beds in the targeted management area of the pond would be expected to require cost of approximately $8,000 plus permitting costs. Treatment should be expected to last for at least two years, perhaps even three, but additional efforts would also be required to address milfoil growth in non-treatment areas. Alternatively, the costs for a nearly whole pond treatment using triclopyr would be expected to exceed $30,000.

Given that triclopyr is relatively fast acting the treatments would need to be performed in a phased approach with no more than half of the pond being treated at a given time to minimize the potential for nuisance algal blooms or fish kills due to low oxygen levels.

2,4-D – Systemic Herbicide: The granular form of the systemic herbicide known as 2,4-D (trade name Navigate) is likely to be the most effective herbicide to combat variable leaf milfoil (Netherland and Glomski, 2008) and is also the most economical given its ability to achieve multiple years of control. Like triclopyr, 2,4-D is a growth regulating herbicide that is selective for dicots, which means that it will be effective on milfoil while having less impact or no impact on desirable plant species such as the native pond weeds and water lilies. The real advantage of using 2,4-D over triclopyr is that it has been shown to be the most effective herbicide at controlling variable leaf milfoil and it can be applied at about half the cost of triclopyr (assuming an application rate of 100 lbs/acre or $500/acre). Therefore, assuming treatment of the 6.1-acre targeted management area plus an allowance for overtreatment, using 2,4-D could achieve two to three years of variable milfoil control in Warner's Pond for a cost of about $4,000.

Of the three herbicide treatment options discussed above for variable watermilfoil, the one that makes the most sense from an economic perspective is the use of 2,4-D since the cost per acre is relatively modest and the effects are more specific to the target plant and will last for more than one year. A major drawback to this herbicide is the potential for the herbicide to migrate through soils and negatively impact wells adjacent to a pond. This option would need to be evaluated with homeowners that may have wells around the pond. If a private well were determined to be in use, it would be necessary to establish setbacks from the pond shore for treatment to minimize the potential for treated water to be drawn into the wells. ESS recommends that the nature of the wells that could potentially be drawing water from Warner's Pond first be investigated by a qualified hydrogeologist and, if necessary, by a human health and environmental risk assessor, to assist in determining the fate and transport potential of 2,4-D so that specific setbacks, if any, can be recommended and included as part of the permitting conditions. Costs for this critical step are likely to be on the order of $4,000 to $5,000. In areas where a setback is required but milfoil control is still required, diquat may be used as long as this option has been included in the permitting application and approved.

Total costs for an herbicide program which included a treatment with 2,4-D to control variable watermilfoil within the targeted management zone (Figure 14) and the use of slow-release fluridone within the same area to control fanwort, along with the necessary investigations, permitting, and monitoring would be on the order of $17,000 for up to three years of control. Costs could escalate if there is any significant opposition to herbicide treatment by watershed stakeholders.

Given the results from the recent attempts to manage fanwort through the use of fluridone, which is the only herbicide currently registered in Massachusetts that is known to be effective against fanwort, it is recommended that other techniques (discussed below) may be more cost effective and appropriate for use over the long-term. If weed growth is not effectively managed through other methods and the fanwort eventually returns to dominate the pond's aquatic plant community within the targeted management zone, then the use of herbicides would be worth considering further, particularly if flumioxazin is approved for use in the state since this herbicide would effectively combat both fanwort and variable watermilfoil.

Herbicide Control of Other Species

Exotic species of emergent plant growths in Warner's Pond could be controlled with the herbicide glyphosate (trade name Rodeo) on a selective basis, if needed. This is not currently recommended, as most of the emergent plant cover consists of native species that do not present a significant detriment to use of the pond by wildlife or enjoyment of the pond for recreation. Purple loosestrife is probably best managed through a combination of biological controls (Section 5.3) and manual removal (Section 5.11). Evidence of leaf damage indicates purple loosestrife is already being devoured by *Galerucella* spp. beetles.

Other species that should be managed at Warner's pond include exotic water chestnut (which has been hand harvested by the Town and WPSC for several years), and if desired, native water lilies. Water chestnut is best managed through mechanical harvesting rather than herbicides. Water lilies are best controlled through hydro-raking or rotovation. These methods are discussed below in Sections 5.10 and 5.11

5.1.2 Macrophyte Harvesting – Recommended for Small Scale Control Only

Macrophyte harvesting covers a wide range of techniques, including mechanical harvesting and hand pulling. Mechanical harvesting, which involves cutting and pulling aquatic plants from a specially-equipped watercraft, is most effective in the short term. As mechanical harvesting simply sets plants back for the season, its use should be reserved for scenarios where there is an immediate but temporary need for widespread reduction of nuisance plant cover.

Mechanical harvesting is not currently a recommended management option for Warner's Pond because it is relatively expensive, typically results in only single season control and may not be physically feasible given the shallow water in many areas of the pond. Furthermore, the dominant plants of concern are milfoil and fanwort which both spread through vegetative fragmentation, therefore using a harvester may actually encourage the spread or re-colonization of these weeds over time.

The simplest form of harvesting is hand pulling of selected plants, which is recommended with approval from the NRC. Depending on the depth of the water at the targeted site, hand pulling may involve wading, raking, snorkeling, or SCUBA diving. Hand pulling often involves collection of pulled plants and fragments in a mesh bag or container that allows for transport and disposal of the vegetation. In deeper water, frequent trips to the surface are necessary to dispose of full bags. The intensive nature of this work limits its application to small areas, typically much less than one acre in size. Hand pulling can directly confirm removal of entire individual plants, typically resulting in longer control of plant growth in targeted areas.

In a small pond like Warner's Pond, hand pulling will be most appropriately used to manage or control the growth and spread of water chestnut since these plants are readily managed by the removal of the flowering portion of the plant which spreads across the pond surface and contains the seed head. Water chestnut should be monitored closely and hand harvested annually to ensure that its levels are kept in check. Harvesting should occur in early summer before the seeds mature and drop from the plants to ensure that new growth will not occur from these seeds. Over time, this effort should deplete the seed bank within the pond's sediment and the overall plant densities may decline or be eliminated.

Hand pulling would also be a feasible and a reasonably cost-effective method of aquatic plant control over select areas where weed-free access is desired. Hand pulling is most effective as a “clean-up” control method to be used in conjunction with other methods, especially where aquatic plant beds are particularly dense or extensive.

5.1.3 Biological Control – Recommended on a Limited Basis for Purple Loosestrife Control

The purpose of a biological control is not to eradicate a species, but to prevent it from becoming problematic. Biological controls do not work as rapidly as other management techniques. Depending on the size of the infestation, it may take five to seven years before any significant level of control is observed.

Eurasian watermilfoil (*Myriophyllum spicatum*) is the only submergent plant that has been shown, at least experimentally, to be able to be controlled using "watermilfoil weevils" (*Euhrychiopsis lecontei*). The larvae of this beetle burrow into the stems of the watermilfoil plant, consuming the plant tissue within the stem, which ultimately results in the collapse of the plant to the pond bottom. As a control technique, the beetle larvae are introduced to a pond by placing infested water milfoil strands within the targeted water milfoil beds of the pond. The best results are usually achieved in controlling watermilfoil in ponds with dense, monotypic stands of Eurasian watermilfoil with several years being required to measure a positive effect. Because Eurasian watermilfoil is not known to be established in Warner's Pond, the water milfoil beetle approach would not be appropriate.

Purple loosestrife (*Lythrum salicaria*) may sometimes be controlled using loosestrife beetles (*Galerucella spp*.). Adult beetles tend to stay within a small territory, especially when beetle density is low, which makes natural dispersal of populations very slow (NCERA-125, 2008). Consequently, loosestrife beetles work best as a control method where contiguous stands of purple loosestrife occur. Where purple loosestrife is present in small patches along shorelines, hand harvesting is likely to be the best control method. As with the watermilfoil weevil, larvae play the biggest role in actual control of the plant. While the damage from adults is mostly limited to superficial leaf damage, larvae can kill back shoots by burrowing into the stem. It may take several years for loosestrife beetle populations to grow to a sufficient density to make a measurable difference in purple loosestrife cover. Additionally, loosestrife beetles are unlikely to eradicate purple loosestrife infestations. This highlights one of the primary drawbacks of biological control using specialist herbivores, namely that a host population of the undesirable plant must be maintained in order to prevent the herbivore population from collapsing.

Adult loosestrife beetles can be obtained (with a permit) at a cost of $275 to $300 for 1,000 beetles. It is recommended that release of adult beetles be limited to areas with significant contiguous infestations, which primarily occur along the shallow western margins of the pond. Isolated purple loosestrife infestations along the remaining shoreline would be best controlled by manual removal (Section 5.11).

Biological controls for the other plant species are almost unknown. An herbivorous fish (*Ctenopharyngodon idella*, the grass carp) has been used for general macrophyte control on an experimental basis in smaller ponds in Connecticut and New York, but has not shown a preference for any one species, and is not approved in Massachusetts. Stocking of grass carp is therefore not recommended at Warner's Pond.

5.1.4 Bottom Sealing – Recommended for Use over Small Areas

Benthic barriers are negatively buoyant materials, usually in sheet form, which can be applied on top of plants to limit light, physically disrupt growth, and allow unfavorable chemical reactions to interfere with further development of plants. They may have positive side effects such as creating more edge habitat within dense plant assemblages and minimizing turbidity generation from fine bottom sediments. Benthic barriers are best used for providing control of milfoil, fanwort, and other nuisance growth on a localized basis. They are likely to be of most use in heavily used areas near shore and in the vicinity of the Warner's Pond access off Commonwealth Avenue or other shoreline structures.

Barrier materials have been commercially available for decades and a variety of solid and porous are available. However, deployment and maintenance of benthic barriers continues to be difficult and this limits their utility over the full range of weed bed sizes.

Plants under the barrier will usually die completely after about a month, with solid barriers more effective than porous ones in killing the whole plant. Barriers of sufficient tensile strength can then be moved to a new location if desired. However, keeping barriers in place is desirable for preventing recolonization by nuisance species.

The ability of vegetative fragments to recolonize porous benthic barriers such as fiberglass screening has made them less useful for combating infestations by milfoil or fanwort on any but the smallest scale, as sheets must be removed and cleaned regularly, often yearly. Solid barriers have been more useful, although the gas released during decomposition in the sediments below can cause the barrier to billow, necessitating the use of anchors or vents that can reduce the lifespan of the barrier.

Problems associated with benthic barriers include long-term integrity of the barrier, billowing caused by trapped gases, accumulation of sediment on top of barriers, and growth of plants on porous barriers. Benthic barriers are also non-selective, which means all plants in the treatment area are killed, including desirable native plants. By smothering bottom sediments, barriers can also impact the benthic macroinvertebrate community within the treatment area, which may locally reduce food sources for some fish. Another drawback of benthic barriers is that recolonization from adjacent plant beds can occur quickly, once the barrier has been removed. Additional effort, such as hand harvesting, might be necessary for two growing seasons or more.

Cost and labor are the main factors limiting the use of benthic barriers in most ponds, and would be prime deterrents in Warner's Pond. The cost per installed square foot is on the order of $2.00, leading to an expense approaching $90,000 per acre. Bulk purchase and use of volunteer labor can greatly decrease costs, but use over large areas of nuisance vegetation is highly unlikely.

Benthic barriers could be useful by the Town or private landowners to address nuisance plant growth along small shoreline areas, where deployment and any subsequent maintenance would be relatively simple. A small installation immediately offshore from the public access point would be worth considering even with the use of other management approaches.

5.1.5 Water Level Control (Drawdown) – Recommended

Drawdown involves lowering the water level of a pond to expose shallow bottom sediments and associated plants (both native and non-native) to drying and/or freezing. It is most effective against species that reproduce mainly by vegetative means, including fanwort and variable watermilfoil. Drawdown is less effective on species that reproduce primarily by seed (such as the invasive exotic species water chestnut and curly-leaf pondweed) and may expand beds of these species. Under some circumstances, drawdown may also encourage the spread of purple loosestrife in hydrologically connected wetlands. In Warner's Pond, this would primarily be a concern in the water willow dominated wetlands on the western margin of the pond, where purple loosestrife is already present.

Ponds with rapid drop-offs to great depths tend to benefit most from drawdown. Due to the shallow bathymetry of much of Warner's Pond, drawdown is only likely to provide limited control of aquatic invasive plant growth. Although drawdown can be conducted at any time, the interaction of drying and freezing that occurs with winter drawdown is usually most effective. Environmental restrictions and recreational uses also limit the appropriate window for drawdown to the winter period. In Massachusetts, winters are often variable in their intensity and the ideal winter condition of very cold weather with limited snow cover (which insulates the plants) is not likely to be achieved any more frequently than every other year.

"Ice rip" is a drawdown technique that focuses on physical removal of rooted aquatic plants by managing ice cover to literally "rip" the plants, including roots, from shallow areas. This technique is not recommended for Warner's Pond as variable watermilfoil and fanwort spread primarily by fragments (not roots) and it is unlikely to be more effective than a standard drawdown program. Additionally, the rapid induced fluctuation of water levels and ice cover may exacerbate shoreline or downstream erosion, suspend bottom sediments and associated nutrients that are lifted with the ice, negatively impact bottom-dwelling fauna, disrupt hibernating reptiles and amphibians along the margins of the pond, reduce the safety of winter recreation activities on the ice, or compromise the dam.

In order to effectively drawdown a pond, there must be an adjustable discharge structure that allows the water level to be safely controlled. The water level must be drawn down to a sufficient depth (typically at least 3 feet) and for a long enough period of time to allow bottom sediments to at least partially de-water. Aside from the practical feasibility of performing a drawdown, the potential impacts on winter recreation (primarily ice fishing and skating) should also be considered.

If drawdown is pursued as a management strategy, a drawdown feasibility study would first need to be developed that would identify potentially sensitive habitats or biota that may be present within the pond, its downstream waters, or within hydrologically connected wetlands. The drawdown feasibility study would also examine the feasibility of drawdown with regard to controlling hydraulics (related to the amount of water Warner's Pond can hold, how much would be lost during the drawdown, and limitations concerning where the water goes downstream), flooding, and impacts to downstream and hydrologically connected wetland resources (e.g., drying) and would be used to establish a current baseline condition as well as to support permitting.

A Drawdown Operations Plan would need to be developed, inclusive of all hydrologic calculations, to guide dam operators on methods for managing the drawdown timing, the release rate, and the magnitude of drawdown. The Drawdown Operations Plan will also provide protocols for monitoring the system to ensure protection of biota within pond and associated waters while also achieving a better level of control on the targeted milfoil and fanwort. Given the substantial amount of relevant data already collected under the current study, the costs for performing the drawdown feasibility study and preparing the Drawdown Operations Plan are likely to be on the order of $8,000.

Once this information has been determined and the Drawdown Operations Plan is developed, it will then be necessary to file a Notice of Intent application with the NRC. Assuming that a Drawdown Operations Plan is developed, filing a permit to conduct a drawdown at Warner's Pond is likely to cost between $3,000 and $4,000 to prepare and file based upon the nature of the impacts and the supporting studies.

Given that Warner's Pond has a recently improved outlet control structure and has recently conducted a minor drawdown for a weed control project, a drawdown of up to 3 feet to manage aquatic vegetation should not be difficult to permit. Figure 15 depicts what the surface of the pond would look like under a 3-foot drawdown scenario. A greater target depth of up to 5 feet could be envisioned for the pond and would be more likely to control weed growth in the shallower portions of the pond due to more intense dewatering. However, a 3 foot drawdown would likely be favored by permitting authorities in order to reduce impacts to fish, amphibians, reptiles, and invertebrates such as freshwater mussels, which are all present at Warner's Pond.

Drawdown typically reduces habitat volume, access to spawning areas, and availability of dissolved oxygen, among other parameters, each of which is an important factor in the success of fish populations and should be considered prior to drawdown implementation. Overwintering amphibians may also be sensitive to fluctuating water levels during drawdown if it exposes them to dry or freezing conditions. Additionally, invertebrate species, especially those that are slower moving, may be desiccated or frozen if drawdown occurs too rapidly. Therefore, ESS would not recommend a drawdown greater than 3 feet without additional study, in light of concerns over potential impacts to fish and wildlife.

If drawdown were determined to be feasible and could be successfully permitted, impacts to aquatic resources in the pond would need to be monitored annually as a permit condition, which could cost $5,000/year. Monitoring for potential impacts due to drawdown should focus on the mollusk population, water quality, wildlife habitat, and changes to hydrologically connected wetland plant communities. Such a drawdown program has been successfully implemented at Nabnasset Lake in Westford, Massachusetts for over 10 years. ESS has worked with the local lake association to monitor the lake and its hydrologically connected wetlands and found little or no permanent impact to sensitive non-target species.

5.1.6 Hydroraking and Rotovation – Recommended only for limited control of water lilies

Hydroraking uses a backhoe-like machine mounted on a barge to remove plants directly from pond sediments. Depending on the attachment used, plants are scooped, scraped, or raked from the bottom and deposited on shore for disposal. Rotovation is essentially underwater rototilling of pond sediments. Rotating blades cut through roots, shoots, and tubers, dislodging and expelling them from their growing locations. Some operations are also outfitted to collect some or most of the rotovated plant materials. Both hydroraking and rotovation are most useful for local control of water lilies and other plants with large rhizomes or tubers, as these methods can physically remove or destroy the bulky portions of the plant.

Hydroraking has been previously attempted at Warner's Pond. It proved to be an effective approach at managing water lilies in selected areas but would not be recommended against vegetatively reproducing species such as milfoil and fanwort. The primary disadvantage of hydroraking and rotovation is that they spread invasive plants that reproduce via vegetative fragmentation. However, this is not currently a major deterrent in Warner's Pond due to the fact that variable watermilfoil and fanwort appear to have colonized all available habitats in the pond. Fragment barriers could be deployed around management areas prior to hydroraking or rotovation to reduce escape of vegetative fragments. If dredging proves to be too costly to implement in the near term, continuing with a hydroraking program within the targeted management zone (Figure 14) may be an appropriate alternative to maintaining some open water habitat within the pond. Costs to perform hydroraking vary depending upon a number of factors, but based on first hand experience at this pond previously it is estimated that costs will be on the order of $7,000 per acre, plus permitting costs. This would need to be repeated periodically, perhaps every three to five years, to maintain desired conditions.

5.2 Long-term Management Recommendations

5.2.1 Control Nutrient and Sediment Loading – Recommended for Long-term Improvement

Nutrient loading analysis indicates that the phosphorus load to Warner's Pond is far beyond the critical level, suggesting that it will continue to be a eutrophic water body under current conditions. This condition is due primarily to the large relative size of the pond's watershed in relation to the size of the water body itself. The system receives a significant fraction of the nutrients from surface flows including storm water runoff being delivered to the pond via its tributaries.

An educational program for watershed residents, particularly those living close to Warner's Pond and the other ponds in its watershed should be developed. Initial education and outreach should focus on items that individual residents could implement easily and at minimal to no cost. These actions include minimizing the impact of yard care (particularly fertilization), pet waste management, maintaining or planting buffers at the pond margins, and other small behavioral changes that would improve the pond's water quality. Development of a full-color tri-fold brochure would be a good way to raise awareness among Concord residents. Brochures could potentially be made available at the Commonwealth Avenue access location and/or distributed to watershed residents at minimal cost by mailing out with water bills or other regular Town correspondence.

Development and redevelopment within the watershed should incorporate LID storm water techniques to prevent further deterioration. This may now be implemented in Concord through enforcement of the newly adopted stormwater regulations; but gaining improvements within the other towns that comprise the majority of the watershed may be more challenging. While implementation of other watershed BMPs should be considered whenever possible, the amount of phosphorus that would need to be removed to bring water quality in Warner's Pond below the critical load threshold is extremely large and achieving needed reductions in such a large watershed would be very difficult. Therefore, while controlling nutrient and sediment loading is recommended as an ongoing effort to maintain or improve water quality watershed-wide, the primary focus for management of Warner's Pond should be on in-pond management.

5.2.2 Dredging – Recommended as Suitable Long-Term Option for Targeted Area

Dredging works as a plant control technique when either a light limitation is imposed through increased water depth or when enough soft sediment is removed to reveal a less hospitable substrate for plant growth (e.g. hard bottom or other nutrient-poor substrate). Light limitation through increased depth is possible in Warner's Pond, particularly since water clarity is already relatively poor. It may not be necessary to dredge the entire pond to achieve a satisfactory level of plant control, but it would be necessary to do a thorough job in any area where control is to be achieved or greater depths are desired.

Dredging in Warner's Pond could be an effective long-term control technique for nuisance aquatic plants within the targeted management area (Figure 14), but will be costly. The challenges of a project of this type are not unreasonable. The key factor influencing the approach and costs for moving forward with a dredge program at Warner's Pond will be the ability to draw down the pond to allow for dredging within the drained basin to occur using conventional excavation equipment. This is most likely an environmentally sound and feasible approach if conducted during the winter months when wetland areas associated with the pond would be dormant. This approach would allow for sediment to be dewatered within the basin itself by pulling the sediment up to the margins of the pond to allow water to drain back into the main portion of the basin. Given that Warner's Pond has a significant amount of water flowing through the system it may not be possible to entirely dewater the targeted work area without advanced water management techniques such as temporary coffer dams or the creation of channels to route the flow of water around the work area.

Geotubes used to dewater hydraulically dredged material

If conventional "dry" dredging is not determined to be feasible for Warner's Pond due to equipment access issues or water management concerns, hydraulic dredging would be a viable alternative. Hydraulic dredging is generally more expensive than conventional dredging for limited projects and it would require a larger and more sophisticated containment area to dewater the sediment as it is removed from the pond.

Alternatively, advanced dewatering techniques such as the use of Geotubes (geotextile fabric for dewatering) or a belt-filter press machine could be used instead but these would add additional costs over traditional dewatering containment. All of these external sediment dewatering options will require land adjacent to the pond to be made available for the dewatering process. The town's public access lot would be adequate space for the use of a belt-filter press machine, but a larger area would be required for either the use of the Geotubes (>1.0 acres) or a standard dewatering basin (> 2 acre). Pumping material to the open land adjacent to the prison to the north east of the pond that would be acceptable; however, the ability to use this location has not been investigated as part of this study.

The amount of material to be removed and the type of disposal or reuse will also have a significant impact on the cost of dredging. Environmental permitting for dredging projects is moderately complex and will require up to a year before the project could receive all required approvals. Federal (USACE 404), state (MEPA Certificate and 401 Water Quality Certificate) and local permits (Notice of Intent filed for Order of Conditions from the DNR) are all required, and would necessitate considerable advance information and review time.

With an estimated soft sediment volume of approximately 220,000 cubic yards in Warner's Pond, the cost of a dry or hydraulic dredging project for the entire pond would likely run between $5,000,000 and $8,000,000 (including permitting and design) for removal of all of the soft sediments, although not all sediments would necessarily need to be removed to achieve light limitation throughout the pond. Costs could increase if sediment cannot be reused or disposed of in the immediate vicinity of the pond.

A more realistically scaled project designed to deepen the critically important area between Scout Island, Pond Street, and the Commonwealth Avenue public access to a maximum depth of 12 feet (the depth needed to provide aquatic macrophyte control through light limitation) would yield a dredge volume of approximately 30,000 cubic yards over the 6.1-acre targeted area depicted in Figure 14. Costs to dry dredge this volume of material would likely range between $550,000 and $800,000 with permitting and design costs likely to add an additional $75,000 to this total.

If dry dredging is not feasible, hydraulic dredging for a similar scale project would range between $725,000 and $1,100,000 plus up to an additional $100,000 for permitting and design depending on the method of dewatering selected.

Chemical content of the material to be dredged is an important consideration in determining the feasibility of reuse or disposal. Disposal costs could vary greatly depending on whether the material can be beneficially reused. If the material removed from the pond is clean, which we believe it will be based on our analysis, it is useful as a soil amendment. It is possible that the material may potentially be sold to local garden suppliers or landscape businesses which would make the project more economically feasible. However, material that is not suitable for beneficial use would need to either be amended with clean material (potentially from within the basin) to dilute the concentrations to suitable levels or trucked to a site for disposal. Either of these options would increase the cost of the project and, depending upon the level of implementation, could potentially make dredging a less cost effective option.

Based on the sediment sampling results obtained as part of this study (Attachment F), sediment is suitable for upland reuse currently, or at a minimum would only need to be amended slightly prior to stockpiling or beneficial use. MassDEP will make a final determination on suitable reuse options for the material as part of the permitting process.

If dredging is considered to be a viable long-term option, the next steps would be:

1. Assessment of specific scope and extent of dredge program including possible funding options.
2. Additional chemical and physical analysis of the sediments in areas targeted for dredging. The cores collected as part of the current study were valid for assessing sediment quality over a large portion of the pond. However, for permitting purposes, one core will need to be collected specifically from the target dredge area for each 1,000 cubic yards of sediment proposed to be dredged. The level of effort will be based on the final volume of material to be dredged. Assuming a total of 30,000 cubic yards, 30 cores (forming 10 composite samples) will need to be collected.
3. Development of an engineering design for submission to permitting authorities.
4. Initiation of the permitting process including an Environmental Notification Form filing for MEPA (Massachusetts Environmental Policy Act) review, filing a local Notice of Intent under the Wetlands Protection Act, filing for a Section 401 Water Quality Certificate from MassDEP, and seeking a U.S. Army Corps of Engineers Section 404 Permit for dredging.

These four activities might be expected to cost up to $50,000 for Warner's Pond given the work already completed as part of this study, but are essential if dredging is to be pursued as a management option. Additional design costs would include final engineering design following the permitting process (incorporating any accepted changes resulting form these reviews) along with the development of a bid specification package for the project.

Assuming the estimated sediment accumulation rate of 43 to 64 cy/year derived in Section 3.5 and a dredge volume of 30,000 cubic yards in the targeted management area, refill could be expected to take several hundred years. Using a conservative estimate of a 100-year project lifespan, the annualized dredging cost of a conventional dredging project would be $5,500 to $8,000 per year, not including permitting. This estimate is based entirely on measured TSS load and could be higher or lower depending on pond circulation patterns, in-pond algae and macrophyte production, and the occurrence of catastrophic weather events.

5.3 Options Considered but not Recommended

5.3.1 Aeration and/or Destratification – Not Recommended

Aeration and/or destratification (or circulation) is used to treat problems with high algal growth and low oxygen concentrations that may occur in smaller ponds. Air diffusers, aerating fountains, and water pumps are typical types of equipment that may be installed to increase circulation in a pond. The cost of purchasing, installing, and maintaining pond circulation equipment becomes substantial as pond size increases. Likewise, the effectiveness of the equipment tends to decline with pond size as it is difficult to achieve sufficient circulation in large ponds.

This approach is not currently recommended for Warner's Pond, primarily because sedimentation and excessive aquatic plant growth (rather than planktonic algal growth) are the targets for restoration of the pond. Additionally, Warner's Pond's high flushing rate would minimize the effects of any aeration since the aerated water would quickly pass downstream.

5.3.2 Plant Competition – No Recommended Actions Identified

The presence of a healthy, native plant community can often suppress the spread of invasive aquatic species. A plant competition biocontrol technique seeks to supplement native species through seeding and planting disturbed or bare areas before they can be colonized by invasives. The overall goal of the technique is to maximize spatial resource use by desirable species to keep out undesirable invasive species (Wagner, 2004).

The advantages of this approach are that it uses natural processes to control aquatic invasives, may be self-perpetuating after an initial establishment period of several years, and can be easily integrated with other approaches. It is likely to be most effective after elimination of an invasive plant community through an initial herbicide treatment or mechanical removal followed by native species plantings.

There are several challenges associated with the plant competition approach which makes its long-term effectiveness uncertain. Periodic natural disturbances within a plant community provide continual opportunities for recolonization by invasives, which would require ongoing effort with supplemental native plantings (Wagner, 2004). The use of seeding or planting native vegetation is also still experimental and these native species may not become established quickly enough to prevent invasion by exotics.

Costs for implementing this approach will vary depending on the species and area being planted and are largely unknown, but estimates of more than $5,000 per acre would not be unexpected. Though it might be useful as a trial approach to determine the feasibility of establishing a viable native plant plot within the pond following treatment with herbicide to document the growth and expansion of a replacement plant community, plant competition is not recommended for widespread use in Warner's Pond because of its high initial cost and the fact that it is still largely experimental and would most likely involve multiple years of ongoing labor to supplement native plants.

5.3.3 Chemical Sediment Treatment – Not Recommended

This management option consists of adding compounds to alter sediment features and thereby limit plant growths or control chemical exchange reactions. Although compounds such as alum and iron(III) chloride have been shown to have some effect on internal nutrient cycling, these compounds must be expertly applied and buffered to be effective while avoiding fish kills. New products, such as lanthanum-modified bentonite clay (trade name Phoslock), might be expected to achieve similar results. However, given the overwhelming load of phosphorus (far larger than the critical load) and sediment from external sources and the expense of conducting a chemical sediment treatment in Warner's Pond, this action is unlikely to result in a cost-effective and long-term reduction in phosphorus or aquatic macrophyte growth. Therefore, chemical sediment treatment is not recommended.

5.3.4 Dilution or Flushing – Not Recommended

Dilution and flushing involve increasing the flow rate so as to dilute or remove concentrations of nutrients or other pollutants in the pond. It requires an appropriate outlet structure and must take into account the potential downstream impacts of increased flow and "flushing" of nutrients. Due to the relatively large ratio of flow to pond volume, Warner's Pond naturally flushes at a rapid rate. Large additional inputs of clean water would need to be continually supplied to effectively dilute the concentration of phosphorus in Warner's Pond. Additionally, pond sediments are believed to hold a large amount of nutrient that would sustain aquatic plant growth, through root uptake, well into the future even if significant dilution or flushing could be achieved. Therefore, dilution and flushing are not recommended.

5.3.5 Shading Dye – Not Recommended

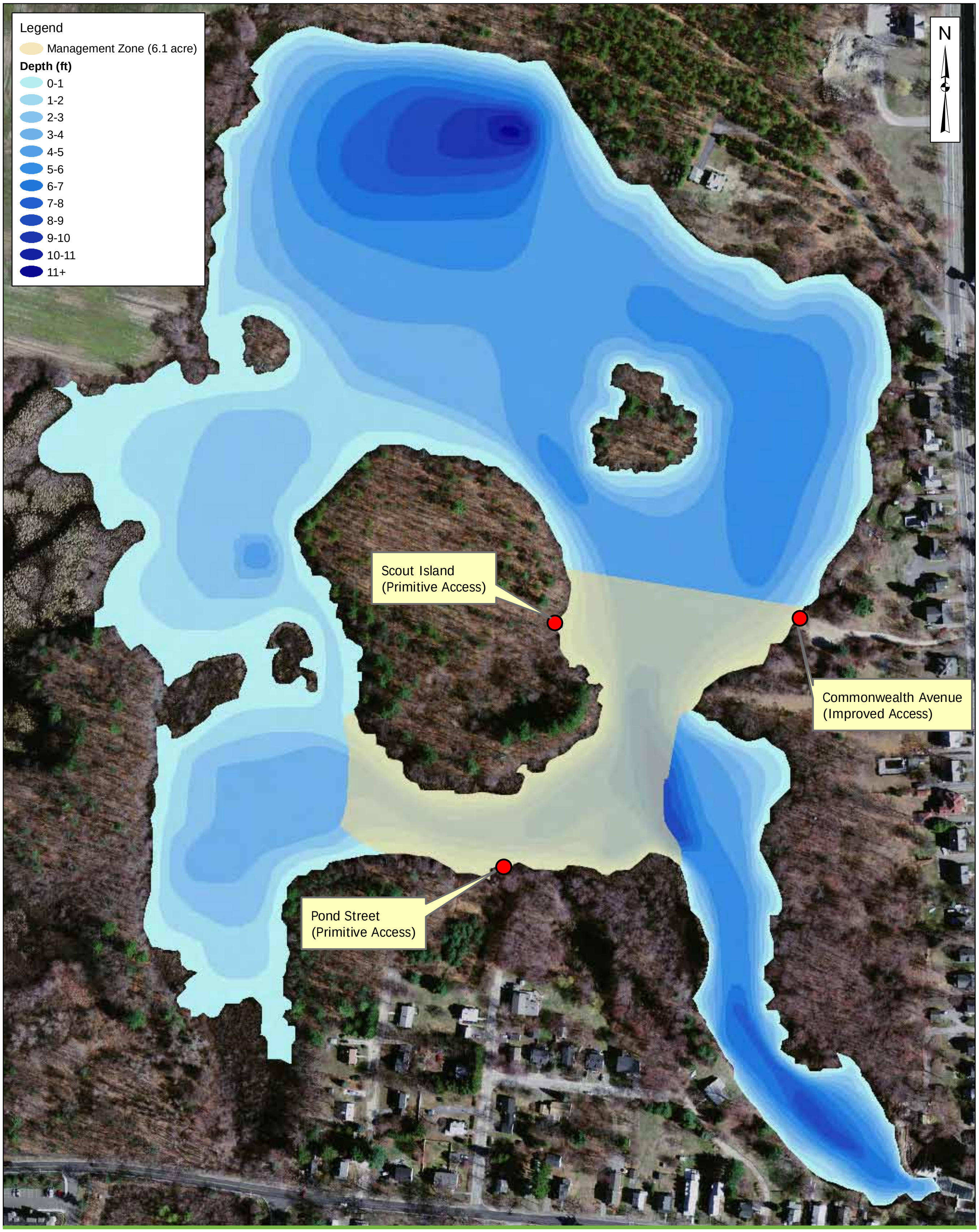
Dyes are used to limit light penetration and therefore restrict the depth at which rooted plants can grow. In essence, they mimic the effect of light inhibition that might be expected during periods of high turbidity or prolonged ice and snow cover. Natural periods of low light are an important variable in determining plant composition and abundance, and use of dyes can produce similar effects. They are only selective in the sense that they favor species tolerant of low light or with sufficient food reserves to support an extended growth period (during which time the plant could reach the euphotic zone). Dyes tend to reduce the maximum depth of plant growth, but are relatively ineffective in shallow water (less than 6 ft or 1.8 m deep). Dyes are unlikely to make a significant difference in plant growth within shallow bodies of water like Warner's Pond. Additionally, maintaining a high concentration of dye in the pond would be impossible, given its very high flushing rate. Therefore, the use of shading dye is not currently recommended.

5.3.6 Nutrient Inactivation – Not Recommended

Nutrient inactivation typically targets dissolved phosphorous (the form most readily available to plants and algae) and involves the addition of alum (aluminum sulfate) or similar aluminum based compounds that bind to this phosphorous to allow it to settle into the pond sediments. In its simplest form, nutrient inactivation is conducted by applying alum directly to the pond as a single dose. More sophisticated nutrient inactivation programs involve proportional injection of alum into stormwater sources or tributaries so that phosphorous is inactivated before it even enters the pond.

Nutrient inactivation is typically used to control algae blooms and improve water clarity. These are not considered to be key target issues for the shallow waters of Warner's Pond, where nuisance growth of aquatic plants and accumulated sediment are the primary problems. An alum dosing system designed to target the incoming phosphorus would be effective, if sized appropriately, at managing the phosphorus content in the waters of the pond; however such a system would be extremely expensive to run given the large volume of inflows that the pond receives. Therefore, nutrient inactivation is not recommended for Warner's Pond.

Location: G:/GIS-Projects/Warners-Pond-Concord/00-mxd/Report/Plant-Cover.mxd



WARNER'S POND WATERSHED MANAGEMENT PLAN

ess group
environmental consulting
& engineering services

Scale: 1" = 300'

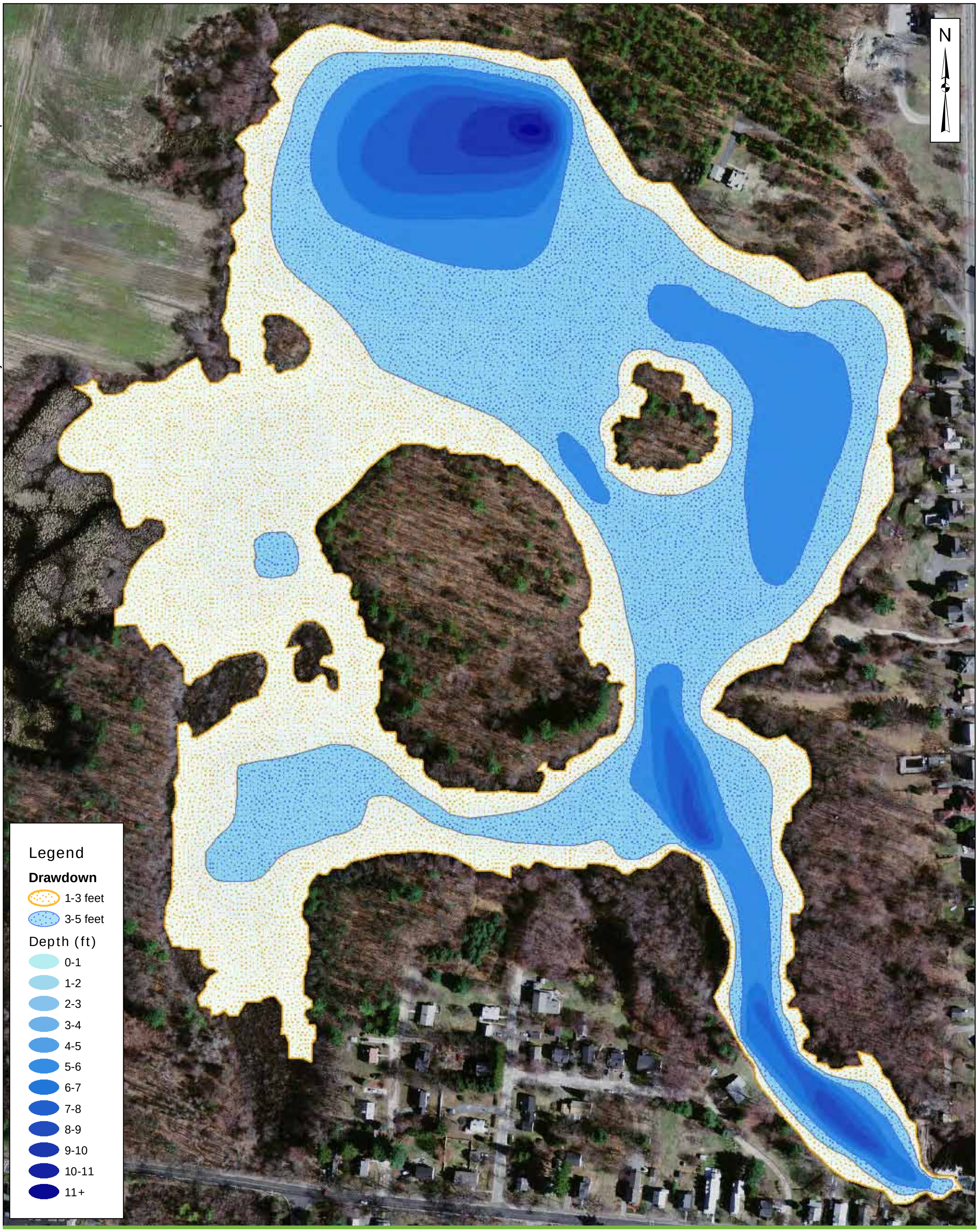
0 300 Feet

Source: 1) MassGIS, Color Orthophotos, 2008

Warner's Pond
Proposed Management Zone

Figure
14

Location: G:/GIS-Projects/Warners-Pond-Concord/00-mxd/Report/Drawdown.mxd



WARNER'S POND WATERSHED MANAGEMENT PLAN

Warner's Pond
Areas Exposed Using Drawdown

ess group
environmental consulting
& engineering services

Scale: 1" = 300'

0 300 Feet

Source: 1) MassGIS, Color Orthophotos, 2008

Figure 15

6.0 IMPROVE PUBLIC ACCESS

Some improvement to the public's ability to access Warner's Pond can be achieved through modest improvements to the existing public access point on Commonwealth Avenue along the pond's eastern shoreline. Such improvements might include the addition of gravel to solidify the parking area, improved signage at the pond or other amenities such as a bench, picnic table, or trash receptacle. Management of weed beds at this location to improve pond access for watercraft should be focused on creating "boating channels" rather than removing all vegetation. Leaving some weed beds intact will provide habitat preferred by larger warmwater game fish, such as largemouth bass, near the access point. This should help to maintain or improve fishing opportunities from shore.

Whatever improvements are made to the actual parking configuration layout or surfacing would require local permitting to be filed through the Natural Resources Commission. Other amenities could be included in this permitting effort for public discussion purposes as well; however, it should be kept in mind that these types of improvements often require maintenance costs (e.g. trash disposal) or periodic replacement due to wear and tear. These structural improvements to this access area, if kept to the modest level envisioned, are likely to cost on the order of $8,000 to $15,000 for design, permitting and construction at the Commonwealth Avenue site.

Creation of a new public access at the end of Pond Street is not recommended. The Commonwealth Avenue access point should be the focus of primary improvements given that this facility is already available and in use. However, the Pond Street area could be improved as a primitive access by maintaining and pruning back vegetation along a defined trail system leading to the pond. Such minor improvements would allow for occasional use by non-motorized boats (canoe or kayak) or shoreline fishing if also combined with a limited shoreline vegetation management program. Likewise, Scout Island could also be similarly maintained to have a primitive but defined access point with selective vegetation clearing, as needed. Having defined and maintained areas for access by boats is actually a wise approach as this will reduce the potential for impacts to shoreline vegetation along other areas of the pond and, if sites are properly maintained, they will also offer a safer access and egress from the pond.

Establishing a Town swimming dock or beach is not currently recommended, due to water quality concerns and budgetary limitations. In addition to the capital improvements this would entail, the liability, maintenance and monitoring costs for public swimming areas are high.

7.0 MONITORING PROGRAM

A cost-effective monitoring program would provide continuous background data for the purpose of tracking the effectiveness of any future management practices at Warner's Pond. Because water quality in Warner's Pond is already failing to meet the stated objectives, the water quality monitoring program should focus on tracking in-pond conditions during the peak growing season each year. This will allow quantification of the normal range of parameter values and recognition of any potentially detrimental shifts or trends. Phosphorus levels would be the key variable in this regard, along with easily measured field parameters (pH, dissolved oxygen, temperatures, conductivity, turbidity, and clarity [Secchi depth]). Evaluation of plant species density and distribution should be the focus of biological monitoring with particular focus on the distribution of exotic plant species.

Evaluating water quality and plant coverage trends requires several years of continuous data, often with multiple sample dates in each year. Evaluation of management techniques would be more immediate, allowing comparisons between pre- and post-management periods. A program could be custom designed to fit within an appropriate budget, but a cost of between $5,000 and $8,000 per year should be dedicated in order to include some level of water quality and plant community assessment along with a review of data by a qualified expert. Monitoring plant cover in the pond should be performed on an annual basis to track expansion of variable watermilfoil and fanwort as well as to direct harvesting efforts for water chestnut as well as to support early detection of any new aquatic invasive species that may spread into Warner's Pond. Plant monitoring also allows evaluations of implemented management actions to be made and strategies adjusted, as necessary.

8.0 SUMMARY OF MANAGEMENT RECOMMENDATIONS AND CONCLUSION

The most critical management action identified through this study is the need to address invasive aquatic weed growth, particularly the extremely dense fanwort and variable watermilfoil present throughout much of the pond. In addition, water chestnut is also an invasive that demands continued attention as it can quickly get out of control if left unmanaged. Purple loosestrife, while problematic and undesirable in surrounding wetlands and shorelines, does not directly impact in-pond recreational opportunities. However, management of this species should be included for ecological reasons. Water quality is very poor, characterized by extreme nutrient loading due to the large volume of nutrient-rich water being delivered to the pond by its extensive watershed. Given this, water quality conditions are beyond a level where active management would make significant improvements. However, this aspect of management should not be overlooked when it comes to developing a comprehensive pond management program.

To address water quality issues in the watershed ESS recommends:

1. Implement an education program for watershed residents, particularly those living close to Warner's Pond and the other ponds in its watershed, about the benefits of proper yard care (fertilization being a key focus), pet waste management, maintaining buffers along stream corridors, and other behavioral changes that can be adopted to make improvements in the pond's water quality.

   Educational costs can vary widely depending upon the level of implementation. A typical program to develop a watershed specific, tri-fold brochure focused on the above topics can be created specifically for Warner's Pond watershed residents for less than $3,000. Some towns have opted to distribute brochures with utility bills or other town mailings for very little additional cost. The 319 Non-Point Source Pollution grant program used to fund a portion of the costs for education as part of a comprehensive project to reduce NPS pollution within the watershed; however, this program may not fund such projects in this watershed going forward due to recent regulatory changes to the program.

2. Additional safeguards for protecting future water quality can also be provided through improvements to the watershed's storm water infrastructure. The addition of storm water detention and infiltration facilities at key runoff locations could greatly reduce the phosphorus reaching the pond and would also be able to significantly reduce bacterial contamination as well. There are numerous storm water BMPs currently in the watershed, although most of these may not be adequately maintained or have been designed to remove water from roadways quickly rather than encouraging infiltration. Going forward it should be encouraged that development and improvements to highway infrastructure be designed incorporate infiltrating chambers to the outflows or other LID features such as grassed swales, rain gardens, detention ponds, etc. Opportunities for enhancing storm water infiltration for developed properties in the watershed should be identified systematically. A study to evaluate the watershed to identify the sites that may be superior candidates for retrofitting with LID or other storm water management techniques would be expected to cost on the order of $30,000 to $40,000.

To address public access at Warner's Pond, ESS recommends:

3. Public access to Warner's Pond can be improved through modest improvements to the existing public access point on Commonwealth Avenue along the pond's eastern shoreline. Such improvements might include the addition of gravel to solidify the parking area, improved signage at the pond or other amenities such as a bench, picnic table, or trash receptacle. These structural improvements to this access area, if kept to the modest level envisioned, are likely to cost $8,000 to $15,000 for design,

permitting, and construction at the Commonwealth Avenue site. Additional maintenance costs would be associated with keeping the area clean and providing trash removal services.

Restoration of Warner's Pond in a manner that is comprehensive and long lasting will require additional investment. Based on our findings in this study and on the previously reported management efforts in this regard, ESS is recommending the following actions be taken to address invasive plant management objectives:

4. For fanwort and variable watermilfoil, herbicides are likely to be the most effective option available at Warner's Pond over the short-term and are recommended as the most appropriate means by which to get the system back to a level where the invasive species can be managed through more sustainable options. Presently, these exotic species occupy over 20 acres of the pond at varying densities.

   Fluridone pellets (trade name Sonar) may be applied to the targeted management zone to control fanwort as needed going forward. Costs for this approach are likely to be on the order of $1,000 per acre or about $8,000 for controlling fanwort within the targeted management zone between Scout Island and the public access point (allowing for some overtreatment beyond the 6.1-acre targeted management area to occur to get the desired results within the target zone). Given the difficulty in achieving ideal herbicide contact times at Warner's Pond, this approach would likely need to be repeated every other year, or at least every third year, until other longer term management actions can be implemented.

   Variable watermilfoil may be controlled with the granular form of the systemic herbicide known as 2,4-D (trade name Navigate). 2,4-D will achieve two to three years of variable milfoil control in Warner's Pond for a cost of about $4,000 for the targeted management area. There are no known public or private supply wells around the perimeter of the pond. However, if a private well were determined to be in use, it would be necessary to establish setbacks from shore to minimize the potential for treated water to be drawn into the wells. We recommend that the nature of the wells that could potentially be drawing water from Warner's Pond first be investigated by a qualified hydrogeologist and, if necessary, by a human health and environmental risk assessor, to assist in determining the fate and transport potential of 2,4-D so that specific setbacks, if any, can be recommended and included as part of the permitting conditions. Costs for this critical step are likely to be on the order of $4,000 to $5,000 for Warner's Pond. In areas where a setback is required but milfoil control is still required, diquat may be used as long as this option has been included in the permitting application and approved.

   Assuming permits are issued without significant complication, total costs for an herbicide program which include a treatment with 2,4-D to control variable watermilfoil within the targeted management zone and the use of slow-release fluridone within the same area to control fanwort, along with the necessary investigations, permitting, and monitoring would be on the order of $25,000 for up to three years of control.

5. Hand harvesting is a cost-effective means of controlling water chestnut growth in Warner's Pond. Plants can be easily identified and pulled by volunteers to save on cost. Water chestnut should be harvested annually in early summer (i.e., prior to seed maturation) to ensure that its levels are kept in check. With persistence, it may be possible to deplete the water chestnut seed bank in Warner's Pond to the point that growths of this plant are effectively eliminated. However, annual monitoring would still be recommended to identify and control any re-infestations due influx of seeds from any upstream sources. While hand harvesting will be most effective for water chestnut control, it may also be used on a small scale to supplement other control methods in invasive watermilfoil and fanwort beds.

6. Purple loosestrife may be controlled using loosestrife beetles. Adult loosestrife beetles can be obtained (with a permit) at a cost of $275 to $300 for 1,000 beetles. Beetle release should focus on contiguous infestations primarily occur along the shallow western margins of the pond. Isolated purple loosestrife infestations along the remaining shoreline would be best controlled by manual removal.

7. Benthic barriers can be used on a localized basis if herbicide use is not welcome or within critical areas that must remain weed free such as at the public access point. Barrier material could be placed at the public access for an estimated cost of between $10,000 and $20,000 depending upon the area to be managed. Although permits are likely to be required, very little long-term environmental impact can be expected from such a management approach. This approach also does not address the weed issue on a basin-wide basis or within a broader area that might be envisioned to benefit broader recreational uses such as boating or fishing.

8. Winter pond level drawdown has been the active management approach used by a number of lake and pond associations within the state for many years to manage nuisance weed growth. It can be very effective for controlling fanwort and milfoil if performed correctly and the approach is well suited to Warner's Pond. Although no rare species are known to inhabit Warner's Pond, sensitive wildlife, including turtles, frogs, and freshwater mussels are present. Therefore, drawdown will need to be properly designed, timed and implemented to provide the greatest impact on the target species and the least impact on native plants, fish, and wildlife.

   Drawdowns are often perceived to be "free" and to have little or no environmental impacts; however, this is often not the case. Furthermore, drawdown will never be able to control nuisance weeds in the deeper areas of the pond. "Extreme" drawdowns conducted at Warner's Pond were implemented previously to make repairs or to replace the dam and not specifically for aquatic weed control. Current environmental protection requirements (state and federal) would generally prohibit an extreme drawdown due to the negative impacts on fish and wildlife as well as to the hydrologically connected wetlands. A targeted drawdown that could prudently be recommended based on the data collected as part of this study would be no more than 3 feet below normal pool elevation.

   If done correctly, drawdowns typically require some level of assessment of the baseline conditions, such as provided in this Pond Management Plan, as well as some drawdown specific assessments and calculations. ESS is recommending that a drawdown feasibility study be performed to address some of the outstanding issues and to develop the necessary Drawdown Operations Plan, inclusive of all hydrologic calculations.

   Cost to perform a drawdown feasibility study and develop a Drawdown Operations Plan, given that a substantial amount of information is now available in this Pond Management Plan, are expected to be on the order of $8,000. The cost for filing this permit application is likely to range between $3,000 and $4,000 plus filing fees. It is also likely that a monitoring program will be required as a permit condition, which could cost on the order of $5,000 per year to execute.

9. If dredging is considered to be a viable long-term option, the next steps would be to assess the specific scope and extent of dredge program including possible funding options, conduct additional chemical and physical analysis of the sediments in areas targeted for dredging, develop an engineering design for submission to permitting authorities, and initiate the permitting process including an Environmental Notification Form filing for MEPA (Massachusetts Environmental Policy Act) review, filing a local Notice of Intent under the Wetlands Protection Act, filing for a Section 401 Water Quality Certificate from MassDEP, and seeking a U.S. Army Corps of Engineers Section 404 Permit for dredging. These four activities might be expected to cost up to $50,000 for Warner's Pond given the work already completed as part of this study, but are essential if dredging is to be pursued as a management option. These steps are also beneficial to preparing the project to be "shovel

ready" to take advantage of funding opportunities that may arise within the town or at the state or federal levels. Additional design costs would include final engineering design following the permitting process (incorporating any accepted changes resulting form these reviews) along with the development of a bid specification package for the project.

In order to restore Warner's Pond in a manner that is comprehensive and will be long-lasting the cost will be significant. However, with proper planning and by being ready to take advantage of funding opportunities as they arise, it can be done in a reasonable amount of time. The work performed to date to gain control of the fanwort and milfoil populations should be followed-up through continued management efforts to ensure that the progress made to date is not wasted effort. Additionally, maintaining diligence regarding the control of water chestnut through hand-pulling or harvesting is also essential.

Given the extensive costs associated with implementing a long-term program for full control of the weed problem in the pond, ESS has offered a solution that targets maintenance of a critical area of open water habitat that will allow for acceptable levels of recreational use of the pond while also maintaining less disturbed areas elsewhere in the pond that can continue to serve the ecological needs of local wildlife populations. It is likely that interim measures will be required in order to meet the short-term objectives of keeping the pond safe for recreational use and to maintain a level of quality with regard to aquatic habitat value. Therefore, it is recommended that a drawdown program be considered for the near-term to assist in managing weed growth around the perimeter of the pond, assuming that the required permits can be obtained. A longer-term recommendation is to pursue dredging as a means of permanently enhancing the open water habitat within the southern end of the pond between Scout Island and the Commonwealth Avenue access point.

9.0 LIST OF REFERENCES REVIEWED

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Attachment A

Warner's Pond Quality Assurance Project Plan
(Electronic Version Only)

Attachment B

Sediment Core Photographic Log

Attachment C

Watershed Assessment Results

Attachment D

Hydrologic Budget and Nutrient Load Model

Attachment E

2011 Project Completion Report
SONAR Herbicide Treatment at Warner's Pond

www.essgroup.com

Attachment F

Sediment Quality Results

Attachment G

Project Photo Log

www.essgroup.com

Attachment H

Glossary of Pond Terms