Total Maximum Daily Loads of Phosphorus for Selected Millers Basin Lakes

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Front Cover

Photograph of Parker Pond in Gardner.

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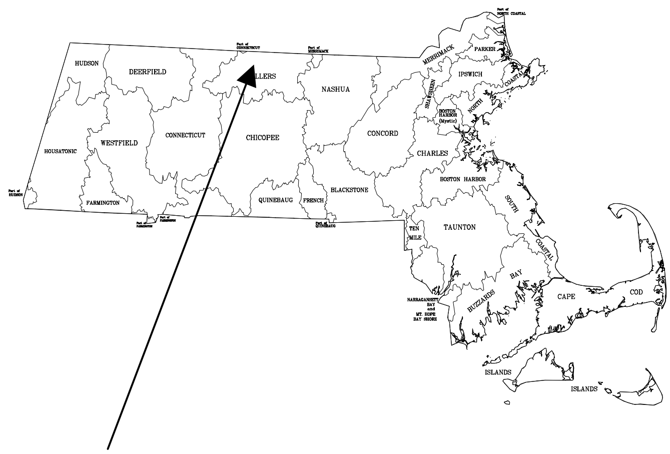

Location of Millers Basins in Massachusetts.

Key Feature: **TMDL assessment Total Phosphorus for 28 lakes in the Millers Basin Watershed.**

Locations: **Beaver Flowage Pond (MA35005), Royalston; Bents Pond (MA35007), Gardner; Bourn-Hadley Pond (MA35008), Templeton; Brazell Pond (MA35010), Templeton; Cowee Pond (MA35013), Gardner; Davenport Pond (MA35015), Petersham/Athol; Lake Denison (MA35017), Winchendon; Depot Pond (MA35018), Templeton; Lake Ellis (MA35023), Athol; Greenwood Pond (MA35025), Westminster; Greenwood Pond (MA35026), Templeton; Hilchey Pond (35029), Gardner; Lower Naukeag Lake (35041), Ashburnham; Minott Pond South (35045), Westminster; Minott Pond (35046), Westminster; Lake Monomonac (MA35047), Winchendon/Rindge, N.H.; Parker Pond (MA35056), Gardner; Ramsdall Pond (MA35062), Gardner; Reservoir No.1 (MA35063), Athol; Reservoir No. 2 (MA35064), Philipston/Athol; Riceville Pond (MA35065), Petersham/Athol; South Athol Pond (MA35078), Athol; Stoddard Pond (MA35083), Winchendon; Wallace Pond (MA35092), Ashburnham; Ward Pond (MA35093), Athol; Whites Mill Pond (MA35099), Winchendon; Whitney Pond (MA35101), Winchendon; and Wrights Reservoir (MA35104), Gardner/Westminster; Massachusetts.**

Pollutants: **Twenty-Eight total phosphorus TMDLs (32 total TMDL stressors)**

Data Sources: **Synoptic lake surveys, Land use information.**

Data Mechanisms: **NPSLAKE model, Reckhow model, Best Professional Judgment**

Monitoring Plan: **Massachusetts Watershed Initiative Five-Year Cycle.**

Control Measures: **Watershed Management, Septic system maintenance, Macrophyte Management**.

Executive Summary

The Massachusetts Department of Environmental Protection (DEP) is responsible for monitoring the waters of the Commonwealth, identifying those waters that are impaired, and developing a plan to bring them back into compliance with the Massachusetts Surface Water Quality Standards. The list of impaired waters, better known as the “303d list” and more recently “Category 5” of the Integrated List, identifies river, lake, and coastal waters and the reason for impairment.

Once a water body is identified as impaired, DEP is required by the Federal Clean Water Act to essentially develop a “pollution budget” designed to restore the health of the impaired body of water. The process of developing this budget, generally referred to as a Total Maximum Daily Load (TMDL), includes identifying the source(s) of the pollutant from direct discharges (point sources) and indirect discharges (non-point sources), determining the maximum amount of the pollutant that can be discharged to a specific water body to meet water quality standards, and developing a plan to meet that goal.

This report represents a TMDL for a group of lakes (see table below) in the Millers River Watershed. The lakes are listed on the state 1998 “303d” list for a variety of pollutants and stressors including low dissolved oxygen, turbidity, nutrients, and an over-abundance of nuisance aquatic plants. All of the pollutants and stressors are indicators of nutrient enriched systems, better known as the process of eutrophication. In freshwater systems the primary nutrient known to accelerate eutrophication is phosphorus. Therefore, in order to prevent further degradation in water quality and to ensure that each lake meets state water quality standards, the TMDL establishes a phosphorus limit for each lake and outlines corrective actions to achieve that goal.

In some cases, while the existing concentrations of phosphorus in the lake may be low enough already to achieve water quality standards, other actions (such as in-lake management activities) are necessary to eliminate noxious aquatic plants and to ensure that the condition does not get worse. In these cases a protective phosphorus load was established. Even when a water body is not listed for nutrients, because of the inter-relationship of the cause and effects of the pollutants and response variables, it is a prudent policy to be conservative when determining loading allocations and planning management strategies. When available, in-lake data used for this analysis were collected by DEP and combined with a landuse based phosphorus export model called NPSLAKE developed by Dr. Mark Mattson and Dr. Russell Isaac of DEP (1999).

The following table lists the lakes that were evaluated, their predicted total phosphorus concentrations and loads using the landuse model, the selected target phosphorus concentration and loads necessary to achieve surface water quality standards.

TMDL Total Phosphorus Targets

WBID	Lake Name	NPSLAKE Predicted TP (ppb)	NPSLAKE Predicted Load (kg/ha/yr)	Selected Target TP (ppb)	Selected Target Load (kg/ha/yr)
MA35005	Beaver Flowage Pond	12.5	56.	12.5	56.
MA35007	Bents Pond	33.3	501.	15	227
MA35008	Bourn-Hadley Pond	31.1	168.	15	81
MA35010	Brazell Pond	42.1	117.	15	41
MA35013	Cowee Pond	12.7	39	12.7	39
MA35015	Davenport Pond	12.7	59	12.7	59
MA35017	Lake Denison	20.1	210.	15	157
MA35018	Depot Pond	32.2	43.	15	20
MA35023	Ellis Pond	17.5	195.	15	167
MA35025	Greenwood Pond 1	13.9	25	13.9	25
MA35026	Greenwood Pond 2	35.5	140	15	58
MA35029	Hilchey Pond	27.4	174	19	122
MA35041	Lower Naukeag Lake	14.5	507	14.5	507
MA35045	Minott Pond South	11.0	32	11.0	32
MA35046	Minott Pond	16.6	44	15	40
MA35047	Lake Monomonac	13.3	887	13.3	887
MA35056	Parker Pond	30.0	432.	15	216
MA35062	Ramsdall Pond	32.4	561	15	269
MA35063	Reservoir No. 1	21.1	71.	15	50
MA35064	Reservoir No. 2 (Secret Lake)	5.1	16.	5.1	16.
MA35065	Riceville Pond	15.1	206	15	204
MA35078	South Athol Pond	17.5	386	15	330
MA35083	Stoddard Pond	21.1	179	15	127
Ma35092	Wallace Pond	13.7	129	13.7	129
MA35093	Ward Pond	15.4	19.	15	19
MA35099	Whites Mill Pond	19.8	776	15	589
MA35101	Whitney Pond	18.5	1918	15	1552
MA35104	Wrights Reservoir	13.5	157	13.5	157

Recommended Implementation by Lake

Recommended Implement-ation	Beaver Flowage	Bents	Bourn-Hadley	Brazell	Cowee	Davenport	Denison	Depot	Ellis	Greenwood1	Greenwood2	Hilchey	Lower Naukeag	Minott South	Minot	Monomonac	Parker	Ramsdall	Reservoir No.1	Reservoir No.2	Riceville	South Athol	Stoddard	Wallace	Ward	Whites Mill	Whitney	Wrights
Public Education	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Watershed Survey	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lake Management Plan	*	*	*	*	X	*	X	*	X	*	*	*	X	*	*	X	X	*	*	X	*	X	X	*	*	*	X	X
Forest BMPs	X				X	X								X	X	X			X	X	X	X		X	X	X	X	
Agriculture BMPs	X		X	X			X		X		X			X	X	X							X			X		
Residential BMPs		X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X
Septic System Inspection & Maintenance			X	X					X	X			X		X	X				X		X	X		X	X		
Urban stormwater BMPs		X	X	X					X	X	X	X	X			X	X	X	X								X	X
Highway BMPs		X	X	X					X		X					X		X	X					X			X	
In-Lake Management									X							X	X										X	
Other (Gravel pits, athletic fields, see text)			X						X								X					X					X	

*May need only town-wide NPS management plan focused on protection of these surface waters.

In most cases, authority to regulate nonpoint source pollution and thus successful implementation of this TMDL is limited to local government entities and will require cooperative support from local volunteers, lake and watershed associations, and local officials in municipal government. Those activities can take the form of expanded education, obtaining and/or providing funding, and possibly local enforcement. Funding support to aid in implementation of this TMDL is available on a competitive basis under various state programs including the Section 319 Grant Program, the State Revolving Fund Program (SRF), and the Department of Environmental Management's Lakes and Pond Small Grants Program.

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Introduction

Section 303(d) of the Federal Clean Water Act requires each state to (1) identify waters for which effluent limitations normally required are not stringent enough to attain water quality standards and (2) to establish Total Maximum Daily Loads (TMDLs) for such waters for the pollutants of concern. TMDLs may also be applied to waters threatened by excessive pollutant loadings. The TMDL establishes the maximum allowable pollutant loading from all contributing sources at a level necessary to achieve the applicable water quality standards. The TMDLs must account for seasonal variability and include a margin of safety (MOS) to account for uncertainty of how pollutant loadings may impact the receiving water's quality. This report will be submitted to the USEPA as a TMDL under Section 303d of the Federal Clean Water Act, 40 CFR 130.7. After public comment and final approval by the EPA, the TMDL will be incorporated into the watershed action plan to be developed by the Executive Office of Environmental Affairs Basin Team (see below) and serve as a guide for future implementation activities. Where permits for wastewater and other discharges are required, TMDLs will be used by DEP to set appropriate limits.

The Massachusetts Watershed Initiative is a new structure in state government that focuses all branches of government within each watershed to manage environmental issues. The Executive Office of Environmental Affairs (EOEA) has set up Watershed Teams with a Team Leader within each watershed in Massachusetts. The Teams represent state and federal agencies and local community partners. Within each watershed a Watershed Community Council may be created that will consist of watershed associations, business councils, regional planning agencies and other groups. Stream Teams may be created to assess environmental quality, identify local problems and recommend solutions. Stream Teams may include watershed associations, municipal government and business representatives. Additional information and contact information on the Watershed Teams is available on the World Wide Web at http://www.state.ma.us/envir/watershd.htm.

The proposed Total Maximum Daily Loads (TMDLs) for the Millers River Watershed lakes are based on Total Phosphorus loadings estimated from the landuse based NPSLAKE model of Mattson and Isaac (1999). For lakes solely impaired by rooted aquatic macrophytes, or in lakes where the existing concentrations of phosphorus in the lake may be low enough already to achieve water quality standards a <u>protective</u> phosphorus load was established to slow the rate of eutrophication; in addition, various plant management options are discussed. For lakes impaired by algae and non-rooted macrophytes (e.g. duckweed) a total phosphorus TMDL is established to meet Massachusetts Surface Water Quality Standards, particularly the 4-foot transparency criterion for public swimming beaches. In many cases the State has limited authority to regulate nonpoint source pollution and thus successful implementation of this TMDL will require cooperative support from the public including lake and watershed associations, local officials and municipal governments in the form of education, funding and local enforcement. Additional funding support is available under various state programs including section 319 (nonpoint source) and the State Revolving Loan Fund Program (SRF) and the Department of Environmental Management's Lakes and Pond grant program.

General Background and Rationale

Nutrient Enrichment: Nutrients are a requirement of life, but in excess can create problems. Lakes are ephemeral features of the landscape and over geological time most tend to fill with sediments and associated nutrients as they make a transition from lake to marsh to dry land. However, this natural successional ("aging") process can be and often is accelerated through the activities of humans—especially through development in the watershed. For highly productive lakes with developed watersheds, it is not easy to separate natural succession from "culturally induced " effects. Nonetheless, all feasible steps should be taken to reduce the impacts from cultural activities. The following discussion summarizes the current understanding of how nutrients influence the growth of algae and macrophytes, the time scale used in the studies, the type of models applied and the data collection methods used to create a nutrient budget. A brief description of the rationale for choosing a target load (the TMDL) as well as a brief discussion of implementation and management options is presented.

A detailed description of the current understanding of limnology (the study of lakes and freshwaters) and management of lakes and reservoirs can be found in Wetzel (1983), Cooke et al., (1993) and Holdren et al., 2001. To prevent cultural enrichment it is important to examine the nutrients required for growth of phytoplankton (algae) and macrophytes. The limiting nutrient is typically the one in shortest supply relative to the nutrient requirements of the plants. The ratio of nitrogen (N) to phosphorus (P) in both algae and macrophyte biomass is typically about 7 by weight or 16 by atomic ratio (Vallentyne, 1974). Examination of relatively high N/P ratios in water suggests P is most often limiting and careful reviews of numerous experimental studies have concluded that phosphorus is a limiting nutrient in most freshwater lakes (Likens, 1972; Schindler and Fee, 1974). Most diagnostic/feasibility studies of Massachusetts lakes also indicate phosphorus as the limiting nutrient. Even in cases where nitrogen may be limiting, previous experience has shown that it is easier, more cost-effective and more ecologically sound to control phosphorus than nitrogen. The reasons include the fact that phosphorus is related to terrestrial sources and does not have a significant atmospheric source as does nitrogen (e.g., nitrates in precipitation). Thus, non-point sources of phosphorus can be managed more effectively by best management practices (BMPs). In addition, phosphorus is relatively easy to control in point source discharges. Finally, phosphorus does not have a gaseous phase, while the atmosphere is a nearly limitless source of nitrogen gas which can be fixed by some types of phytoplankton (the blue-greens, or cyanobacteria) even in the absence of other sources of nitrogen. For all of the reasons noted above, phosphorus is chosen as the critical element to control freshwater eutrophication, particularly for algal dominated lakes or in lakes threatened with excessive nutrient loading.

There is a direct link between phosphorus loading and algal biomass (expressed as chlorophyll a) in algae dominated lakes (Vollenweider, 1976). The situation is more complex in macrophyte dominated lakes where the rooted aquatic macrophytes may obtain most of the required nutrients from the sediments. In organic, nutrient rich sediments, the plants may be limited more by light or physical constraints such as water movement than by nutrients. In such cases, it is difficult to separate the effects of sediment deposition, which reduce depth and extend the littoral zone, from the effects of increased nutrients, especially phosphorus, associated with the sediments. In Massachusetts, high densities of aquatic macrophytes are typically limited to depths less than ten feet and to lakes where organic rich sediments are found (Mattson et al., 1998). Thus, the response of rooted macrophytes to reductions in nutrients in the overlying water will be much weaker and much slower than the response of algae or non-rooted macrophytes, which rely on the water for their nutrients. In algal or non-rooted macrophyte dominated systems nutrient reduction in the water column can be expected to control growth with a lag time related to the hydraulic flushing rate of the system. In lakes dominated by rooted macrophytes, additional, direct control measures such as harvesting, herbicides or drawdowns will be required to realize reductions in plant biomass on a reasonably short time scale. In both cases, however, nutrient control is essential since any reduction in one component (either rooted macrophytes or phytoplankton) may result in a proportionate increase in the other due to the relaxation of competition for light and nutrients. In addition, it is critical to establish a Total Maximum Daily Load so that future development around the lake will not impair water quality. It is far easier to prevent nutrients from causing eutrophication than to attempt to restore a eutrophic lake. The first step in nutrient control is to calculate the current nutrient loading rate or nutrient budget for the lake.

Nutrient budgets: Nutrient budgets and loading rates in lakes are determined on a yearly basis because lakes tend to accumulate nutrients as well as algal and macrophyte biomass over long time periods compared to rivers, which constantly flush components downstream. In cases of short retention time (less than 14 days) reservoirs, nutrient budgets may be developed on a shorter time scale (e.g. monthly budgets from waste water treatment plants) but the units are expressed on a per year basis in order to be comparable to nonpoint sources estimated from landuse models. Nutrients in lakes can be released from the sediments into the bottom waters during the winter and summer and circulated to the surface during mixing events (typically fall and spring in deep lakes and also during the summer in shallow lakes). Nutrients stored in shallow lake sediments can also be directly used by rooted macrophytes during the growing season. In Massachusetts lakes, peak algal production, or blooms may begin in the spring and continue during the summer and fall while macrophyte biomass peaks in late summer. The impairment of uses is usually not severe until summer when macrophyte biomass reaches the surface of the water interfering with boating and swimming. Also, at this time of year the high daytime primary production and high nighttime respiration can cause large fluctuations in dissolved oxygen. In addition, oxygen is less soluble in warm water of summer as compared to other times of the year. The combination of these factors can drive oxygen to low levels during the summer and may cause fish kills. For these reasons the critical period for use impairment is during the summer, yet the modeling is done on a yearly basis.

There are three basic approaches to estimating current nutrient loading rates: the measured mass balance approach; the landuse export modeling approach; and modeling based on the observed in-lake concentration. The measured mass balance approach requires frequent measurements of all fluvial inputs to the lake in terms of flow rates and phosphorus concentrations. The yearly loading is the product of flow (liters per year) times concentration (mg/l), summed over all sources (i.e., all streams and other inputs) and expressed as kg/year. The landuse export approach assumes phosphorus is exported from various land areas at a rate dependent on the type of landuse. The yearly loading is the sum of the product of landuse area (Ha) times the export coefficient (in kg/Ha/yr). Using a model of in-lake phosphorus concentrations is a indirect method of estimating loading and does not provide information on the sources of input but can be used in conjunction with other methods to validate results. The mass balance method is generally considered to be more accurate, but also more time consuming and more costly due to the field sampling and analysis. For this reason, the mass balance results are used whenever possible. If a previous diagnostic/ feasibility study or mass balance budget is not available, then a landuse export model, such as Reckhow et al., (1980) or the NPSLAKE model (Mattson and Isaac, 1999) can be used to estimate nutrient loading.

Individual point sources phosphorus loadings are estimated from the most recent National Pollutant Discharge Elimination System (NPDES) data reported in the Discharge Monitoring Reports (DMRs) for the site. In many cases the permits are written with more stringent permit requirements during the non-winter months when both use and impairments are greatest. Generally, the impoundments downstream of NPDES discharges have short residence times and thus April-October data are used to compute total phosphorus loads based on actual measured flow times concentrations. If the discharge is immediately to a lake via a pipe, channel or short stream segment, then no phosphorus uptake is assumed. That is, the lake is assumed to receive 100 percent of the discharge. For lakes or reservoirs located further downstream, retention in each lake is calculated and in some cases, uptake or other retention by plants is calculated based on best available information from previous research on the pond. Thus, the TMDL reflects the amount of phosphorus which is predicted to actually reach the lake in question.

Target Load: Once the current nutrient loading rate is established, a new, lower rate of nutrient loading must be established which will meet surface water quality standards for the lake. This target load or TMDL, can be set in a variety of ways. Usually a target concentration in the lake is established and the new load must be reduced to achieve the lower concentration. This target nutrient concentration may be established by a water quality model that relates phosphorus concentrations to water quality required to maintain designated uses or specific water quality standards, such as the four-foot transparency criterion at Massachusetts swimming beaches. Alternatively, the target concentration may be set based on concentrations observed in background reference lakes for similar lake types or from concentration ranges found in lakes within the same ecological region (or sub-ecoregion). In cases of impoundments or lakes with rapid flushing times (e.g., less than 14 days), somewhat higher phosphorus targets may be used because the planktonic algae are rapidly flushed out of the system and do not have time to grow to nuisance conditions in the lake.

Various models (equations) have been used for predicting productivity or lake total phosphorus concentrations in lakes from analysis of phosphorus loads. These models typically take into consideration the waterbody's hydraulic loading rate and some factor to account for settling and storage of phosphorus in the lake sediments. Among the more well known metrics are those of Vollenweider (1975), Dillon-Rigler (1974) and Reckhow (1979). The TMDL must account for the uncertainty in the estimates of the phosphorus loads from the sources identified above by including a "margin of safety". The margin of safety can be specifically included, and/or included in the selection of a conservative phosphorus target, and/or included as part of conservative assumptions used to develop the TMDL.

After the target TMDL has been established, the allowed loading of nutrients is apportioned to various sources that may include point sources as well as private septic systems and various land uses within the watershed. In Massachusetts, few lakes receive direct point source discharges of nutrients. In cases where point sources exist upstream of a lake or impoundment, the point source will in most cases be targeted for a large percentage reduction in total phosphorus loading. The current loads for NPDES point sources are calculated based on current DMR data, not on the permitted discharge loading. New discharge limits at the treatment plant may be computed based on the percent reduction of current loads estimated by DMR reports. The new permitted concentrations of total phosphorus can then calculated based on total mass loading divided by permitted flow rate for the discharge.

In some cases the impairment issues include ammonia toxicity, BOD and suspended solids loadings which may require more extensive modeling (Qual2 or HPSF) which is beyond the scope of this report. The nutrient source analysis generally will be related to landuse that reflects the extent of development in the watershed. This effort can be facilitated by the use of geographic information systems (GIS) digital maps of the area that can summarize landuse categories within the watershed. The targeted reductions must be reasonable given the reductions possible with the best available technology and Best Management Practices (BMPs). The first scenario for allocating loads will be based on what is practicable and feasible for each activity and/or landuse to make the effort as equitable as possible.

Implementation: The implementation plan or watershed management plan to achieve the TMDL will vary from lake to lake depending on the type and degree of development. While the impacts from development cannot be completely eliminated, they can be minimized by prudent "good housekeeping" practices, known more formally as best management practices (BMPs). Among these BMPs are control of runoff and erosion, well-maintained subsurface wastewater disposal systems and reductions in the use of fertilizers. Activities close to the waterbody and its tributaries merit special attention for following good land management practices. In addition, there are some statewide efforts that provide part of an overall framework. These include the legislation that curbed the phosphorus content of many cleaning agents, revisions to regulations that encourage better maintenance of subsurface disposal systems (Title 5 Septic systems), and the Rivers Protection Act that provides for greater protection of land bordering waterbodies. In addition, there is the public's concern about the environment that is being harnessed to implement remediation and protection plans through efforts associated with the Massachusetts Watershed Initiative and the Watershed Teams. In some cases, structural controls, such as detention ponds, may be used to reduce pollution loads to surface waters.

Although the landuse approach gives an estimate of the magnitude of typical phosphorus export from various landuses, it is important to recognize that nonpoint phosphorus pollution comes from many discrete sources within the watershed. Perhaps the most common phosphorus sources in rural areas are leaching from failed or inadequate septic systems; phosphorus associated with soil erosion and use of phosphorus lawn fertilizers. Soils tend to erode most rapidly following soil disturbances such as construction, gravel pit operations, tilling of agricultural lands, overgrazing, and trampling by animals or vehicles. A common problem with erosion in rural areas is erosion from unpaved roads. Soils may also erode rapidly where runoff water concentrates into channels and erodes the channel bottom. This may occur where impervious surfaces such as parking lots direct large volumes of water into ditches which begin to erode and may also result from excessive water drainage from roadways with poorly designed ditches and culverts. Any unvegetated drainage way is a likely source of soil erosion.

Discrete sources of nonpoint phosphorus in urban, commercial and industrial areas include a variety of sources that are lumped together as 'urban runoff' or 'stormwater' and may be considered as point sources under wasteload allocations in the tables below. As many of these urban sources are difficult to identify the most common methods to control such sources include reduction of impervious surfaces, street sweeping and other best management practices as well as treatment of stormwater runoff in detention ponds or other structural controls.

Other sources of phosphorus include phosphorus based lawn fertilizers used in residential areas, parks, cemeteries and golf courses and fertilizers used by agriculture. Manure from animals, especially dairies and other confined animal feeding areas is high in phosphorus. In some cases the manure is inappropriately spread or piled on frozen ground during winter months and the phosphorus can leach into nearby surface waters. Over a period of repeated applications of manure to local agricultural fields, the phosphorus in the manure can saturate the ability of the soil to bind phosphorus, resulting in phosphorus export to surface waters. In some cases, cows and other animals including wildlife such as flocks of ducks and geese may have access to surface waters and cause both erosion and direct deposition of feces to streams and lakes.

Perhaps the most difficult source of phosphorus to account for is the phosphorus recycled within the lake from the lake sediments. In most north temperate lakes, phosphorus that accumulated in the bottom waters of the lake during stratification is mixed into surface waters during spring and fall turnover. Phosphorus release from shallow lake sediments may be a significant input for several reasons. These reasons include higher microbial activity in shallow warmer waters that can lead to sediment anoxia and the resultant release of iron and associated phosphorus. Phosphorus release may also occur during temporary mixing events such as wind or powerboat caused turbulence or bottom feeding fish, which can resuspend phosphorus rich sediments. Phosphorus can also be released from nutrient 'pumping' by rooted aquatic macrophytes as they extract phosphorus from the sediments and excrete phosphorus to the water during seasonal growth and senescence (Cooke et al., 1993; Horne and Goldman, 1994). Shallow lakes also have less water to dilute the phosphorus released from sediment sources and thus the impact on lake water concentrations is higher than in deeper lakes.

The most important factor controlling macrophyte growth appears to be light (Cooke et al., 1994). Due to the typically large mass of nutrients stored in lake sediments, reductions in nutrient loadings by themselves are not expected to reduce macrophyte growth in many macrophyte-dominated lakes, at least not in the short-term. In such cases additional in-lake control methods are generally recommended to directly reduce macrophyte biomass. Lake management techniques for both nutrient control and macrophyte control have been reviewed by in "Eutrophication and Aquatic Plant Management in Massachusetts. Draft Generic Environmental Impact Report" (Mattson et al., 1998). The Massachusetts Department of Environmental Protection will support in-lake remediation efforts that cost-effective, long-term and meet all environmental concerns, however, instituting such measures will depend on continued Federal support via EPA and State support via the Massachusetts Department of Environmental Management.

Financial support for implementation is potentially available on a competitive basis through both the non-point source (319) grants and the state revolving fund (SRF) loan program. The 319 grants require a 40 percent non-federal match of the total project cost although the local match can be through in-kind services such as volunteer efforts. Other sources of funding include the 604b Water Quality Management Planning Grant Program, the Community Septic Management Loan Program and the DEM Lake and Pond Grant Program. Information on these programs are available in a pamphlet "Grant and Loan Programs – Opportunities for Watershed Protection, Planning and Implementation" through the Massachusetts Department of Environmental Protection, Bureau of Resource Protection and the Massachusetts Department of Environmental Management (for the Lake and Pond Grant Program).

Since the lake restoration and improvements can take a long period of time to be realized, follow-up monitoring is essential. This can be accomplished through a variety of mechanisms including volunteer efforts. Recommended monitoring may include Secchi disk readings, lake total phosphorus, macrophyte mapping of species distribution and density, visual inspection of any structural BMPs, coordination with Conservation Commission and Board of Health activities and continued education efforts for citizens in the watershed.

Waterbody Descriptions and Problem Assessment

The pollutant stressors reported on the 1998 303d list which are related to this phosphorus TMDL are listed in Table 1 below.

Table 1. Pollutant Stressors listed on 1998 303d list.

WBID	Lake Name, Town	303d list pollutant/stressor
MA35005	Beaver Flowage Pond, Royalston	Noxious aquatic plants, Turbidity
MA35007	Bents Pond, Gardner	Noxious aquatic plants, Turbidity
MA35008	Bourn-Hadley Pond, Templeton	Noxious aquatic plants
MA35010	Brazell Pond, Templeton	Noxious aquatic plants
MA35013	Cowee Pond, Gardner	Noxious aquatic plants
MA35015	Davenport Pond, Petersham/Athol	Noxious aquatic plants
MA35017	Lake Denison, Winchendon	Organic enrichment/Low DO
MA35018	Depot Pond, Templeton	Noxious aquatic plants
MA35023	Ellis Pond, Athol	Noxious aquatic plants
MA35025	Greenwood Pond 1, Westminster	Noxious aquatic plants
MA35026	Greenwood Pond 2, Templeton	Noxious aquatic plants
MA35029	Hilchey Pond, Gardner	Turbidity

MA35041	Lower Naukeag Lake, Ashburnham	Noxious aquatic plants
MA35045	Minott Pond South, Westminster	Noxious aquatic Plants
MA35046	Minott Pond, Westminster	Noxious aquatic plants
MA35047	Lake Monomonac, Winchendon/Rindge, N.H.	Noxious aquatic Plants
MA35056	Parker Pond, Gardner	Noxious aquatic plants
MA35062	Ramsdall Pond, Gardner	Noxious aquatic plants
MA35063	Reservoir No. 1, Athol	Noxious aquatic plants
MA35064	Reservoir No. 2, Philipston/Athol	Noxious aquatic plants
MA35065	Riceville Pond, Athol/Petersham	Noxious aquatic plants
MA35078	South Athol Pond, Athol	Noxious aquatic plants
MA35083	Stoddard Pond, Winchendon	Noxious aquatic plants
MA35092	Wallace Pond, Ashburnham	Noxious aquatic plants
MA35093	Ward Pond, Athol	Noxious aquatic plants
MA35099	Whites Mill Pond	Noxious aquatic plants
MA35101	Whitney Pond	Noxious aquatic plants, Turbidity
MA35104	Wrights Reservoir	Noxious aquatic plants

Landuse information for each watershed is based on MassGIS digital maps derived from aerial photography taken in 1985 or 1999. To account for changes in landuse, population growth rates are reported for towns closest to the lake. Population (census) data and estimated growth rates are from projections provided on the internet (www.umass.edu/miser/) by the Massachusetts Institute for Social and Economic Research (MISER) at the University of Massachusetts, Amherst.

Data collected from each lake varies depending on the type of survey conducted. During the 1970s-early 1990s and beginning again in 1999, baseline surveys were conducted on lakes by the Department. These early baseline surveys typically were conducted during the summer by a team of two spending one day per lake. Baseline data collected including total phosphorus concentrations, dissolved oxygen and temperature profiles, Secchi disk depth and macrophyte density and species distribution maps. Baseline surveys in 1999 and later were conducted by a team of two visiting the lake for ½ day three times during the summer. Baseline data for Stoddard Pond and Whitney Pond, which were sampled in 2000 are available in Appendix I. In addition, less detailed synoptic surveys were conducted by the Department between 1993-1998 and were usually limited to visual surveys of macrophyte distributions and species types. Typically, synoptic surveys were conducted from observations at several points around the shore. Data from other sources is used as indicated.

The locations of the twenty-eight lakes are shown in Figure 1 below. The local environs of the ponds are shown along with descriptions of the ponds, below. Macrophyte maps were available for Bents Pond, Davenport Pond, Lake Denison, Ellis Pond, Lower Naukeag Lake, Lake Monomonac, Parker Pond, Stoddard Pond, Ward Pond, Whitney Pond and Wrights Reservoir as shown below. The key to macrophyte species codes is available in the Appendix.

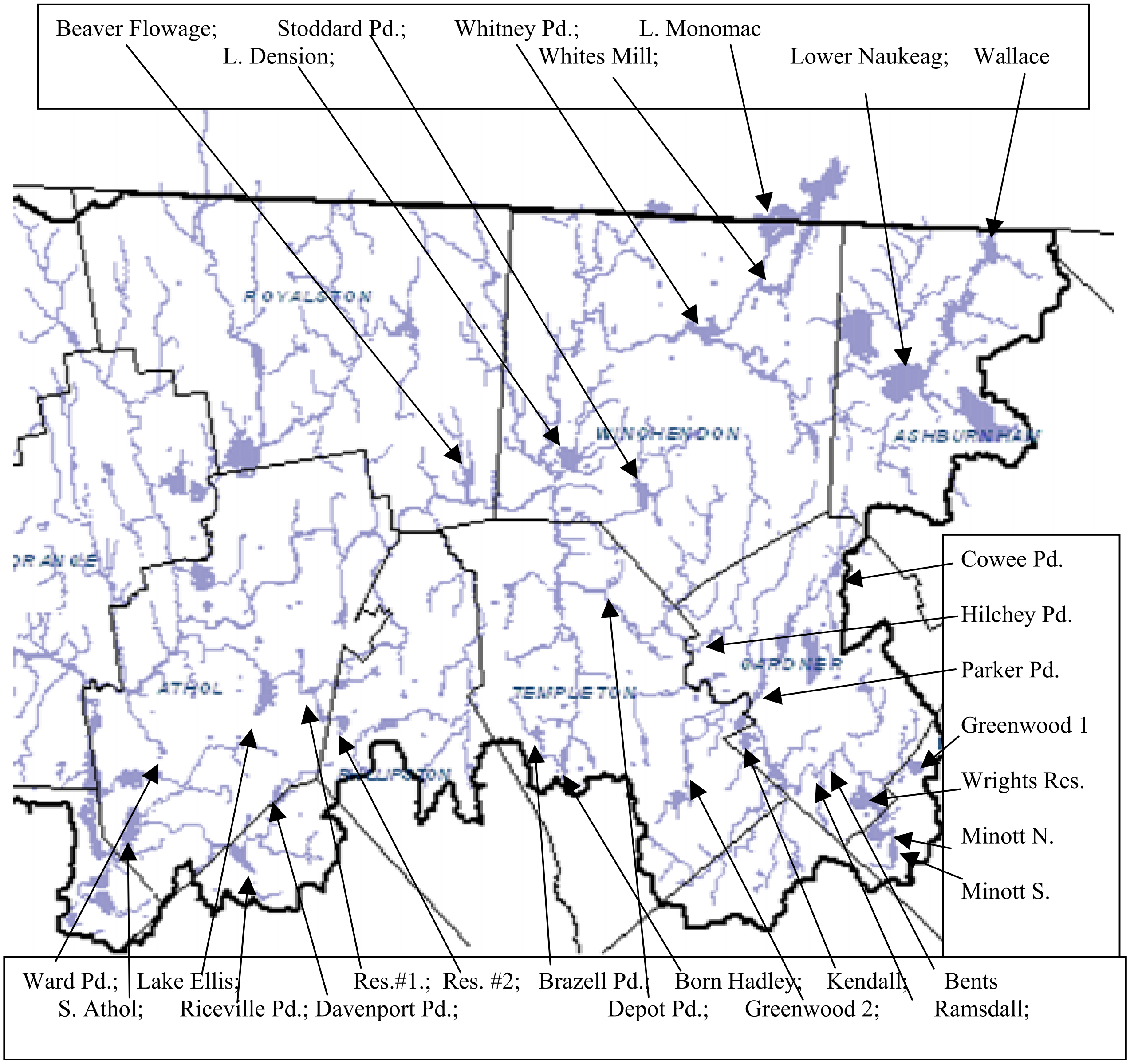


Figure 1. Locations of ponds within the Millers Basin.

Beaver Pond

(AKA Beaver Flowage Pond) in Royalston is a medium pond of approximately 38 acres which is part of the Army Corps of Engineers Birch Hill Dam flood control project. The dominant landuse in the watershed are 78 percent forest, followed by 12 percent agricultural and 5 percent rural landuse. The remainder of the watershed consists of water and wetlands. A segment of MassHighways Route 116 is within the watershed. Population in Winchendon ranged between 955 and 1,147 from 1980 to the 1990 census. Miser predictions on growth are 970 for the year 2000 and 941 for the year 2010 with an estimated 20 year growth rate of about minus(-)18 percent. Beaver Pond was assessed by DEP in the summer of 1997 and the assessment comments reported: " August 18, 1995 synoptic survey indicated almost 100% covered with very dense floating leaf vegetation. Small area of open water near dam showed strong "tea" stain and turbidity (Secchi disk <1.0 meters)." A site visit in September of 2002 by DEP staff estimated Secchi visibility at greater than the 1.2m swimming criteria. The tea color is probably a natural condition of the organic carbon in the water (e.g. tannins, humics).

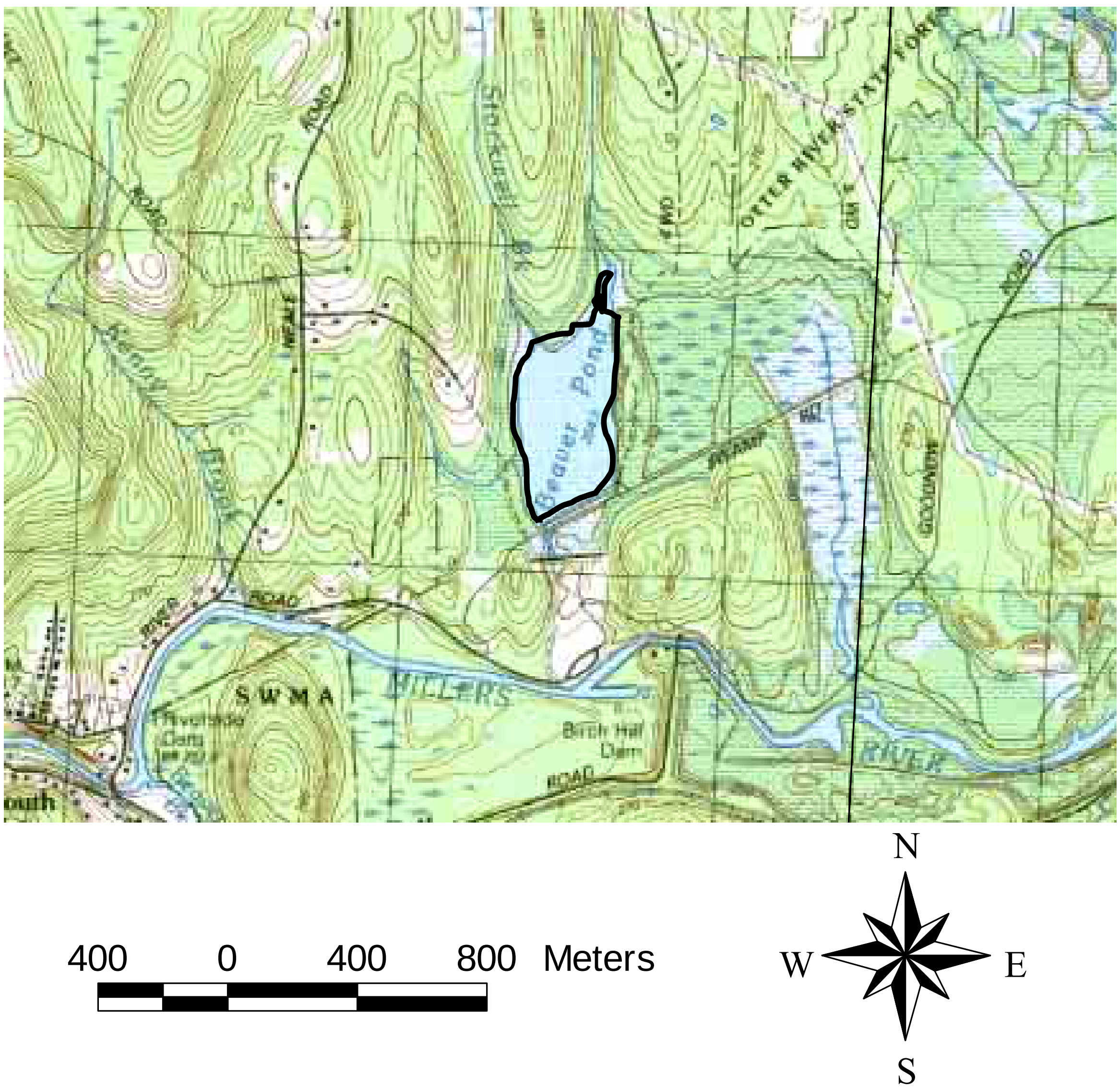


Figure 2. Beaver Pond Environs.

Bents Pond

in Gardner is a small urban pond of approximately 6 acres with a dam holding approximately 5 vertical feet of water. The dominant landuse in the watershed are 61 percent forest, followed by 15 percent urban and 13 percent rural (including open space) landuse. The remainder of the watershed consists of mostly water and wetlands with the exception of about 3 percent in agricultural landuse. MassHighways Route 2 crosses the watershed. Also segment of MassHighways Route 140 and the interchange between Route 2 and Route 140 lie within the watershed boundary. Population in Gardner ranged between 17,900 and 20,125 from 1980 to the 1990 census. Miser predictions on growth are 21,261 for the year 2000 and 23,272 for the year 2010 with an estimated 20 year growth rate of about 16 percent. The assessment comments from summer 1988 reported: " Very dense growths of aquatic macrophytes over about half the pond, fecal coliform counts >200, and transparency below the safety criteria (4 ft. Secchi disk.)". Bents Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: " Very dense growths of aquatic macrophytes over one half of the pond; no indication of restoration to reduce them. Fecal coliform data and transparency data too old to be reliable". An August 24, 1995 synoptic survey indicated about a third of the pond filled in with emergent and floating vegetation. Open water very turbid (estimated Secchi disk <1.2m). Scum on surface and evidence of a blue-green bloom on the shoreline.

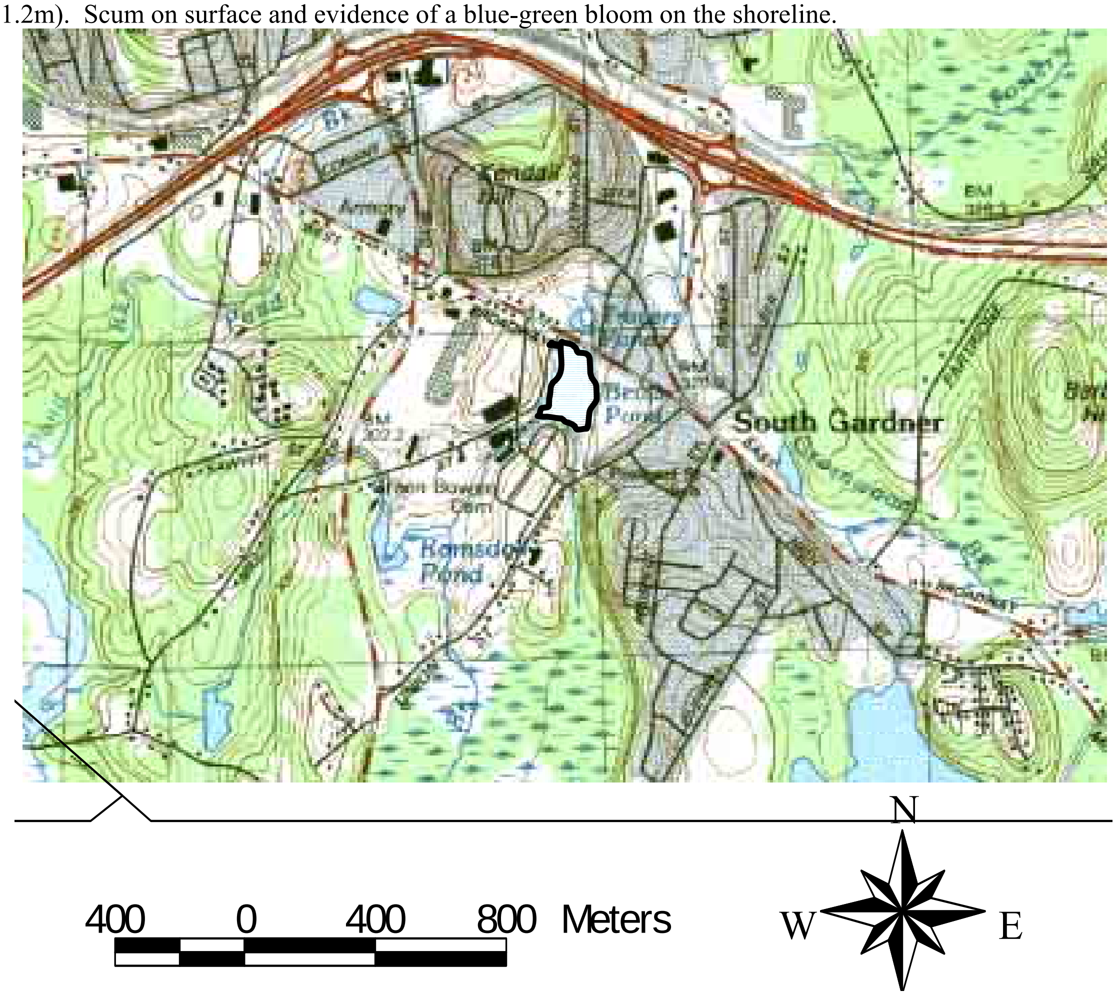


Figure 3. Bents Pond Environs.

A site visit by DEP staff in September and October of 2002 and noted that the Secchi disk was 1.0 m (below the 1.2m swimming guideline). The low visibility was thought to be due to high levels of natural color (tea color) that was recorded at 135 PCU, while turbidity was relatively low at 3.8 NTU. Apparently this pond suffers from occasional surface blooms but the high color limits submersed plants and algae.

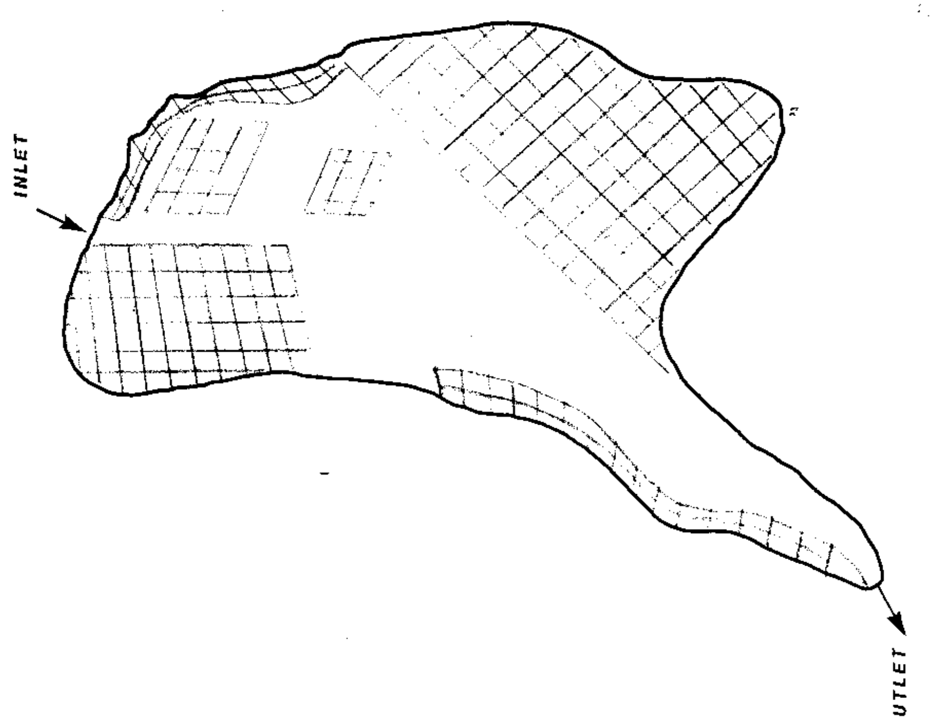


Figure 4. Bents Pond Macrophyte density distribution (1988).

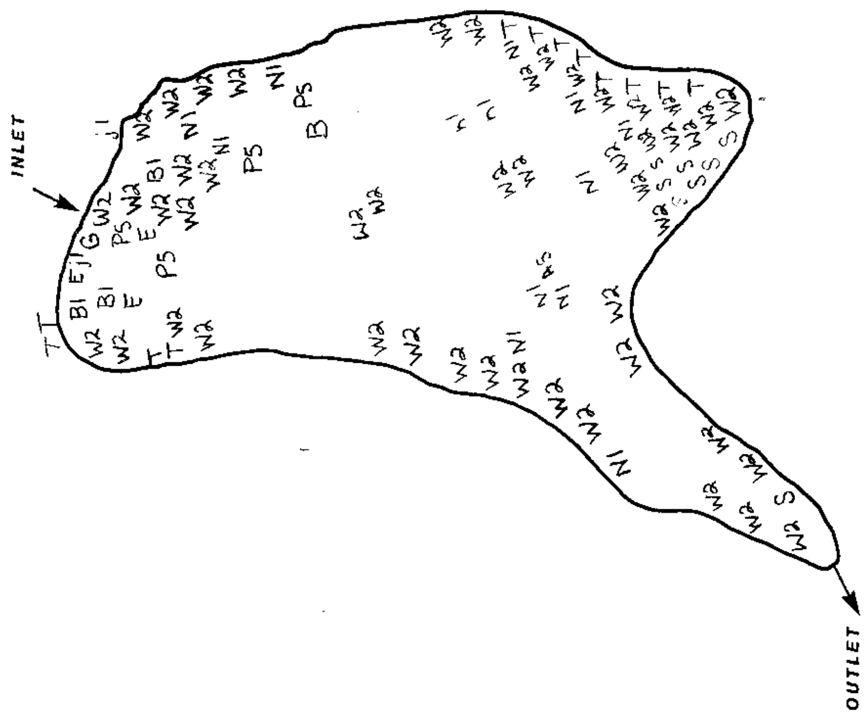


Figure 5. Bents Pond Macrophyte species distribution (1988).

Bourn-Hadley Pond

in Templeton is a small pond of approximately 26 acres with a ten foot dam. The dominant landuse in the watershed are 64 percent forest, followed by 12 percent rural and 10 percent agricultural landuse. Water and wetlands account for about 8 percent of the watershed. The remainder is urban land which consists of mostly commercial-industrial landuse and only less than half a percent covers high density residential housing. Population in Templeton ranged between 6,070 and 6,438 from 1980 to the 1990 census. Miser predictions on growth are 6,835 for the year 2000 and 7,156 for the year 2010 with an estimated 20 year growth rate of about 11 percent. MassHighways Route 2 crosses the watershed. Also segments of MassHighways Route 2A, Route 202 and the interchange between Route 2A and Route 202 are within the watershed boundary. Bourn-Hadley Pond was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 22, 1995 synoptic survey indicated that very dense floating and submergent vegetation covered about 25% of the northern basin. A possible non-native species of *Myriophyllum* (possibly *M. heterophyllum*) was observed." A site visit in September of 2002 by DEP staff noted that a gravel pit operation was clearing trees within 40 feet of the shoreline and indicated erosion may be contributing sediment to the pond.

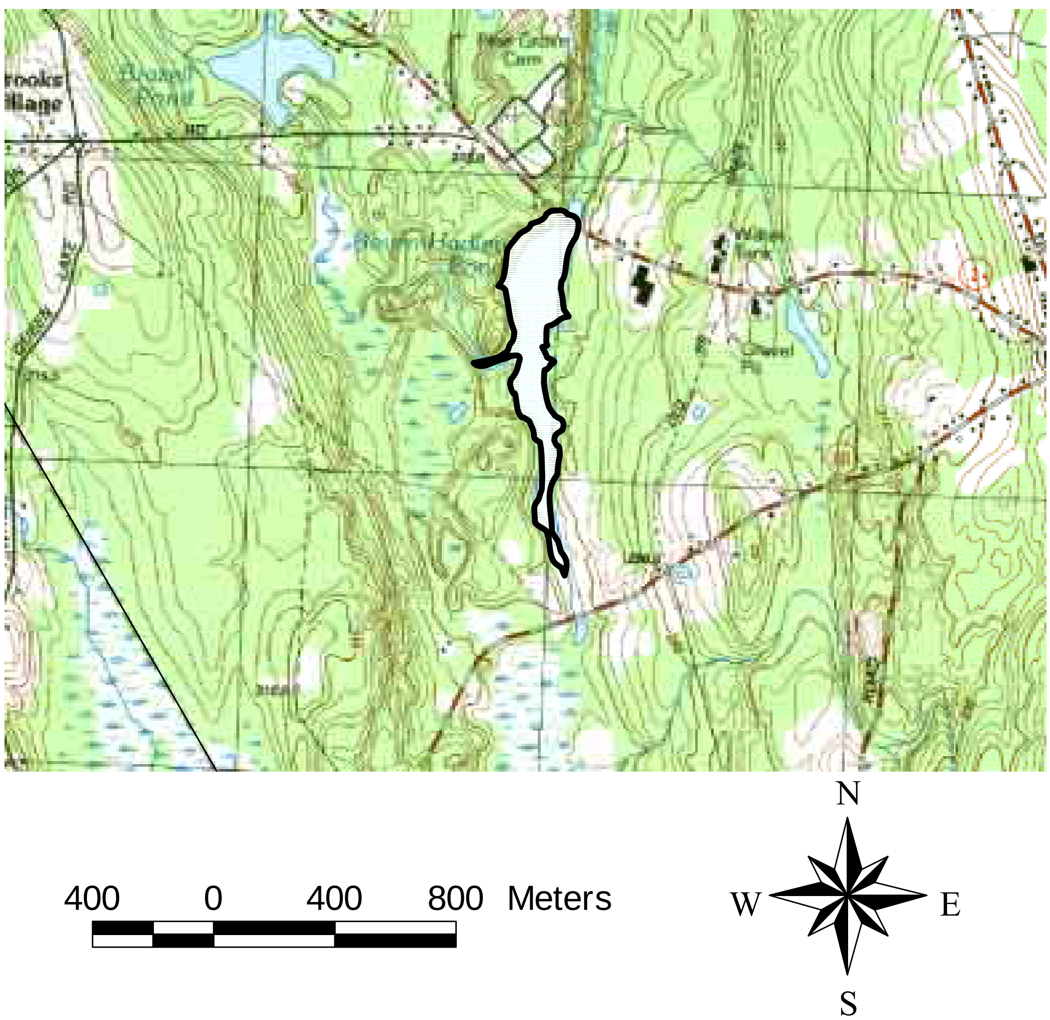


Figure 6. Bourn-Hadley Pond Environs.

Brazell Pond

in Templeton is a small pond of approximately 15 acres with a seven foot dam. The dominant landuse in the watershed are 60 percent forest, followed by 15 percent rural and 13 percent agricultural landuse. Approximately 8 percent of the watershed consists of urban landuse, which is mostly commercial-industrial land with small area of high density residential housing. The remaining watershed consists of water and wetlands. Population in Templeton has been described above. MassHighways Route 2 crosses the watershed. Also segments of MassHighways Route 2A, Route 202 and the interchange between Route 2A and Route 202 are within the watershed boundary. Brazell Pond was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 22, 1995 synoptic survey indicated that very dense cover of floating and submergent vegetation was present in coves at the north end and along the east shore (about a third of the pond surface)." A site visit in September of 2002 by DEP staff noted one house with a green lawn near the shore.

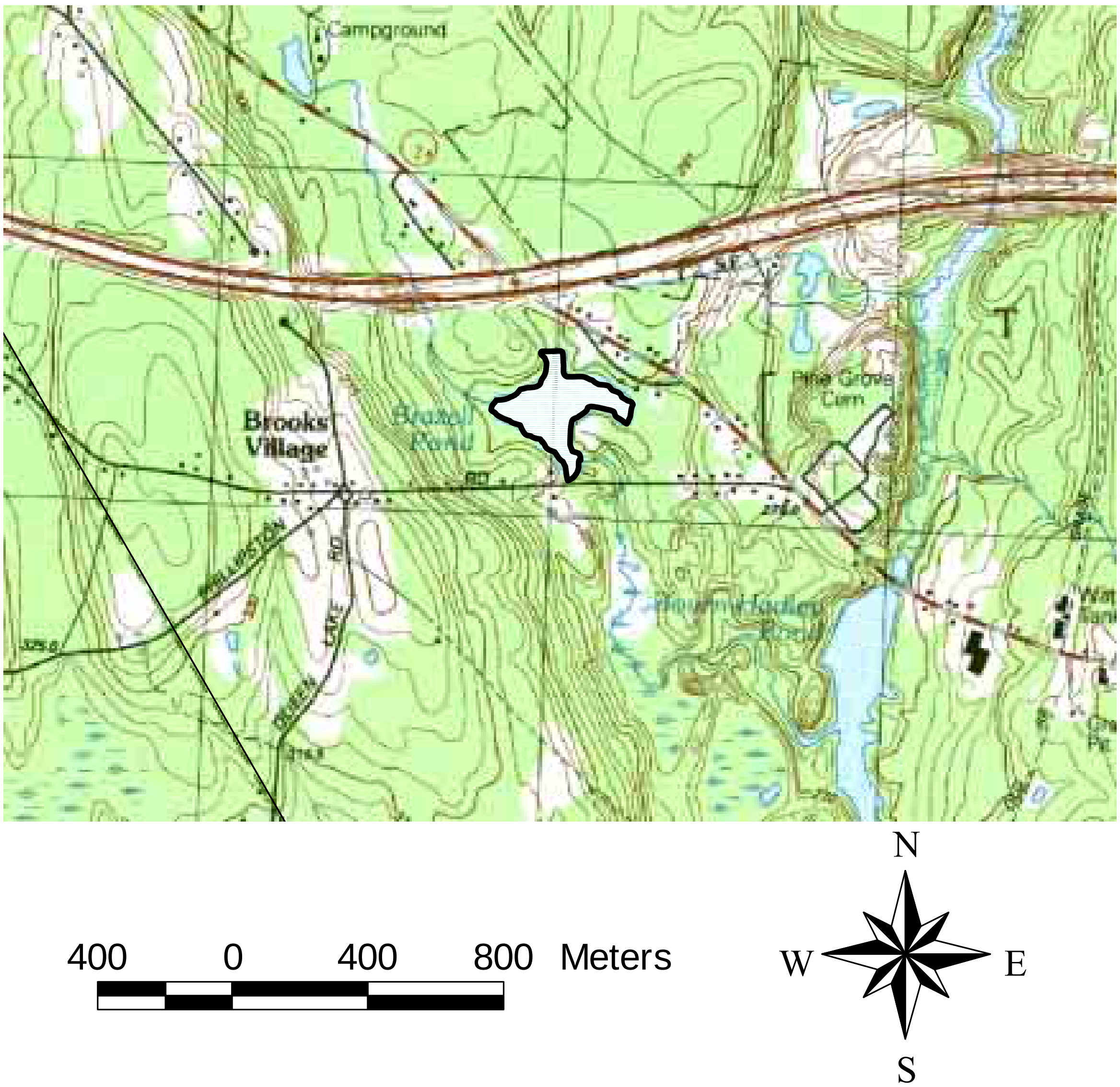


Figure 7. Brazell Pond Environs.

Cowee (Mamjohn) Pond

in Gardner is a small pond of approximately 18 acres with a 12 foot dam. The watershed is 95 percent forested and water and wetlands account for about 3 percent. The rest of the watershed consists of mostly agricultural land. Only about half a percent of the entire watershed covers rural landuse that consists of low density residential housing. Population in Gardner has been described above. Section of the Ashburnham State Forest falls within the watershed. Cowee Pond was assessed by DEP in the summer of 1995 and the assessment comments reported: "August 24, 1995 synoptic survey indicated very dense patches of floating vegetation along west and east sides. North end of pond had very dense vegetation and exposed mud; about a third of the upper pond affected." A site visit in September of 2002 by DEP staff noted some "tea" color in the water but visibility probably greater than 10 feet.

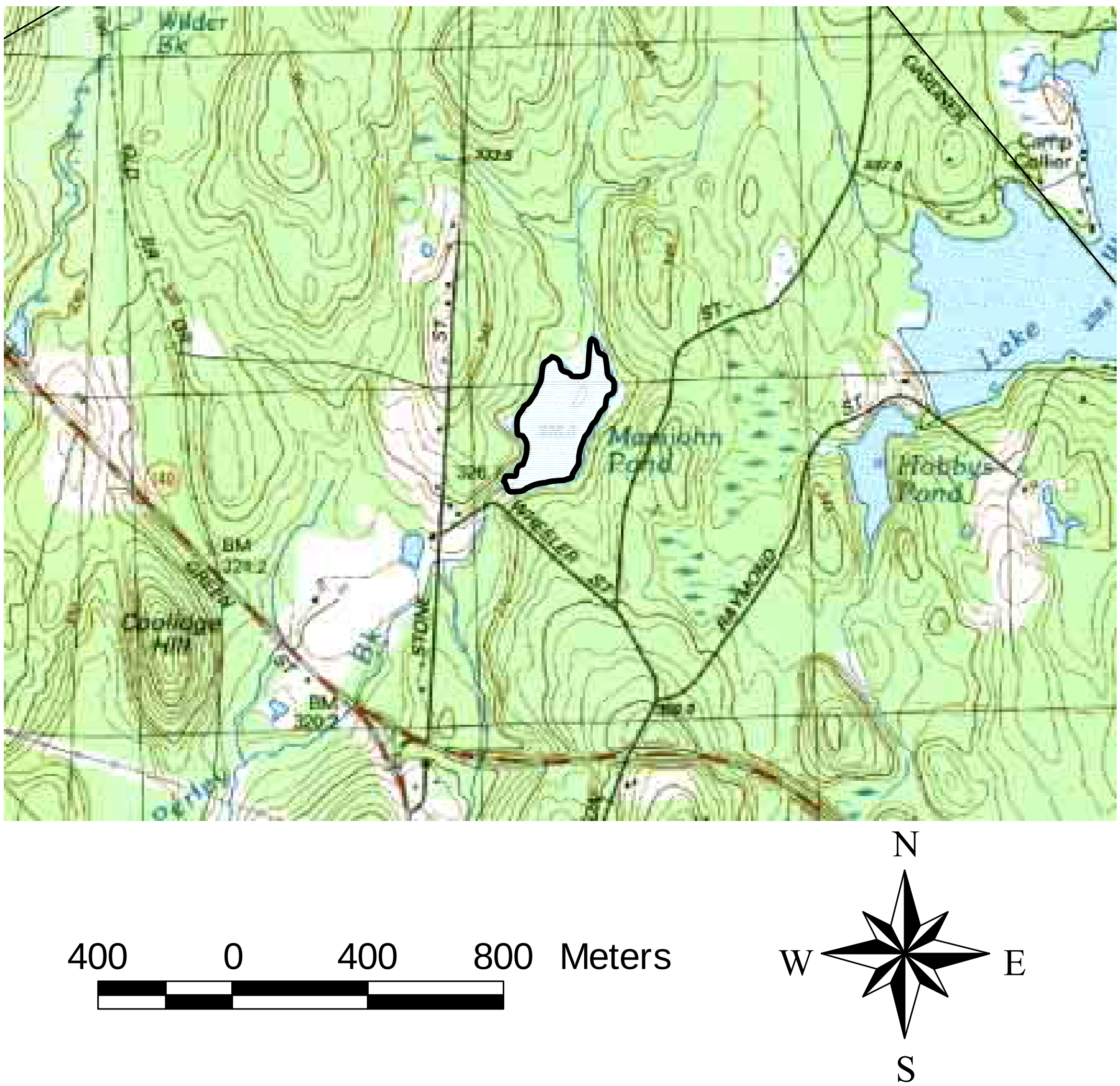


Figure 8. Cowee (Mamjohn) Pond Environs.

Davenport Pond

in Petersham/Athol is a small pond of approximately 18 acres. The watershed is 92 percent forested and rural and agricultural landuse account for about 5 percent. The rest of the watershed consists of water and wetlands. Population in Petersham ranged between 1,024 and 1,131 from 1980 to the 1990 census. Miser predictions on growth are 1,262 for the year 2000 and 1,401 for the year 2010 with an estimated 20 year growth rate of about 24 percent. Population in Athol ranged between 10,634 and 11,451 from 1980 to the 1990 census. Miser predictions on growth are 11,293 for the year 2000 and 11,641 for the year 2010 with an estimated 20 year growth rate of about 2 percent. MassHighways Route 32 crosses watershed. Davenport Pond was assessed by DEP in the summer of 1982 and the assessment comments reported: "Very dense growths of aquatic macrophytes (primarily *Nymphaea* sp.) cover the entire pond and surface D.O. is low". Also an August 15, 1995 synoptic survey indicated the pond to be completely covered with floating leaf and emergent plants. A site visit in September of 2002 by DEP staff noted 100% cover but water appears clear.

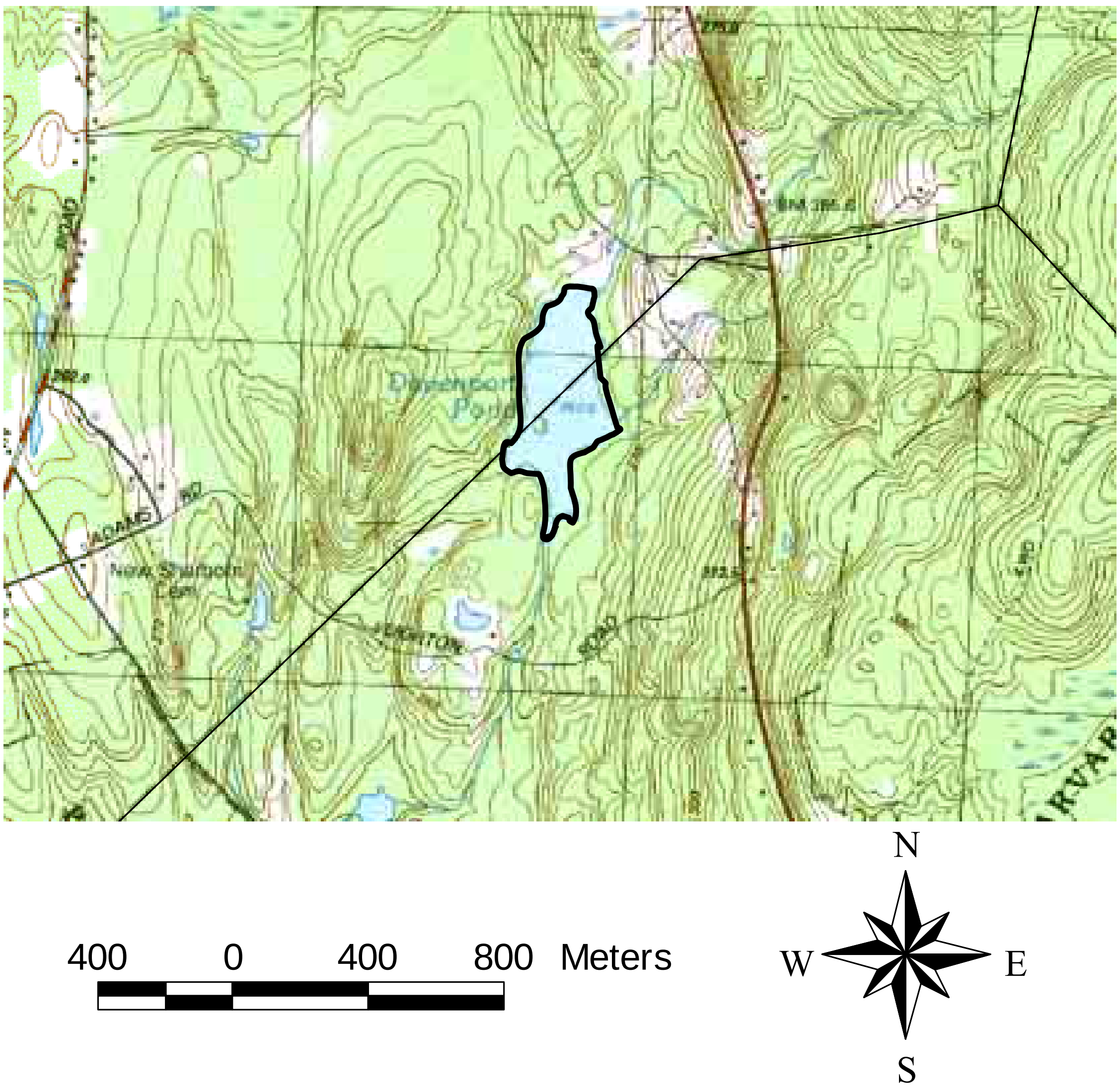


Figure 9. Davenport Pond Environs.

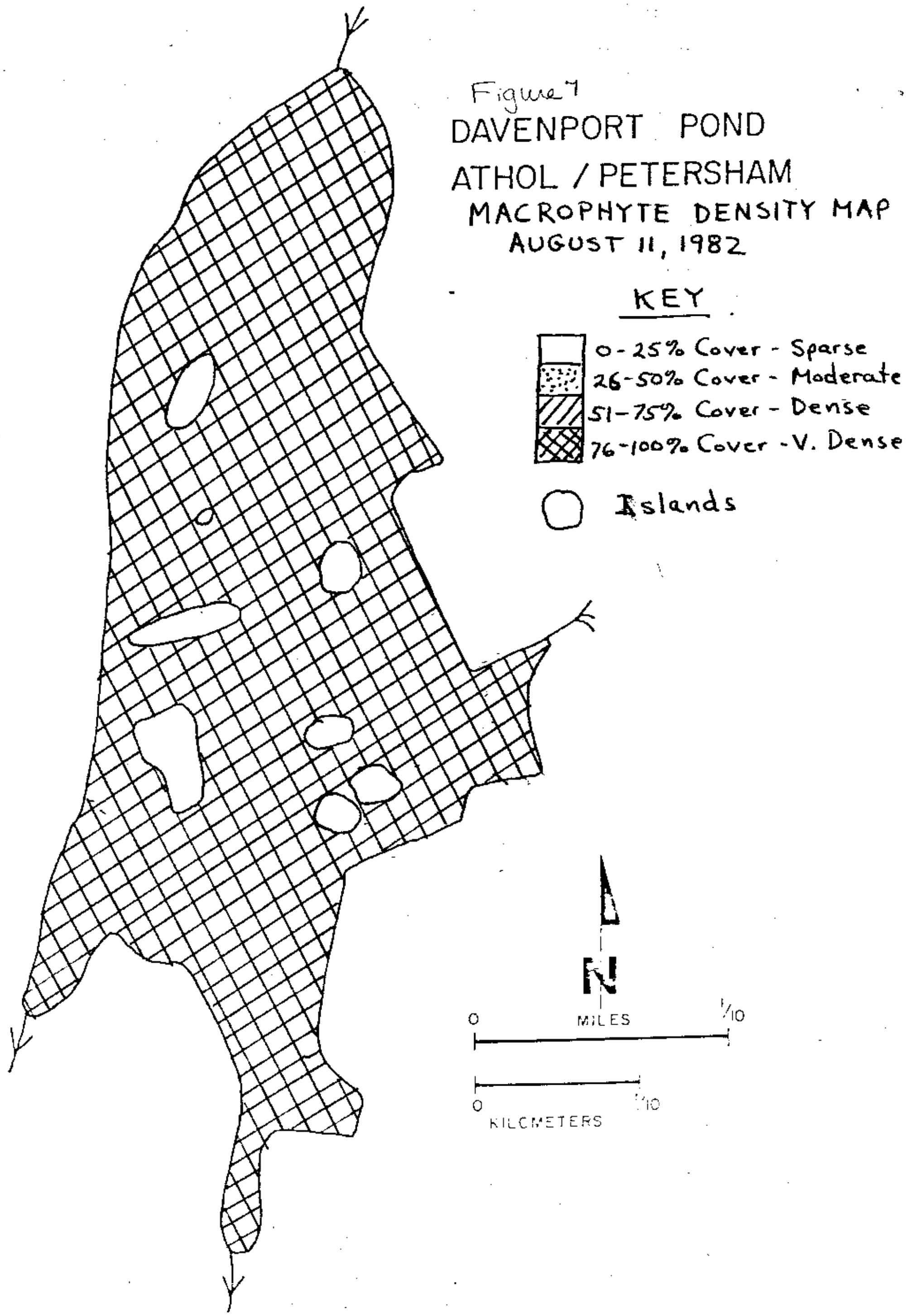


Figure 10. Davenport Pond density distribution (1982).

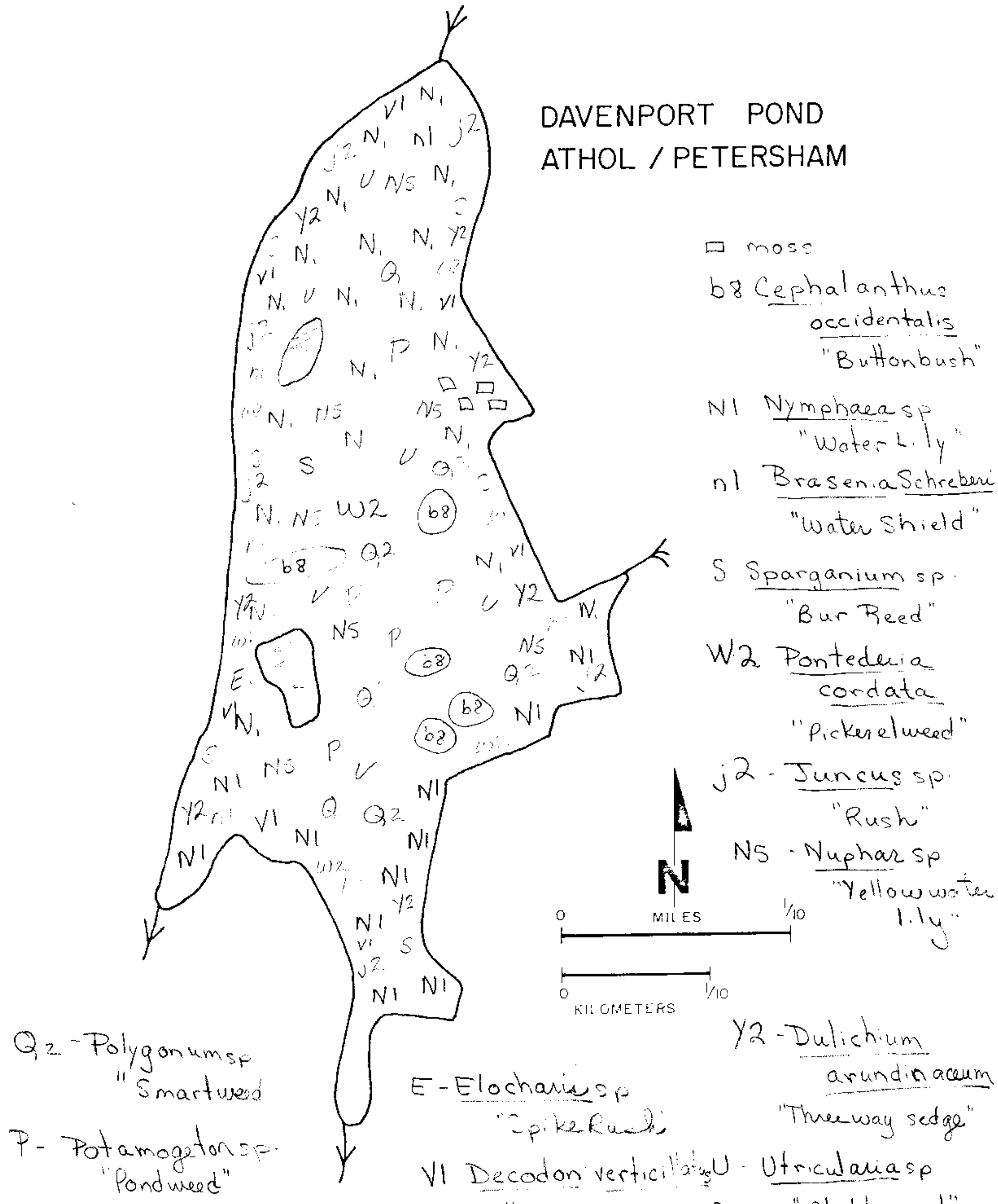


Figure 11. Davenport Pond species distribution (1982).

Lake Denison

in Winchendon is a large pond of approximately 84 acres owned by the Army Corps of Engineers but managed by DEM as a park and campground. The watershed is 74 percent forested and most of remaining watershed consists of rural (including substantial open space) and agricultural landuse with the following exceptions. Approximately 4 percent of the watershed is water and wetlands. Commercial-industrial landuse covers about 3 percent of the watershed that includes segment of MassHighways Route 202. High density residential housing covers only half a percent of the entire watershed. Population in Winchendon ranged between 7,019 and 8,805 from 1980 to the 1990 census. Miser predictions on growth are 9,637 for the year 2000 and 11,054 for the year 2010 with an estimated 20 year growth rate of about 26 percent. Cortell (1987) reported total phosphorus concentrations of 0.01 mg/l in July of 1986. Moderate color was noted in the report with a visibility of about 5 feet. No short term management was proposed in the Cortell report other than continued monitoring. A DEP survey in July of 1992 reported a Secchi disk transparency of 3.6m and a total phosphorus concentration of 0.032mg/l. The macrophyte survey shows sparse vegetation along the majority of the shore but several minor coves had very dense vegetation. Assessment comments reported: "Historically dense growths of aquatic macrophytes (primarily *Utricularia purpurea*) covering the entire littoral zone and algal "blooms" reducing transparency were not evident. Low dissolved oxygen found below 4.0 meters for part of the season. Metals and PCBs in fish tissue were analyzed on 31 Jan. 1990, but no advisory resulted." A site visit in September of 2002 by DEP staff noted clear water and very little plant cover.

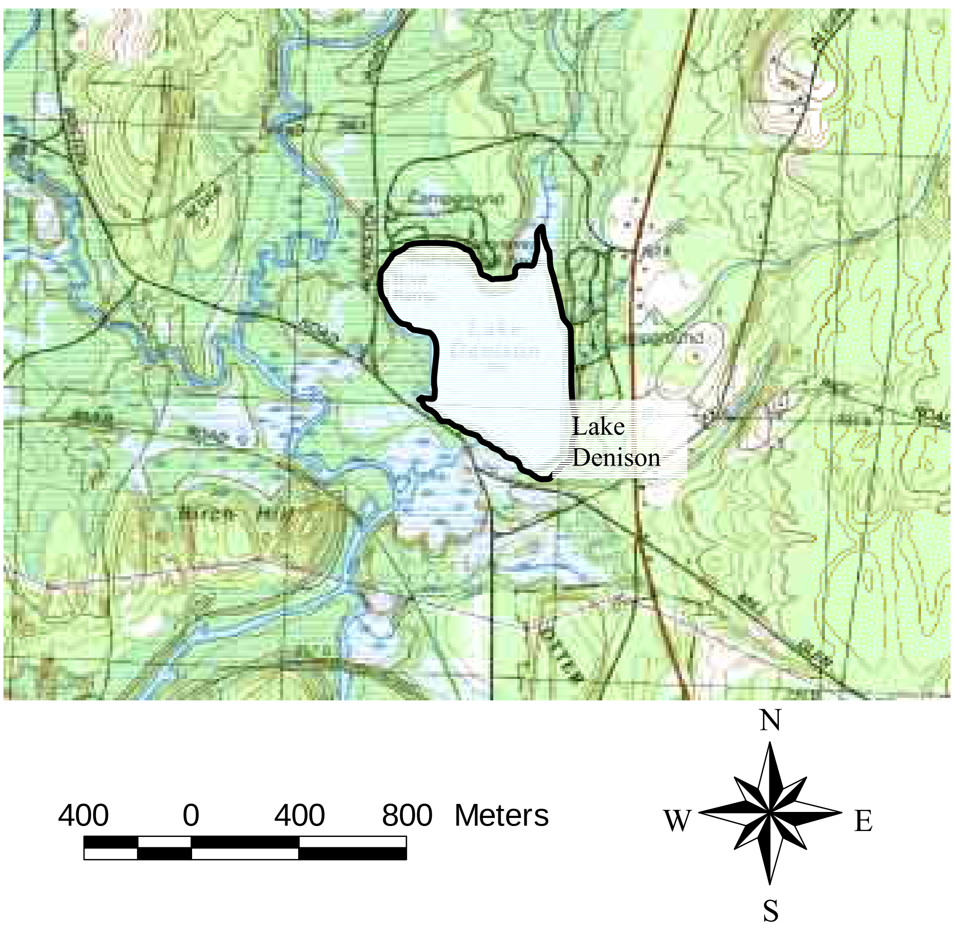


Figure 12. Lake Denison Environs.

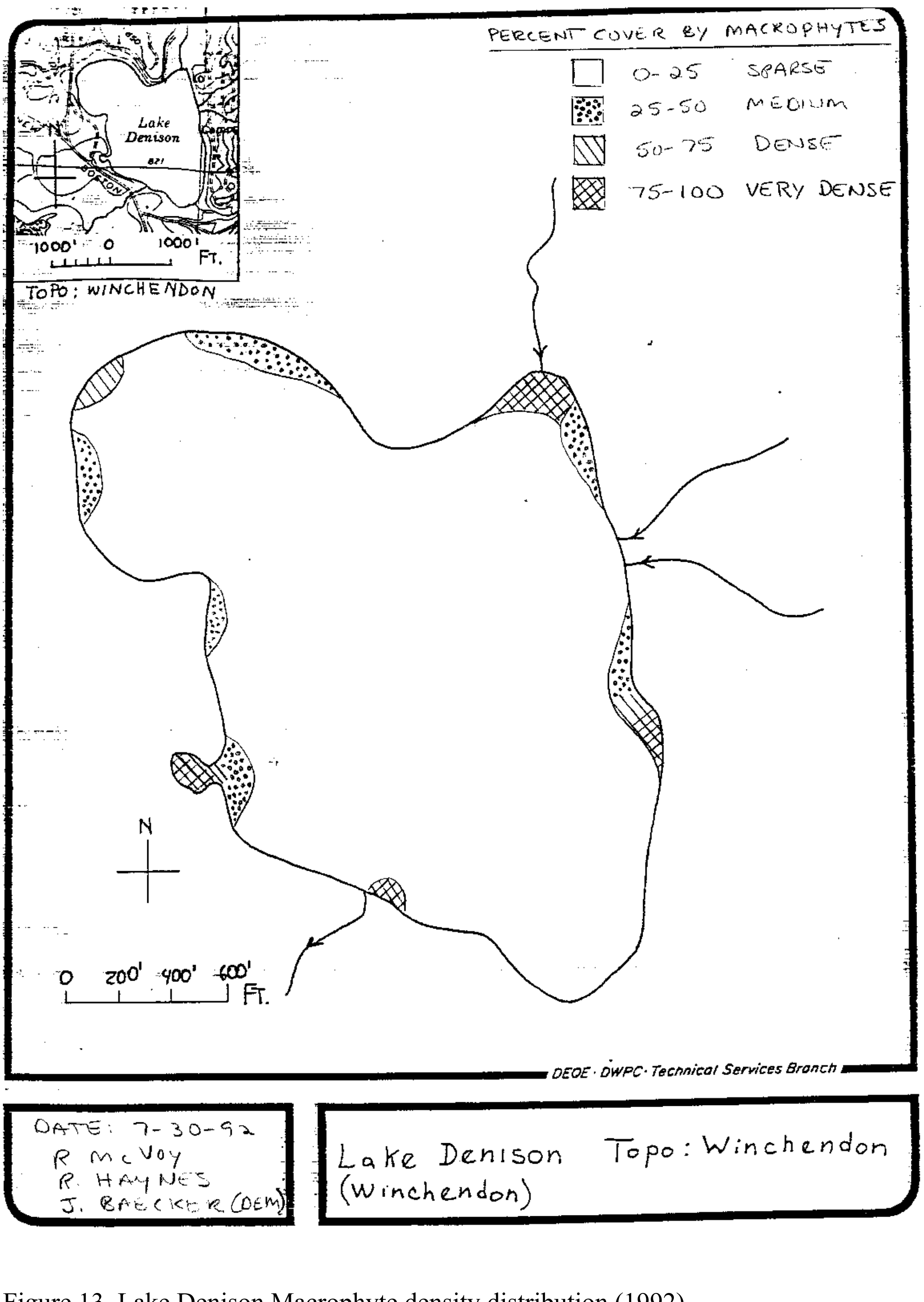


Figure 13. Lake Denison Macrophyte density distribution (1992).

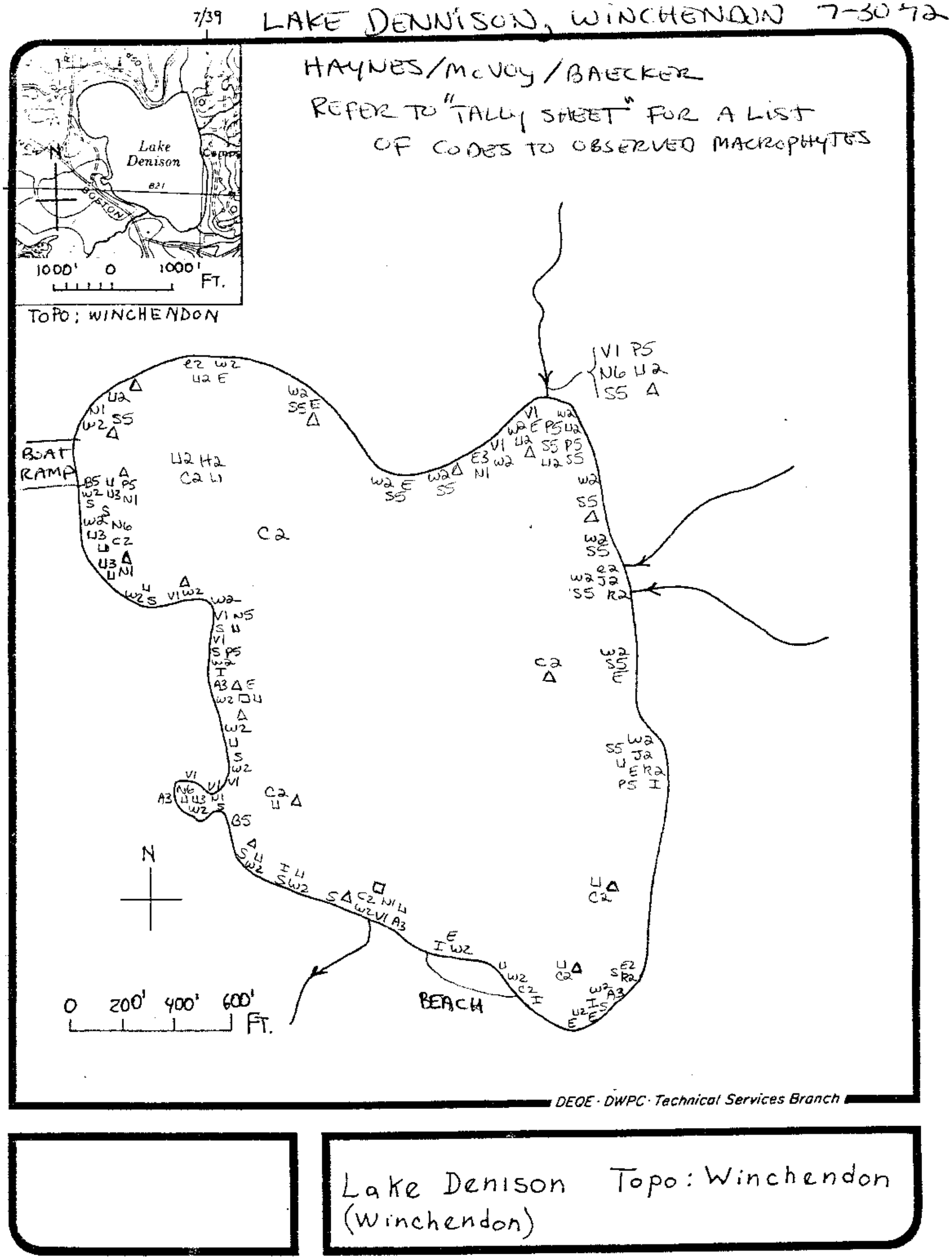


Figure 14. Lake Denison Macrophyte species distribution (1992).

Depot Pond

in Templeton is a small pond of approximately 15 acres with a seven foot dam. The dominant landuse in the watershed are 63 percent forest, followed by 23 percent rural and agricultural landuse. Approximately 9 percent of the watershed consists of water and wetlands, high density residential landuse accounting for the rest. Population in Templeton has been described above. Depot Pond was assessed by DEP in the summer of 1997 and the assessment comments reported: " August 22, 1997 synoptic survey indicated about a third of the pond covered by very dense floating, emergent and submergent plants.” A site visit in September of 2002 by DEP staff noted clear water and limited plant cover.

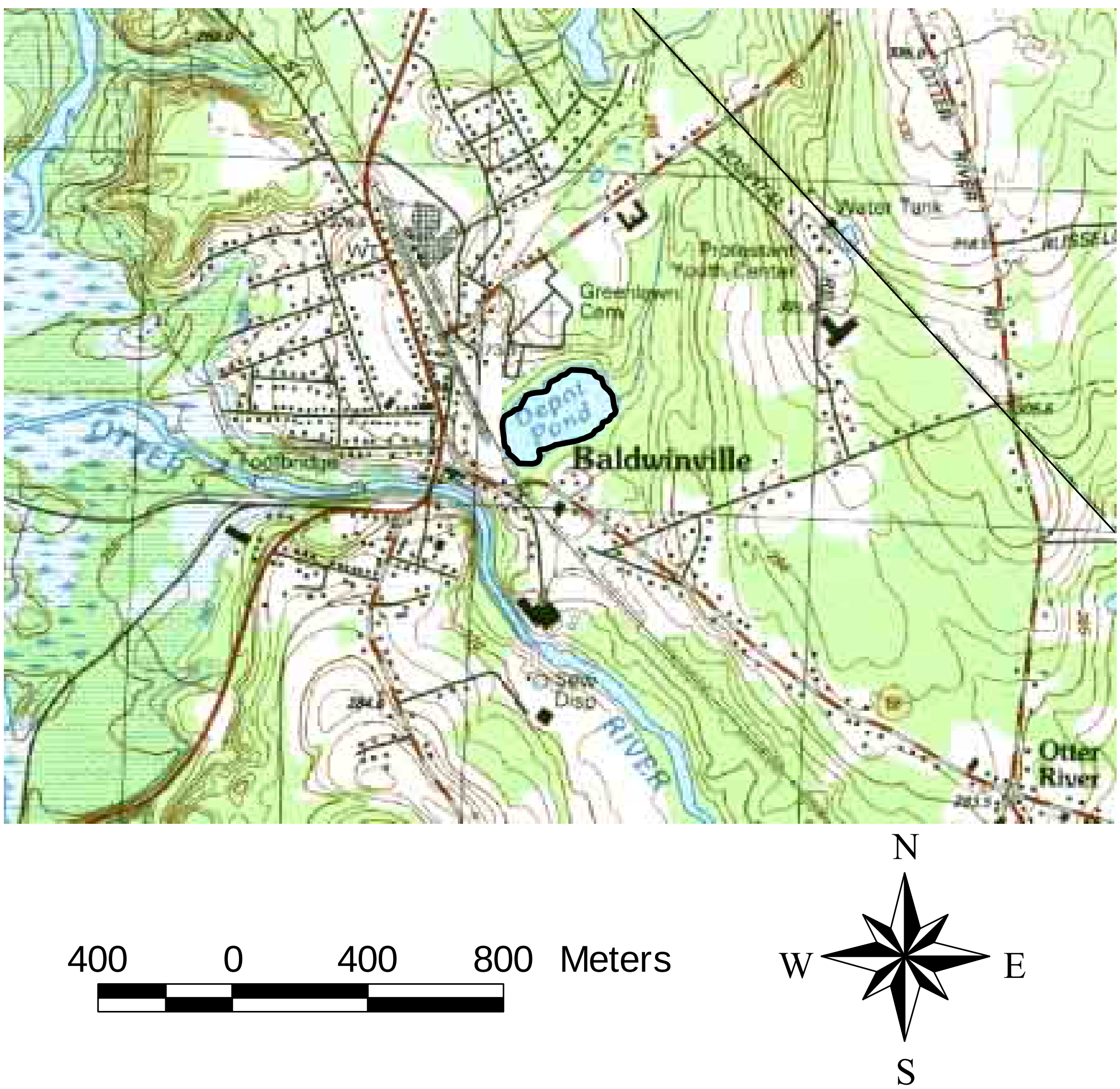


Figure 15. Depot Pond Environs.

Ellis Pond (Lake Ellis)

in Athol is a large pond of approximately 88 acres with an 11 foot dam. The dominant landuse in the watershed are 79 percent forest, followed by 11 percent rural and agricultural landuse and 8 percent water and wetlands. The remaining watershed consists of high density residential houses as well as commercial-industrial landuse that includes sections of MassHighways Route 2A and Route 32 and the interchange between Route 2 and Route 32. Population in Athol has been described above. An August 1979 baseline survey showed dense growths of macrophytes in Ellis Pond and assessment comments reported: "Very dense growths of aquatic macrophytes (primarily *Utricularia* sp.) cover the south and northeast portions of the lake. Given the shallow nature of the lake there is good potential for rapid proliferation of macrophytes." In 1987 a Diagnostic/Feasibility Study was conducted on Lake Ellis by Baystate Environmental Consultants (BEC, 1987). The average total phosphorus concentration at that time was about 15 ug/l with a mean Secchi disk transparency of 2.8 meters. The total phosphorus budget was estimated at 132 kg/year and is rough agreement to the estimate given here (see Table 2i in Appendix V). Ellis Pond was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 18, 1995 synoptic survey indicated presence of non-native macrophytes (*Cabomba caroliniana* and *Eichornia crassipes*) near the boat access. Very dense submergent vegetation near outlet and coves covered with floating vegetation. Assumed 1987 Diagnostic/Feasibility study (BEC) cover estimates still adequate (about 25%). Presence of *Myriophyllum heterophyllum* and *Myriophyllum spicatum* also reported then." It is assumed that the water hyacinth *Eichornia crassipes* was an anomaly and would not overwinter in the lake, however it appears the fanwort spread to nuisance densities in the lake.

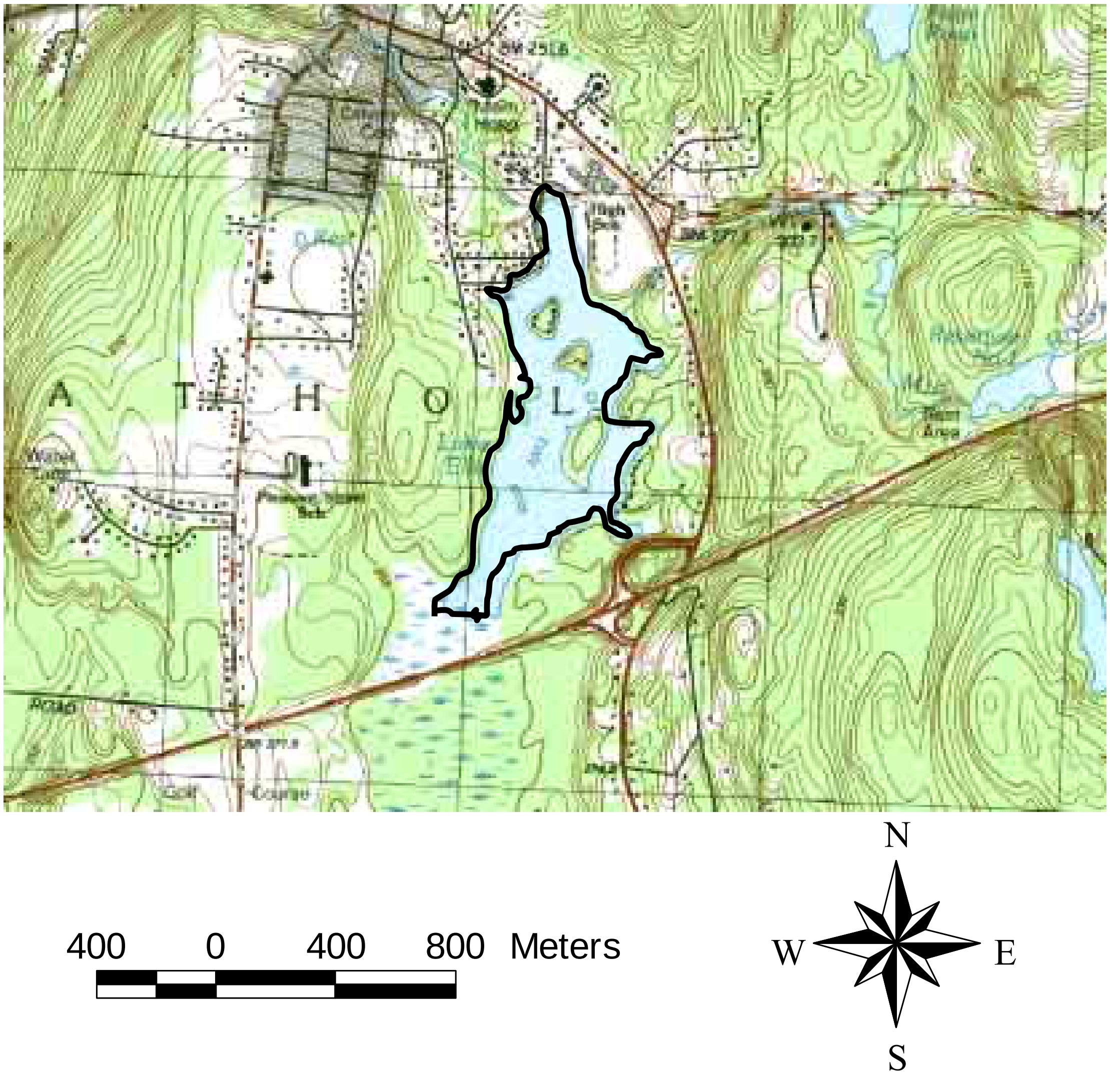


Figure 16. Lake Ellis Environs.

In 2000 a DEM grant for $10,000 was awarded to use herbicides (fluridone, complexed copper and glyphosate) to control the fanwort (*Cabomba caroliniana)* and milfoil and to produce an educational brochure. The herbicide treatment was repeated in 2001. Apparently this treatment was reported to be successful (C. Taylor, Lake Ellis Assoc., pers. comm.). A site visit in September of 2002 by DEP staff noted clear water apparently meeting the guideline for swimming.

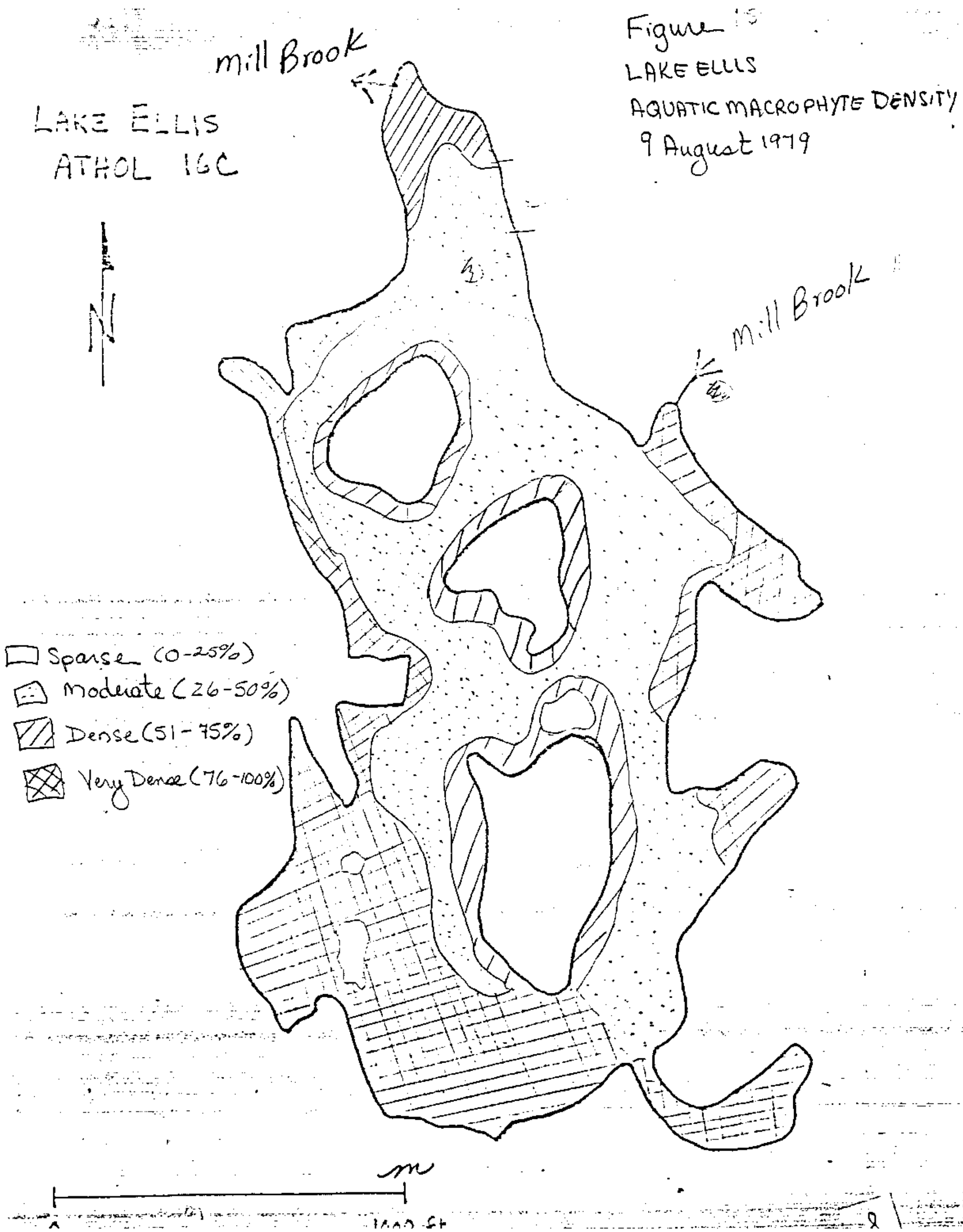


Figure 17. Lake Ellis Macrophyte density distribution (1979).

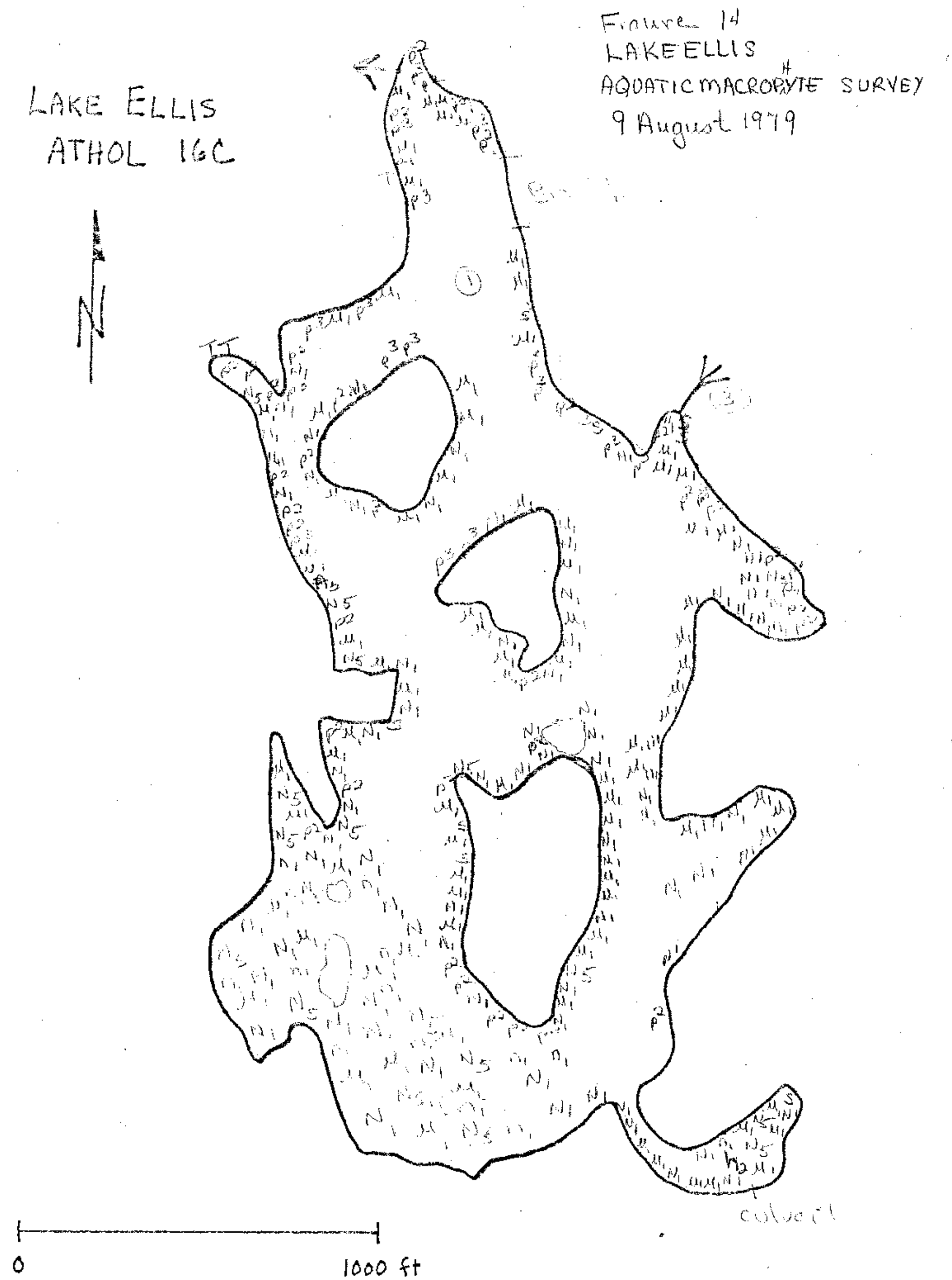


Figure 18. Lake Ellis Macrophyte species distribution (1979).

Greenwood Pond (#1)

in Westminster is a small pond of approximately 27 acres with a seven foot dam located between Route 2 and Route 2A. The dominant landuse in the watershed are 52 percent forest, followed by 27 percent rural landuse and 20 percent water and wetlands. The remaining watershed consists of high density residential landuse. Population in Westminster ranged between 5,139 and 6,218 from 1980 to the 1990 census. Miser predictions on growth are 6,629 for the year 2000 and 7,539 for the year 2010 with an estimated 20 year growth rate of about 22 percent. Greenwood Pond was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 24, 1995 synoptic survey indicated very dense growth of floating leaf, emergent and submergent plants at north end, along western shore and in patches in the center of the lake, less than 50% of the pond affected (estimated at 10 acre)." A site visit in September of 2002 by DEP staff noted conditions unchanged.

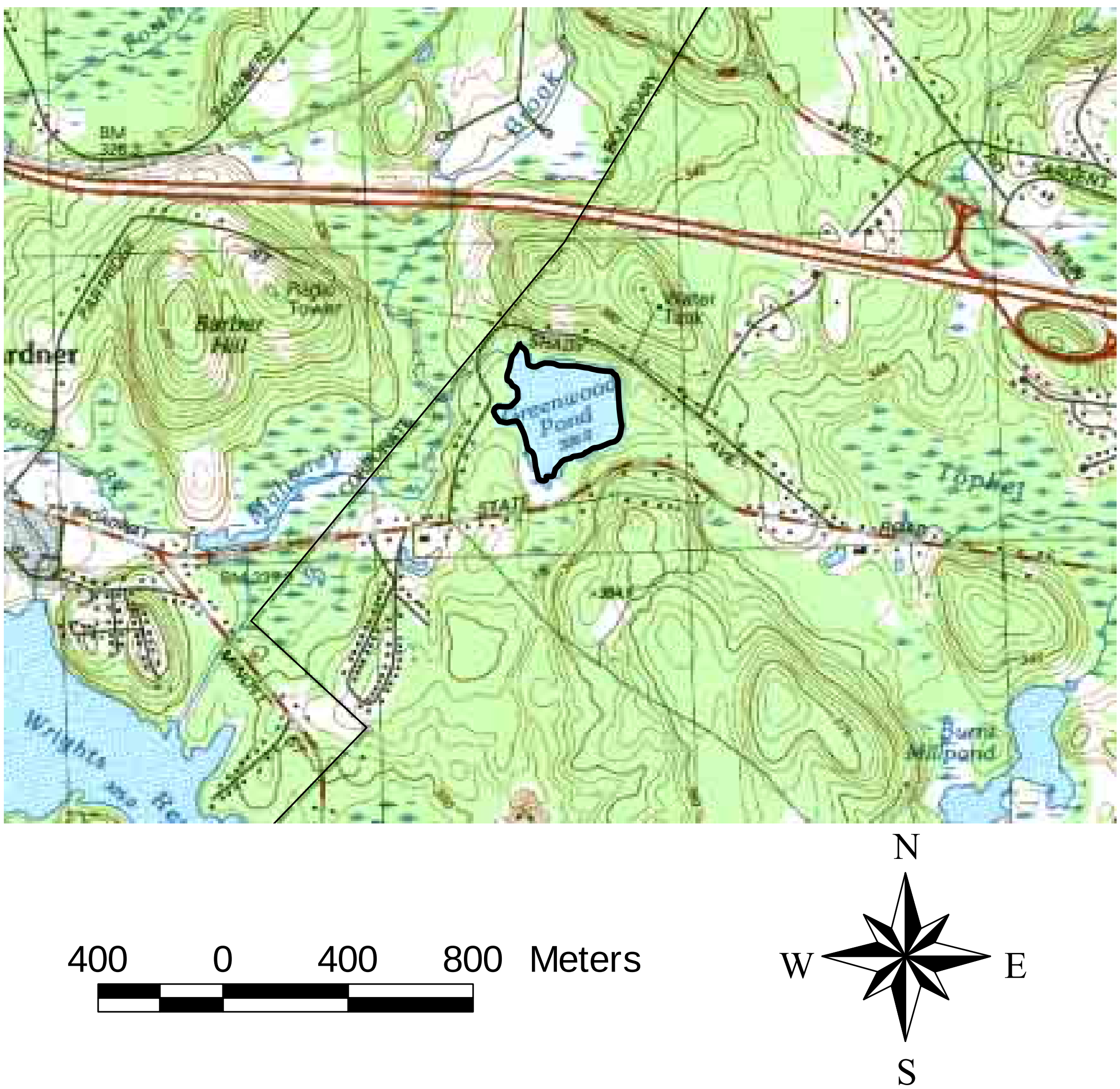


Figure 19. Greenwood Pond 1(Westminster) Environs.

Greenwood Pond (#2)

in Templeton was a small pond of approximately 6 acres which has been split into three basins by the construction of Route 2. The dominant landuse in the watershed are 71 percent forest, followed by 16 percent rural landuse and 5 percent water and wetlands. Approximately 3 percent of the watershed consists of agricultural landuse. Most of the remaining watershed covers high density residential housing except for 1 percent which is in commercial-industrial landuse. Population in Templeton has been described above. Section of Templeton State Forest is within the watershed. Greenwood Pond was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 22, 1995 synoptic survey indicated pond covered entirely with very dense emergent vegetation; little open water." A site visit in September of 2002 by DEP staff noted conditions unchanged although beavers and ducks evident at the site.

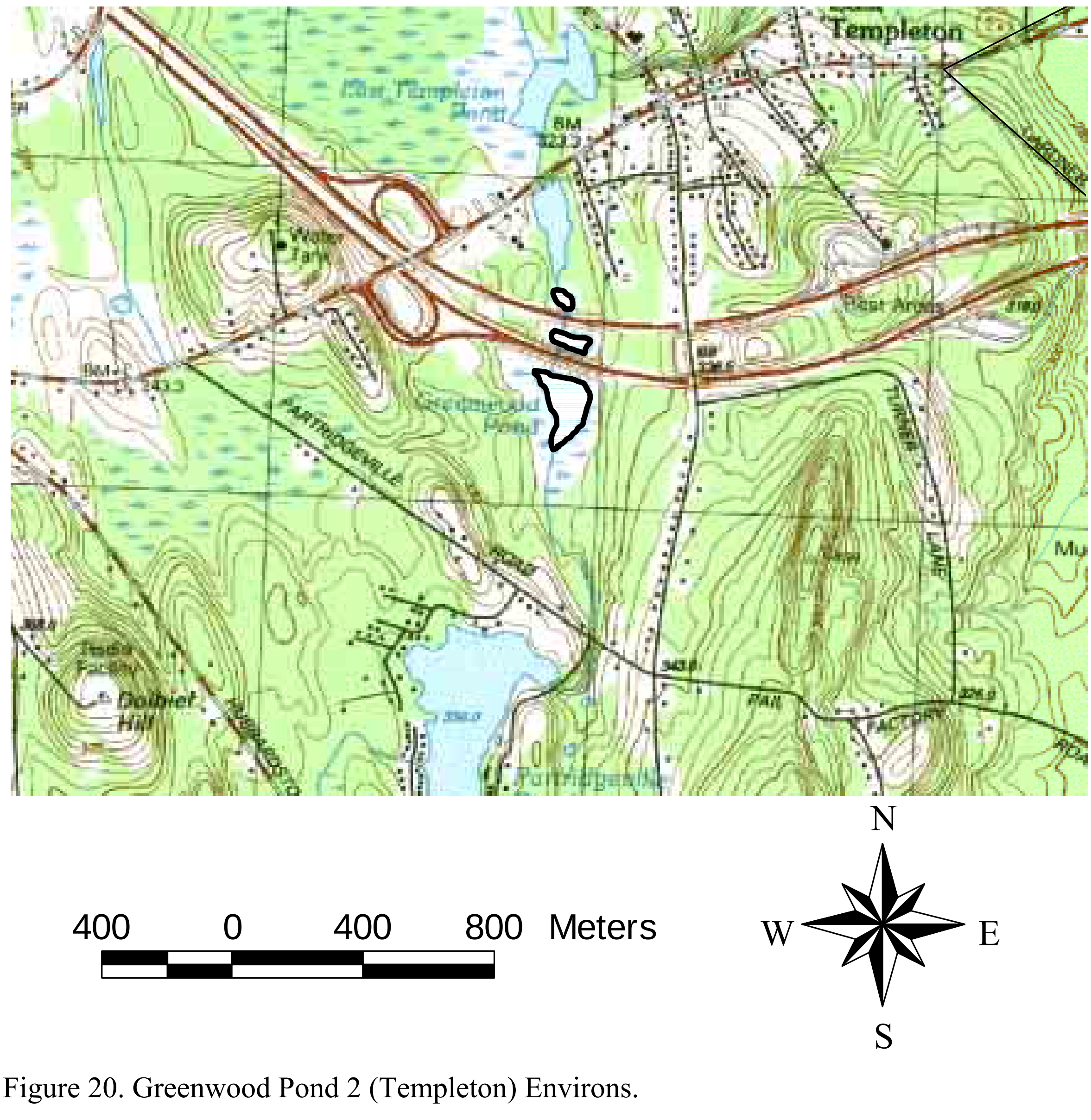


Figure 20. Greenwood Pond 2 (Templeton) Environs.

Hilchey Pond

in Gardner is a small pond of approximately 8 acres with a five foot dam. The watershed is 90 percent forested and rural and agricultural landuse accounts for 5 percent. Approximately 3 percent of the watershed is employed in the urban category, water and wetlands accounting for the rest. Population in Gardner has been described above. Section of Winchendon State Forest is within the watershed boundary. Hilchey Pond was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 22, 1995 synoptic survey indicated brown turbidity reducing transparency (estimated as <4 feet Secchi disk) below the bathing beach criteria. Patches of dense vegetation along western shore, but pond largely open water." A site visit was conducted by DEP staff in September and October of 2002 and noted that the Secchi disk was only 0.55m. This low visibility was thought to be due to high levels of natural color (tea color) that was recorded at 270 PCU, while turbidity was not markedly elevated and was measured at 8.1 NTU.

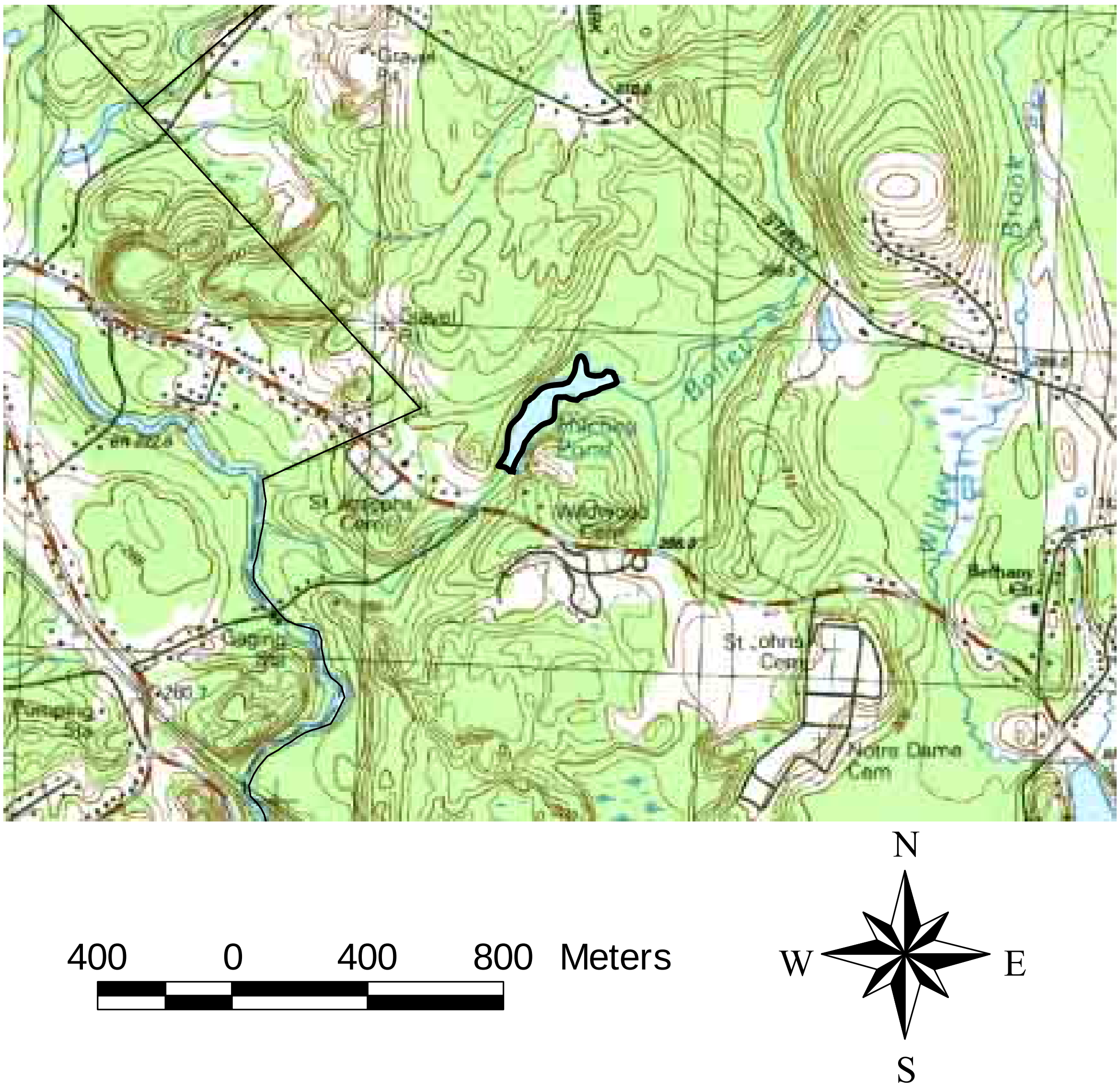


Figure 21. Hilchey Pond Environs.

Lower Naukeag Lake

in Ashburnham is a large pond of approximately 295 acres with a 14 foot dam. The watershed is 76 percent forested and water and wetlands account for 15 percent. Approximately 7 percent of the watershed consists of rural and agricultural landuse, high density residential landuse accounting for the rest. Population in Ashburnham ranged between 4,075 and 5,433 from 1980 to the 1990 census. Miser predictions on growth are 6,841 for the year 2000 and 8,822 for the year 2010 with an estimated 20 year growth rate of about 62 percent. Cranberry bogs and section of Ashburnham State Forest are within the watershed. Segment of the watershed falls within the boundary of the state of New Hampshire. Lower Naukeag Pond was assessed by DEP in the summer of 1991 and the assessment comments reported:" Very dense growths of aquatic macrophytes only in northeastern inlet arm of the lake." The lake has been repeatedly treated with diquat in 1992, 1993, 1995, 1997, 1999, 2000 and 2001. A site visit in September of 2002 by DEP staff noted tea colored water with very few aquatic plants noted.

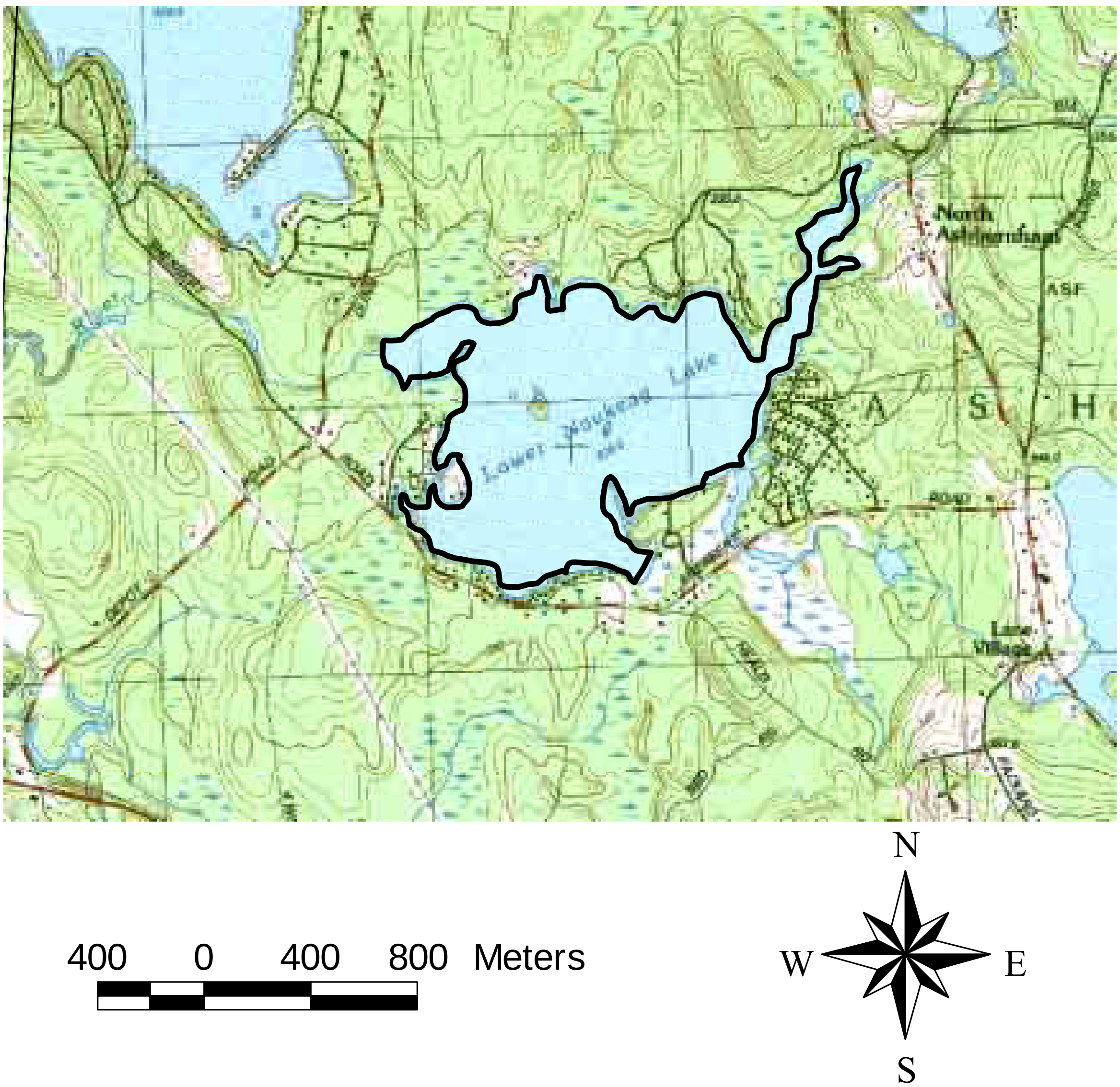


Figure 22. Lower Naukeag Lake Environs.

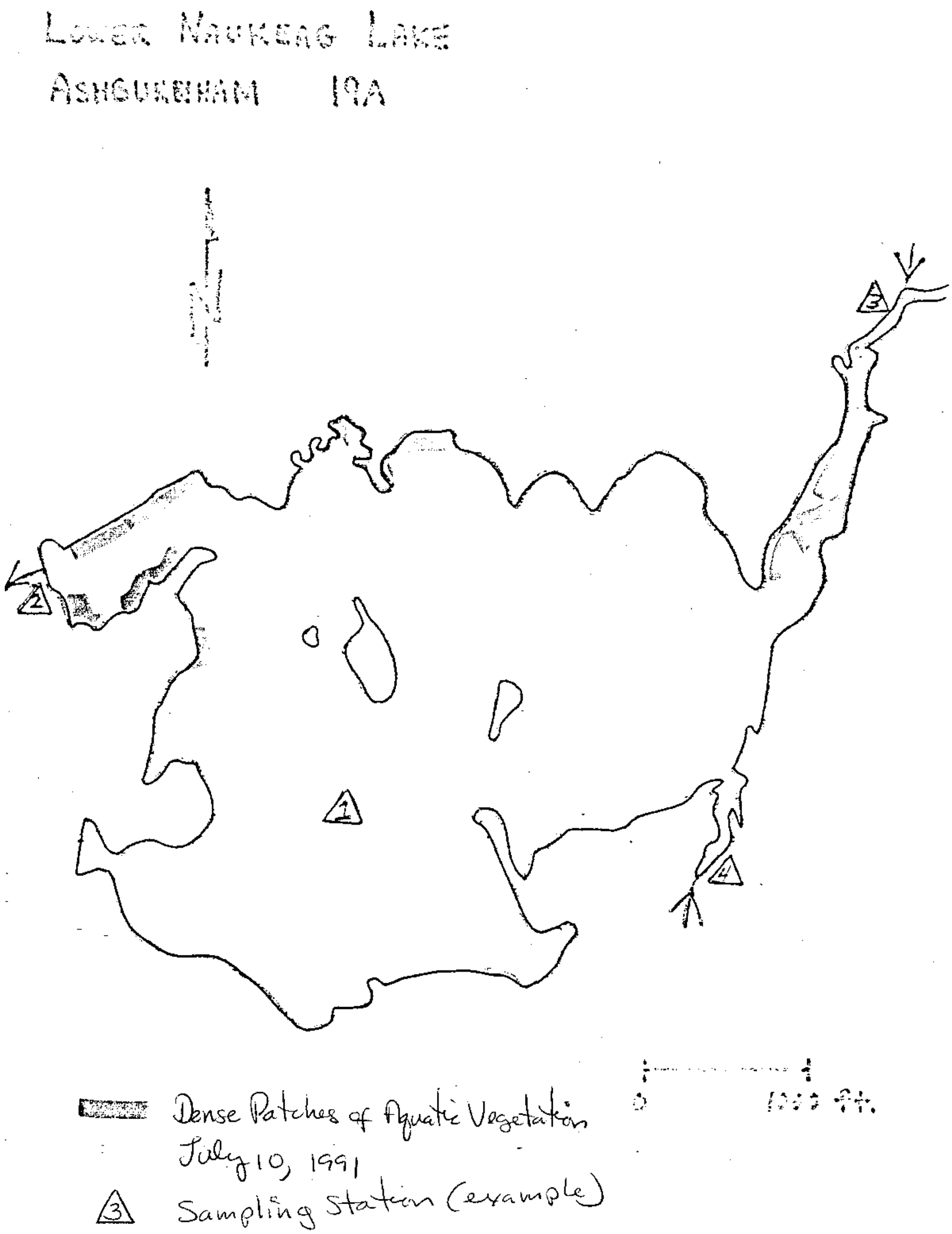


Figure 23. Lower Naukeag Macrophyte density distribution (1991).

Minott Pond South

in Westminster is a small pond of approximately 27 acres. The watershed is 78 percent forested and low density residential landuse accounts for 10 percent. Approximately 8 percent of the watershed consists of water and wetlands, agricultural landuse accounting for the rest. Population in Westminster has been described above. Minott Pond South was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 24, 1995 synoptic survey indicated pond is entirely covered with floating and submergent plants." No other data was available to make assessments. A site visit in September of 2002 by DEP staff noted clear water and dense plant cover with many ducks on the lake.

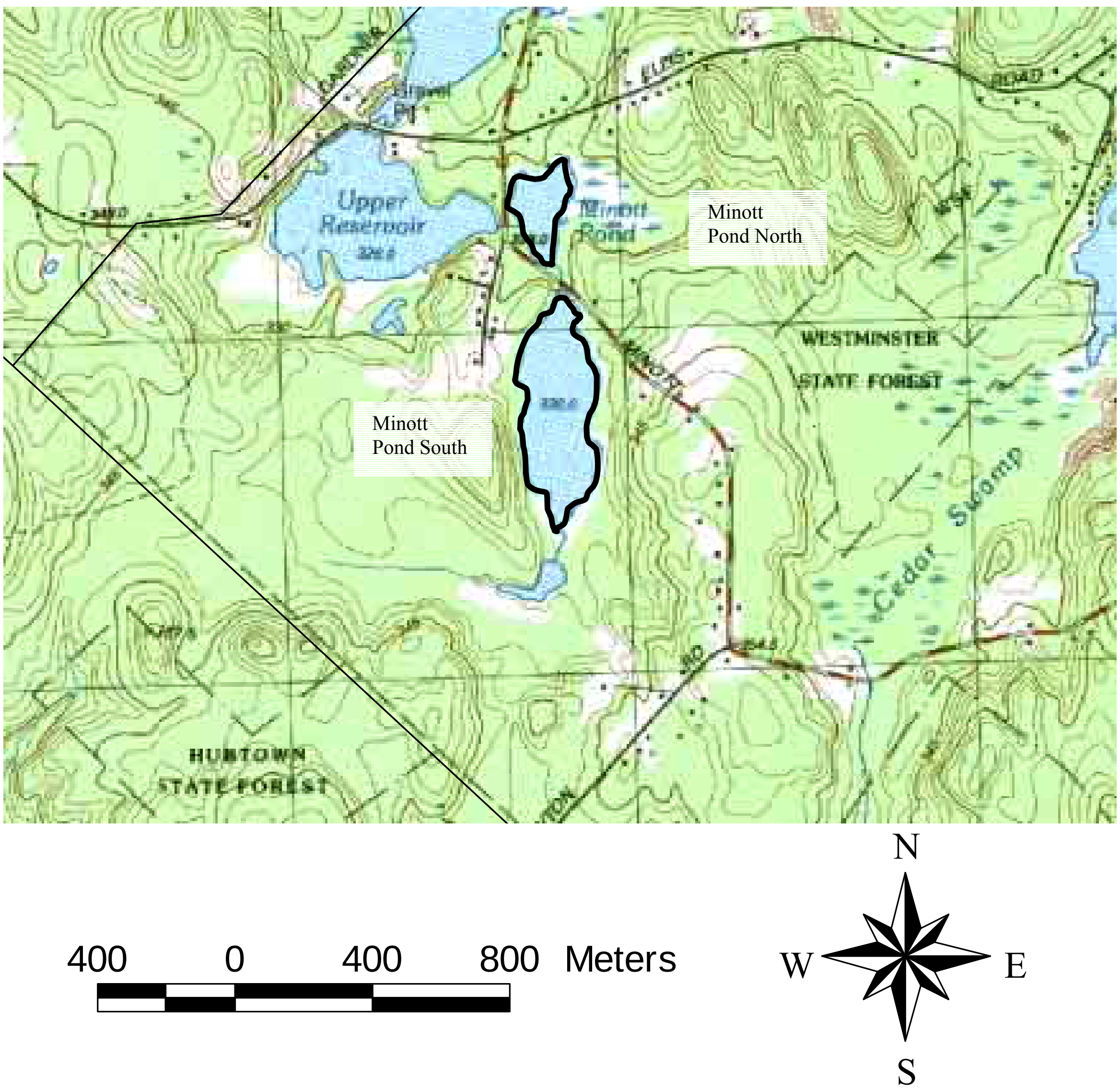


Figure 24. Minott Pond (North and South Basins) Environs.

Minott Pond

in Westminster is a small pond of approximately 8 acres with a seven foot dam. The watershed is 80 percent forested and low density residential landuse accounts for 9 percent. Approximately 8 percent of the watershed consists of water and wetlands, agricultural landuse accounting for the rest. Population in Westminster has been described above. Minott Pond was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 24, 1995 synoptic survey indicated about a third of the pond in the northeast portion filled in or with very dense submerged vegetation." No other data was available to make assessments. A site visit in September of 2002 by DEP staff noted clear water and limited plant cover.

Figure 25. Minott Pond Environs. See Figure 24 above.

Lake Monomonac

Straddles the state border between Winchendon Massachusetts and Rindge, New Hampshire. It is a large lake of approximately 591 acres with a large dam at the outlet. The watershed is 81 percent forested and water and wetlands accounts for 10 percent. Approximately 8 percent of the watershed consists of low density residential landuse, open space accounting for the rest. Population in Winchendon has been described above. Lake Monomonac was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 22, 1995 synoptic survey indicated very dense aquatic vegetation along the east and west shores of the southwestern arm of the lake; about a third of the surface area that is in MA (292 acres) was affected or about 100 acres." The lake was treated with diquat for variable milfoil in both 2000 and 2001 and a study was funded to explore the feasibility of drawdown. A site visit in September of 2002 by DEP staff noted tea colored water but visibility still estimated at 8 feet or more. Dense plant growths were noted in the southwest bays with boat channels from docks apparently cut through to open water areas.

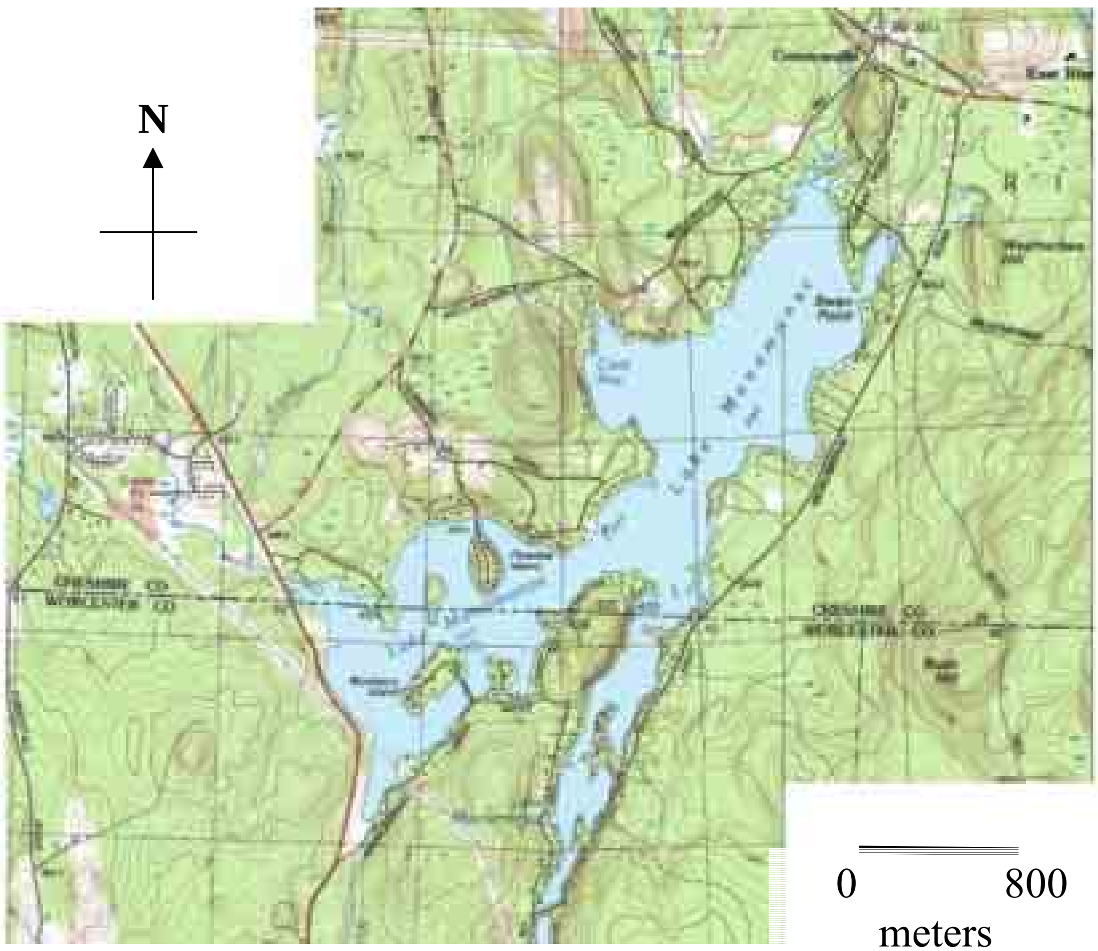


Figure 26. Lake Monomonac Environs.

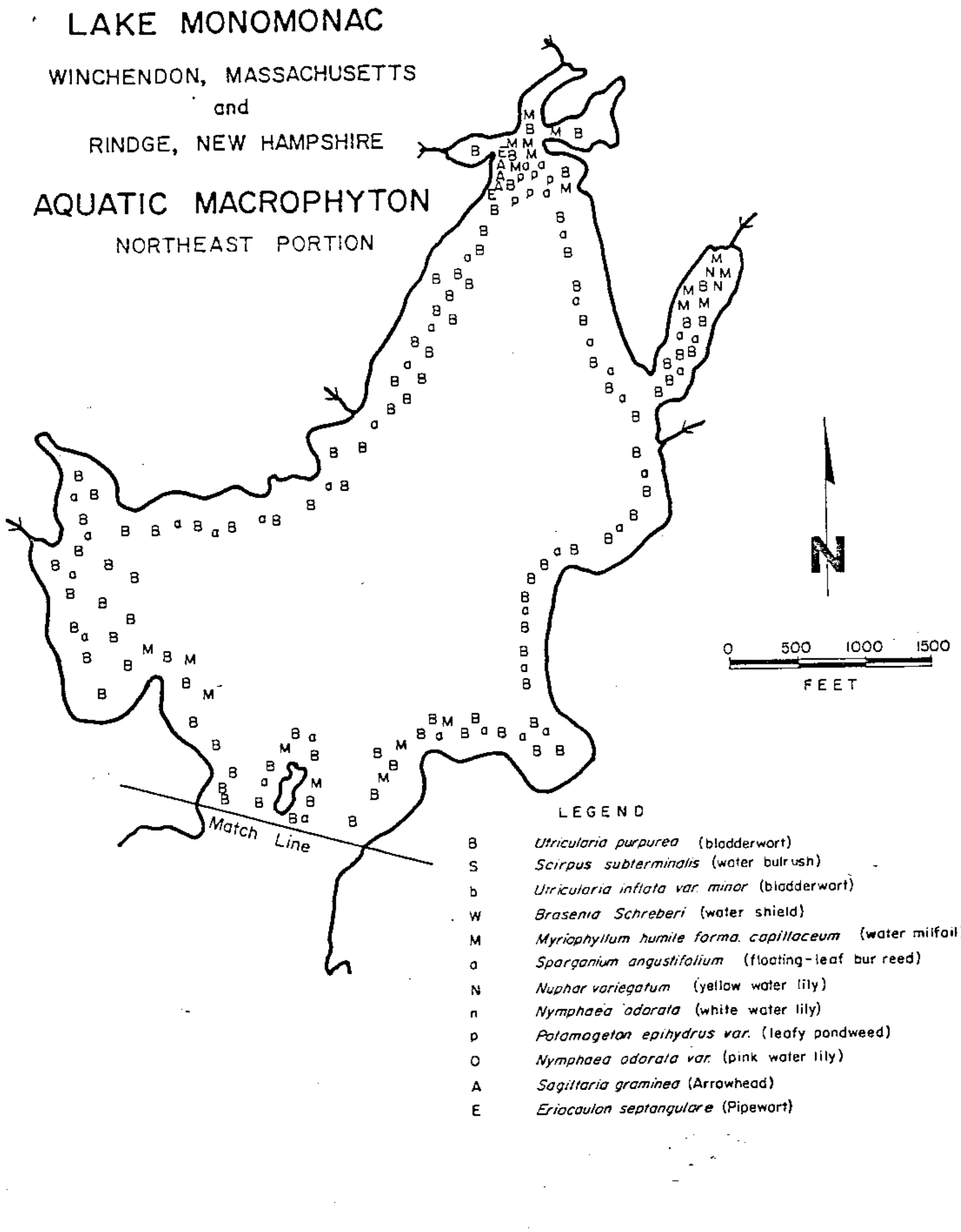


Figure 27. Lake Monomonac Northeast Portion Macrophyte species map (1976).

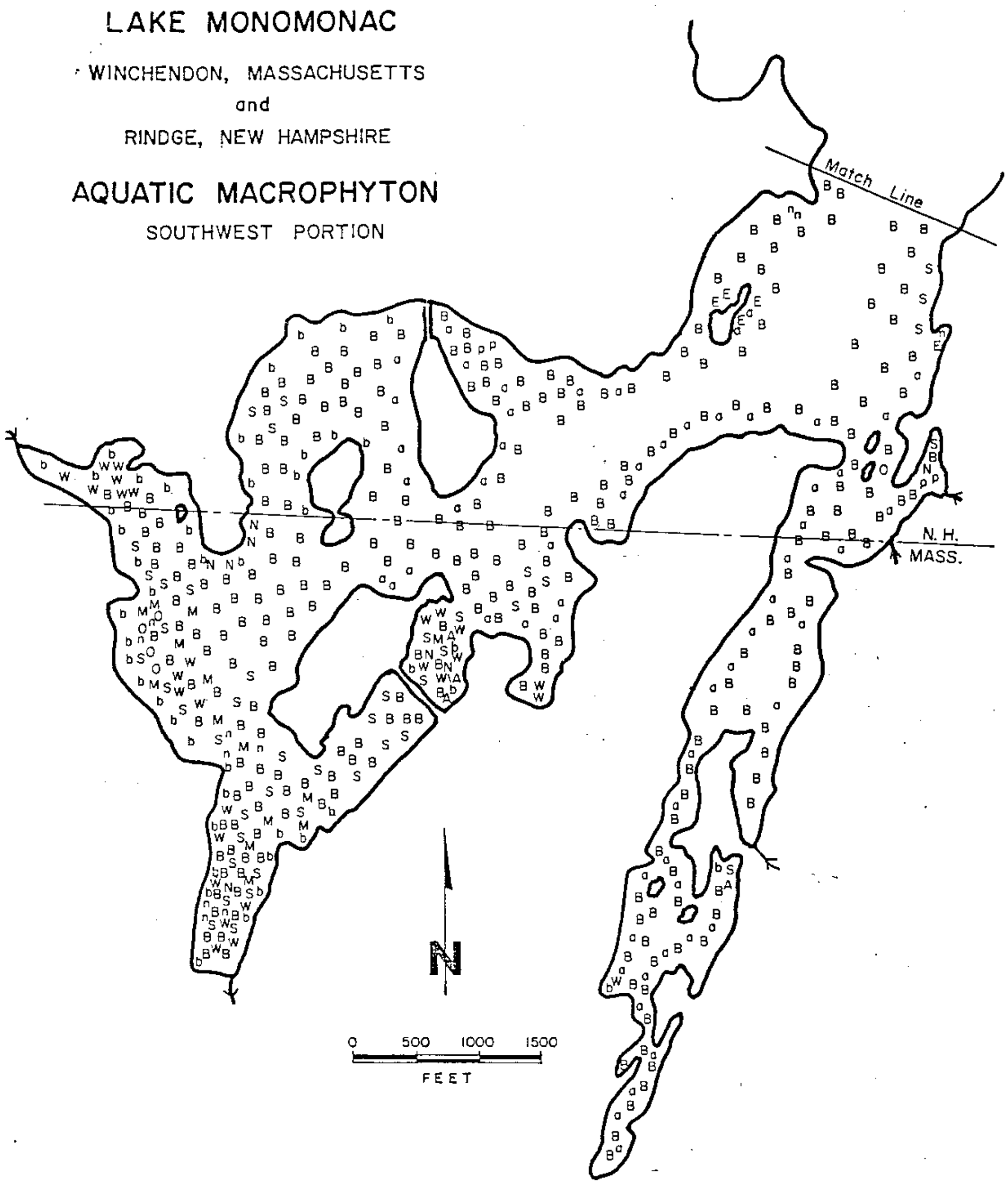


Figure 28. Lake Monomonac Southwest Portion Macrophyte species map (1976).

Parker Pond

in Gardner is a small pond of approximately 32 acres with a 13 foot dam. The watershed is 73 percent forested and urban landuse accounts for 14 percent. Approximately 9 percent of the watershed consists of rural (mostly open space) landuse, water and wetlands accounting for the rest. Population in Gardner has been described above. Parker Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: " Historically high total phosphorus and transparency below the safety criteria (4 ft. Secchi disc), but these data considered too old to use for making adequate assessments. Historically very dense growths of aquatic macrophytes (primarily Cabomba caroliniana) covered the entire pond; this information still considered adequate to make assessments." In 1996 a management plan study was initiated under a DEM grant. A DEP 319 grant was awarded to Gardner to control stormwater inputs by means of several Vortechs sediment chambers on the one large stormwater drain leading to the pond. A site visit in September of 2002 by DEP staff noted the large sediment delta extending nearly across the pond from the stormwater pipe (the pond was drawndown several feet for repairs to the dam). The non-native *Cabomba* was extremely dense throughout the pond.

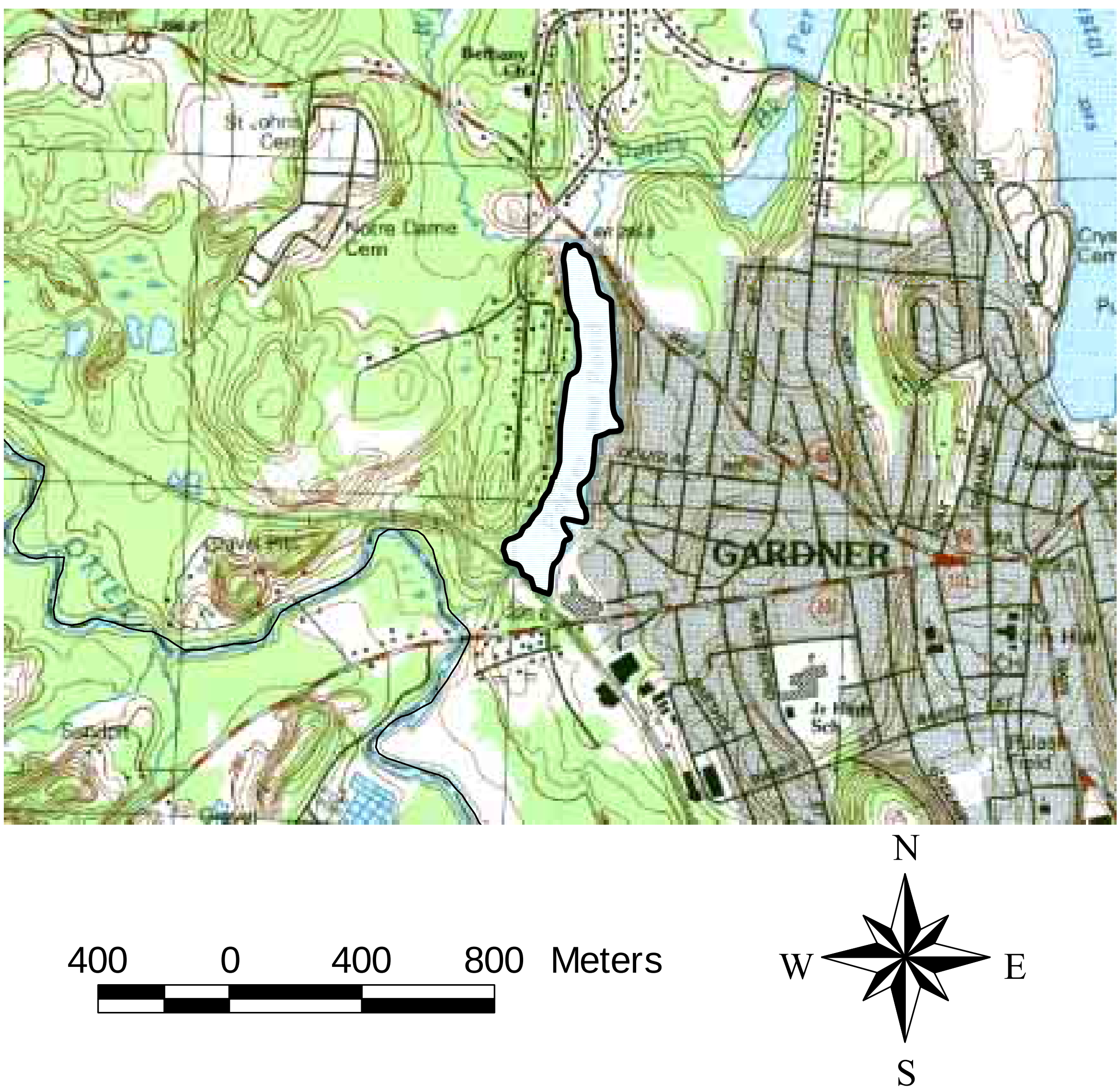


Figure 29. Parker Pond Environs.

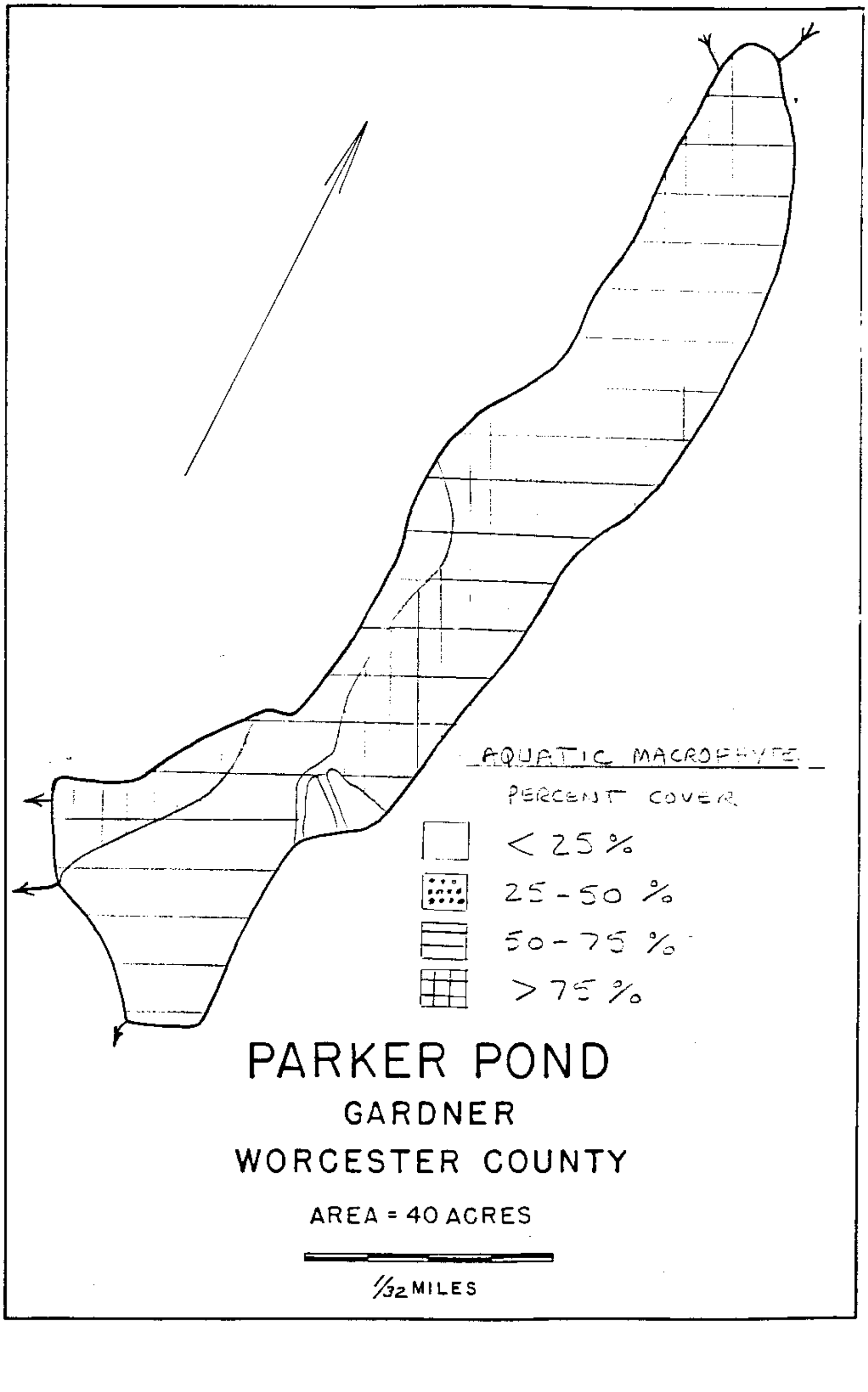


Figure 30. Parker Pond Macrophyte density distribution (1986).

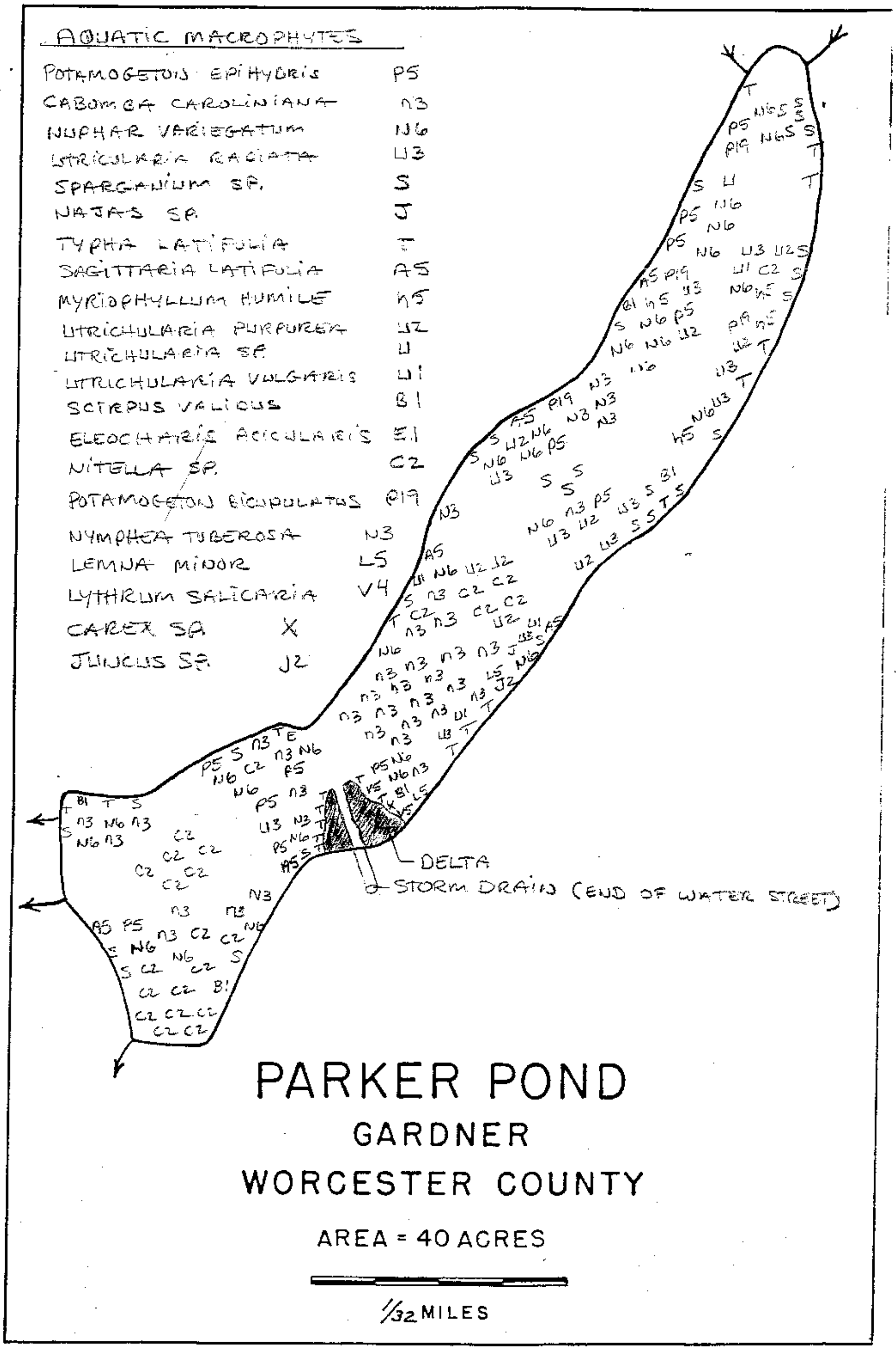


Figure 31. Parker Pond Macrophyte species distribution (1986).

Ramsdall Pond

in Gardner is a small reservoir of approximately 2 acres with a ten foot dam. The dominant landuse in the watershed are 62 percent forest, followed by 13 percent rural (including open space) landuse, 9 percent high density residential landuse and 8 percent water and wetlands. Approximately 5 percent of the watershed consists of commercial-industrial landuse that includes sections of MassHighways Route 2A, Route 40 and Route 2 as well as the interchanges between Route 2 and Route 40 and Route 2A and Route 40. Agricultural landuse covers the remainder of the watershed. Population in Gardner has been described above. A site visit in September of 2002 by DEP staff noted the pond was largely open water but a previous visit had noted a wet marsh so apparently the water level is variable.

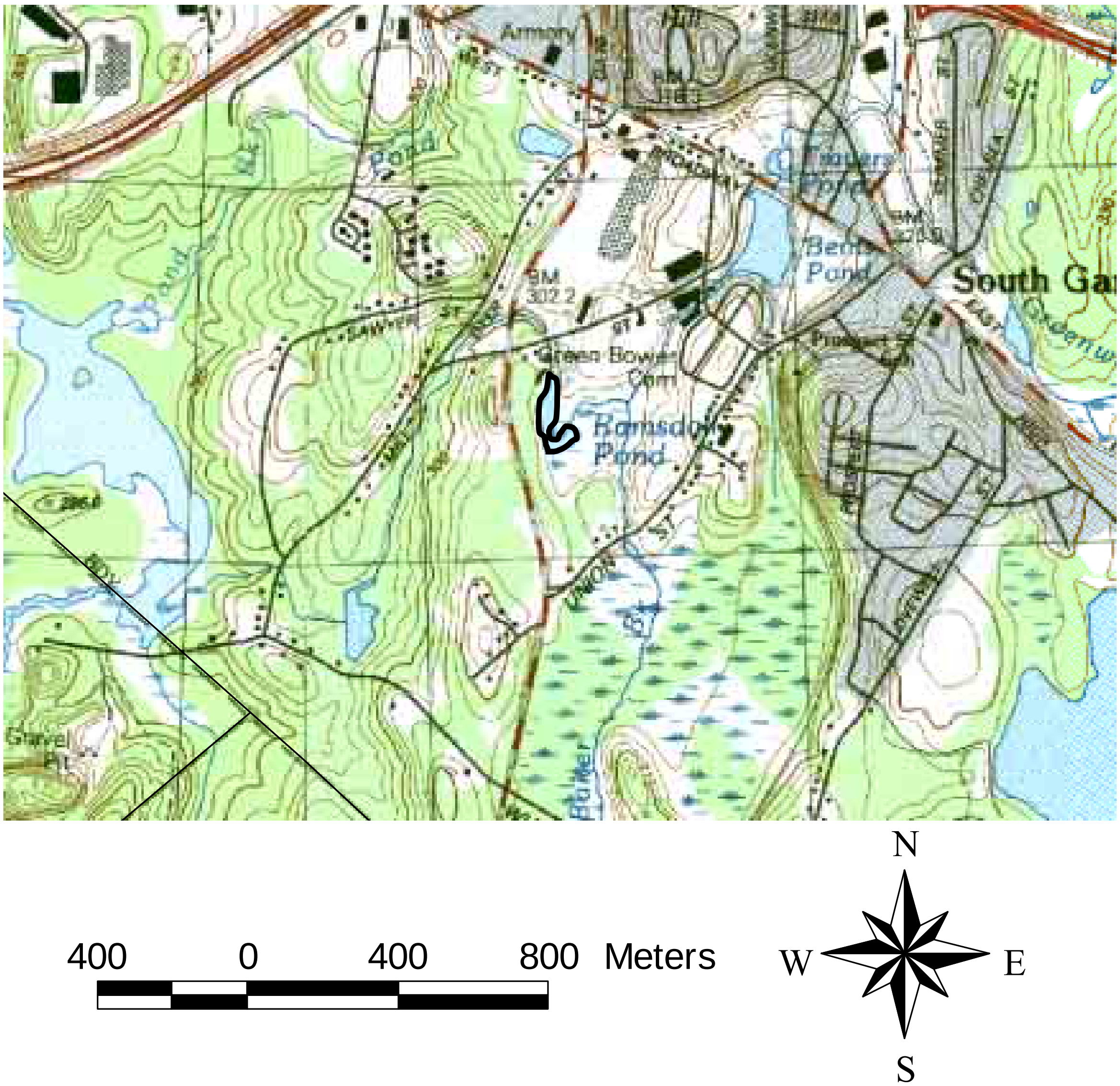


Figure 32. Ramsdall Pond Environs.

Reservoir No. 1

in Athol is a small pond of approximately 7 acres with a beaver dam at the outlet. The watershed is 80 percent forested and rural landuse accounts for 10 percent. Water and wetlands covers the remainder of the watershed. Population in Athol has been described above. Reservoir No. 1 was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 18, 1995 synoptic survey indicated about 75% of the pond covered with very dense growths of floating and emergent vegetation." A site visit in September of 2002 by DEP staff noted the pond was about 25% covered with floating vegetation and good water transparency.

Reservoir No. 2

is known locally as Secret Lake in Philipston/Athol is a small pond of approximately 48 acres. The watershed is 78 percent forested and water and wetlands account for 18 percent. The remaining watershed consists of low density residential landuse. Population in Philipston ranged between 953 and 1,485 from 1980 to the 1990 census. Miser predictions on growth are 2,010 for the year 2000 and 2,856 for the year 2010 with an estimated 20 year growth rate of about 92 percent. Population in Athol has been described above. Reservoir No. 2 was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 18, 1995 synoptic survey indicated about 75% of the total pond surface covered with very dense floating vegetation." The pond was treated with diquat in 1995 and 2,4D in 1996. A site visit in September of 2002 by DEP staff noted the pond was almost entirely covered with dense vegetation but water transparency was good.

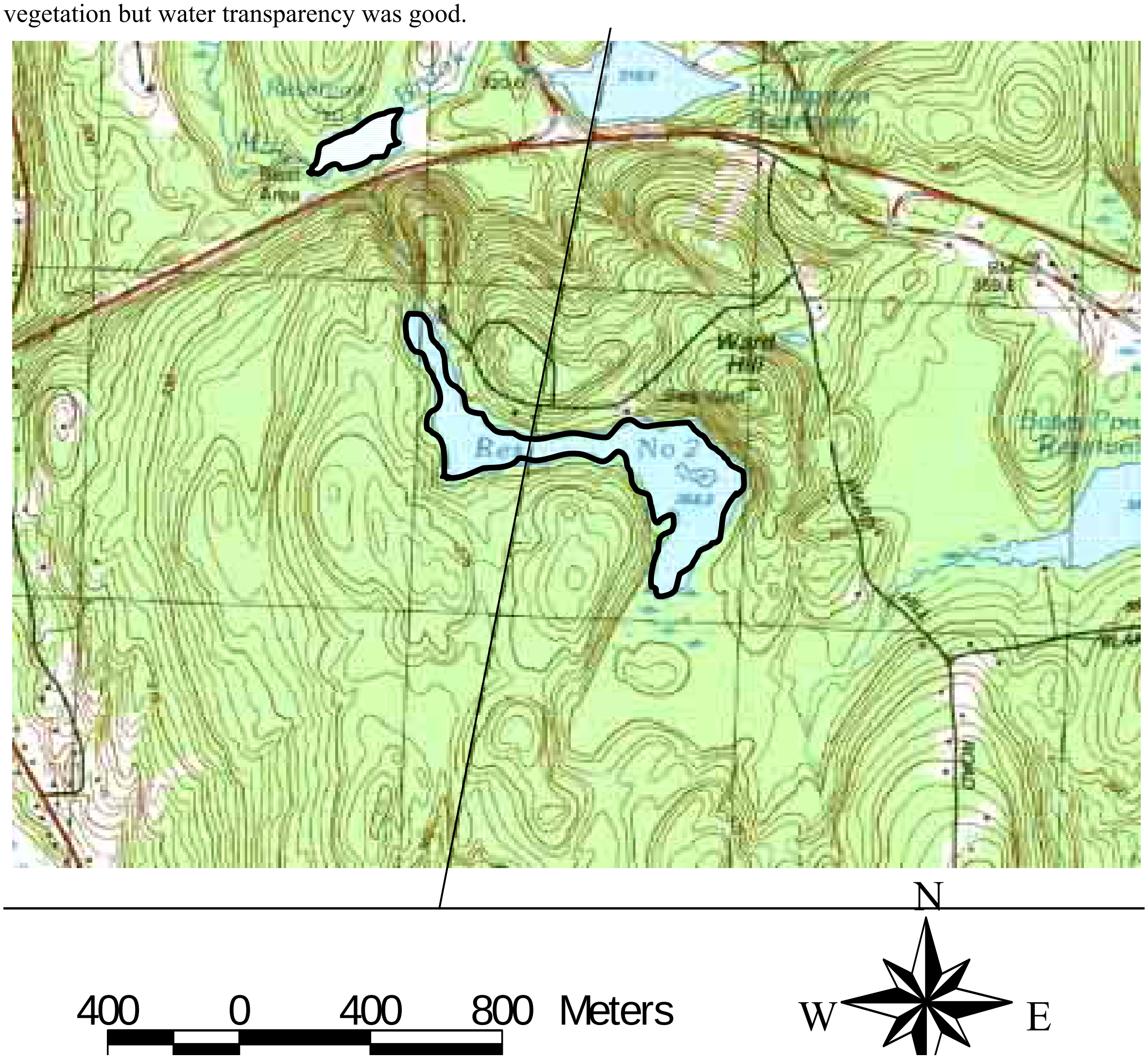


Figure 33. Reservoir No 1 and No. 2 (Secret Lake) Environs.

Riceville Pond

in Petersham/Athol is a large pond of approximately 61 acres with an 11 foot dam. The only access appears to be walk-in along closed logging roads. The watershed is 90 percent forested and rural landuse accounts for 5 percent that includes open space. Approximately 4 percent of the watershed consists of water and wetlands, agricultural land accounting for the rest. Population in Petersham and Athol have been described above. Riceville Pond was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 15, 1995 synoptic survey indicated at least half of the upper end of the pond (from dam) was covered with very dense growths of floating vegetation." A site visit in September of 2002 by DEP staff noted the conditions were unchanged, but noted fairly transparent water.

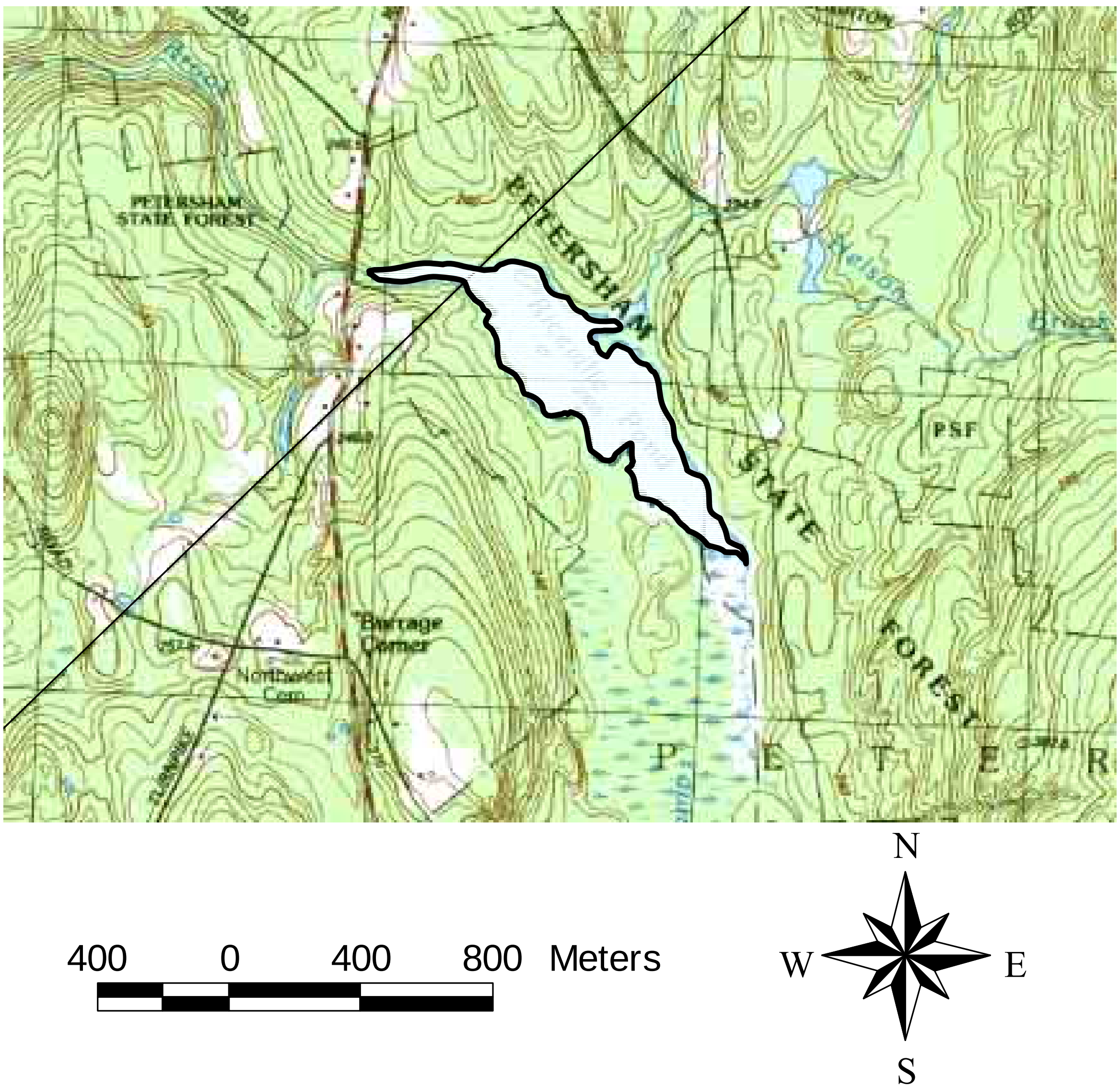


Figure 34. Riceville Pond Environs.

South Athol Pond

in Athol is a large pond of approximately 83 acres with a dam holding 6 feet of water at the southern end. Morgan Memorial Camp runs a summer camp for children on the shore of the pond. The watershed is 87 percent forested and rural and agricultural landuse accounts for 8 percent. The remaining watershed consists of water and wetlands with the exception of about half a percent which is employed in the commercial-industrial landuse category. E.W. Sykes operates a gravel pit near the shore of the lake. Population in Athol has been described above. South Athol Pond was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 15, 1995 synoptic survey indicated very dense growths of vegetation covered the upper half of the lake and more than half of the lower lake (total about 80%). The non-native species *Cabomba caroliniana* was present." A site visit in September of 2002 by DEP staff noted the conditions were unchanged and noted fairly transparent water.

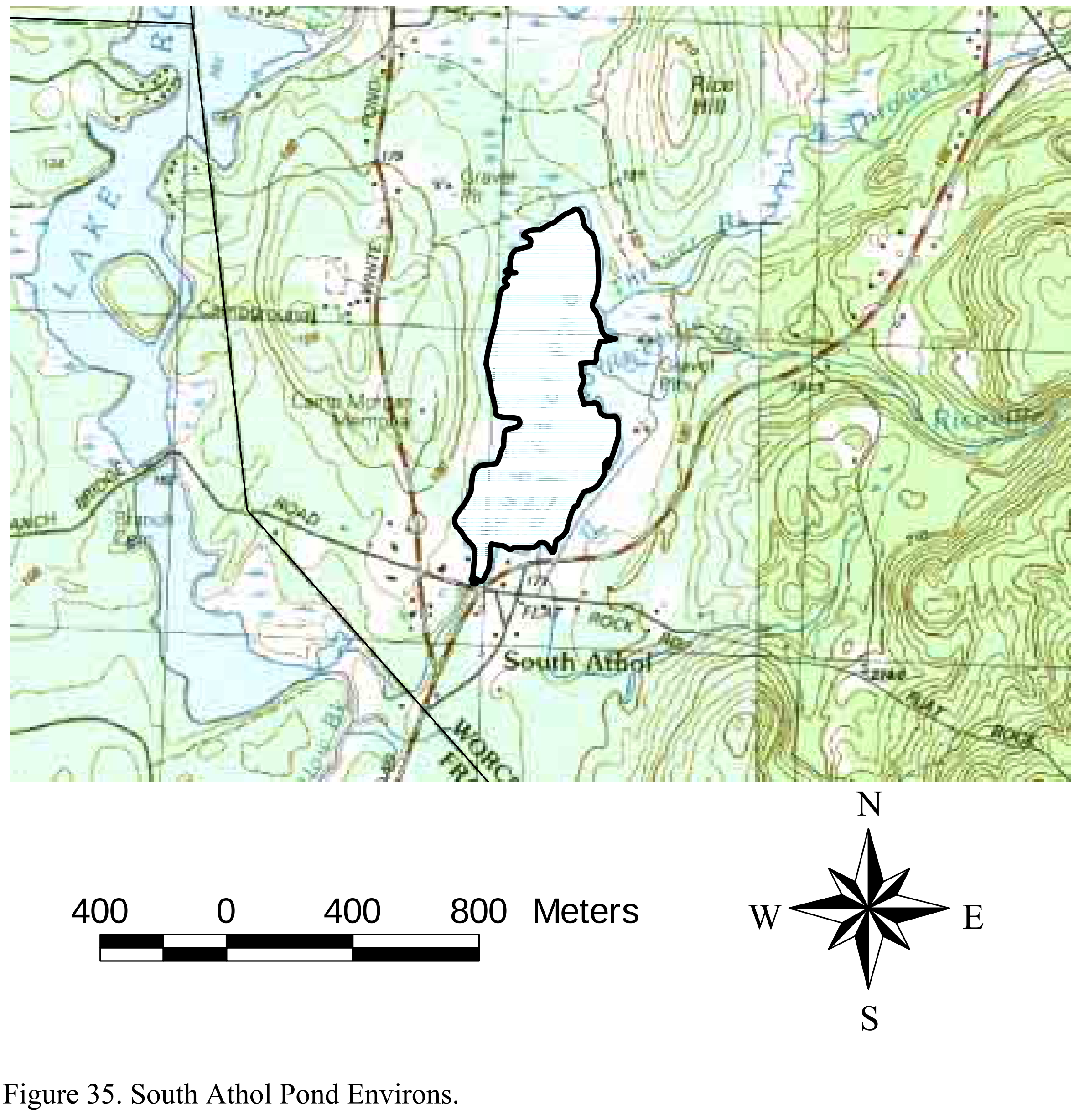
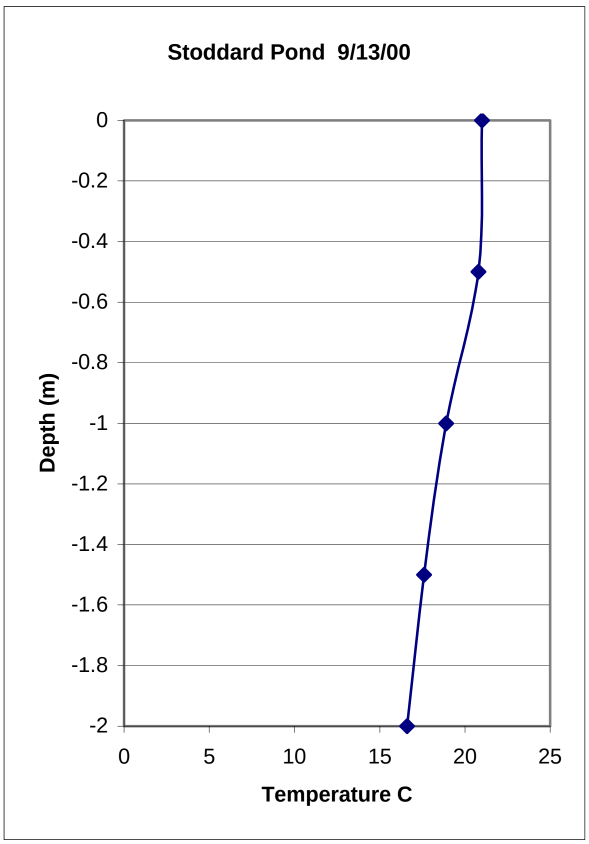


Figure 35. South Athol Pond Environs.

Stoddard Pond

in Winchendon is a large pond of approximately 52 acres with an 8 foot dam (maximum depth of 2.7m or 9 feet). The dominant landuse in the watershed are 76 percent forest, followed by 10 percent rural and 9 percent agricultural landuse. Most of rest of the watershed consists of water and wetlands. Population in Winchendon ranged between 7,019 and 8,805 from 1980 to the 1990 census. Miser predictions on growth are 9,637 for the year 2000 and 11,054 for the year 2010 with an estimated 20 year growth rate of about 26 percent. Stoddard Pond was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 22, 1995 synoptic survey indicated about 30% of the pond surface was covered with patches of floating leaf plants." Data from a 3 month baseline survey conducted by DEP/MDFW during the summer of 2000 showed the lake covered with dense beds of native macrophytes. These macrophytes allow weak stratification and oxygen depletion below 1 m depth (see figures below). The pond had an average total phosphorus at the surface of 0.025 mg/l. The average Secchi disk transparency ranged from 1.4 to 1.8 meters (average 1.6) but some of this low transparency was due to color which averaged 150 PCU (one qualified point omitted). The chlorophyll a ranged between 2.9 and 8.6 ug/l. The Carlson Trophic Index of 50 indicates eutrophic conditions with indications of reduction in transparency due to natural color (See Appendix I and Appendix IV).



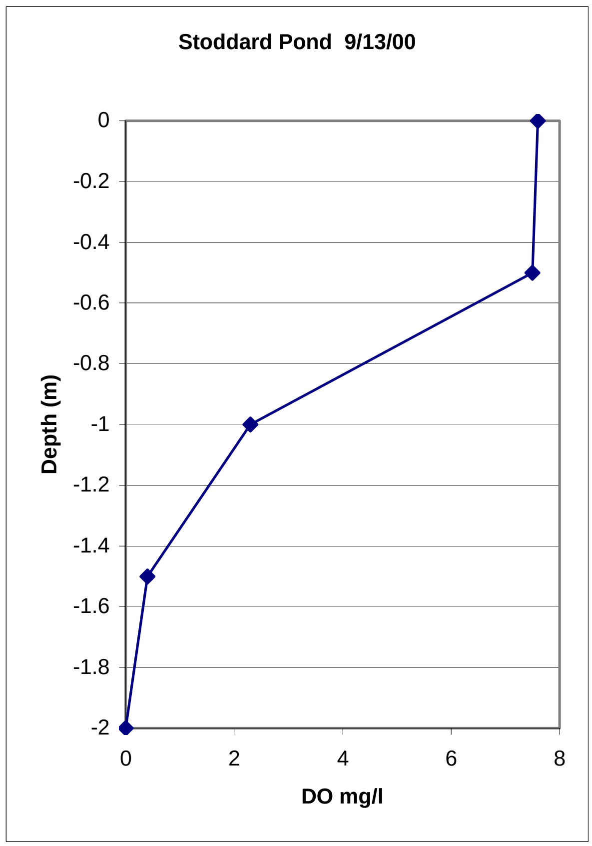


Figure 36. Stoddard Pond Temperature and Oxygen Profiles.

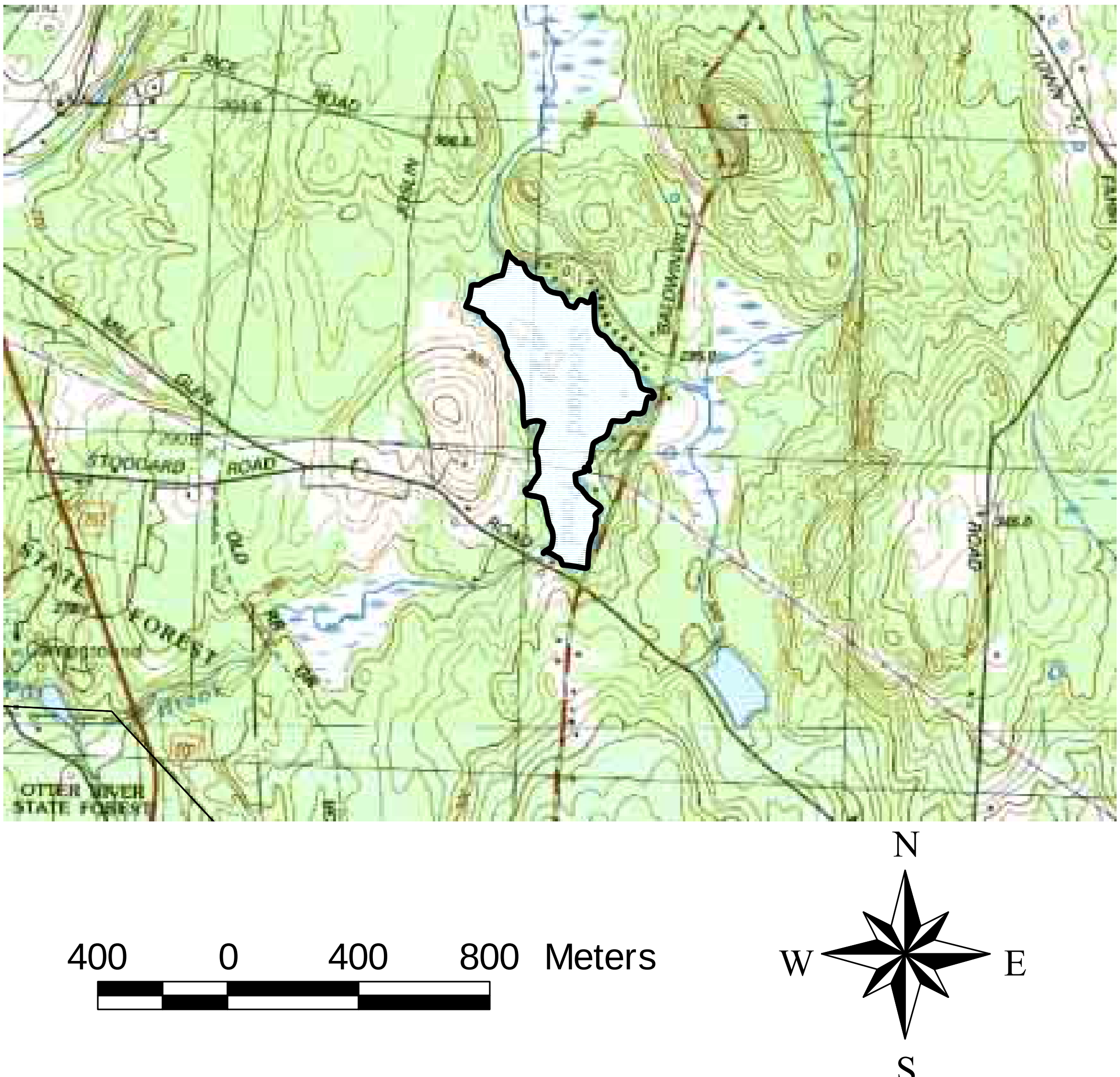


Figure 37. Stoddard Pond Environs.

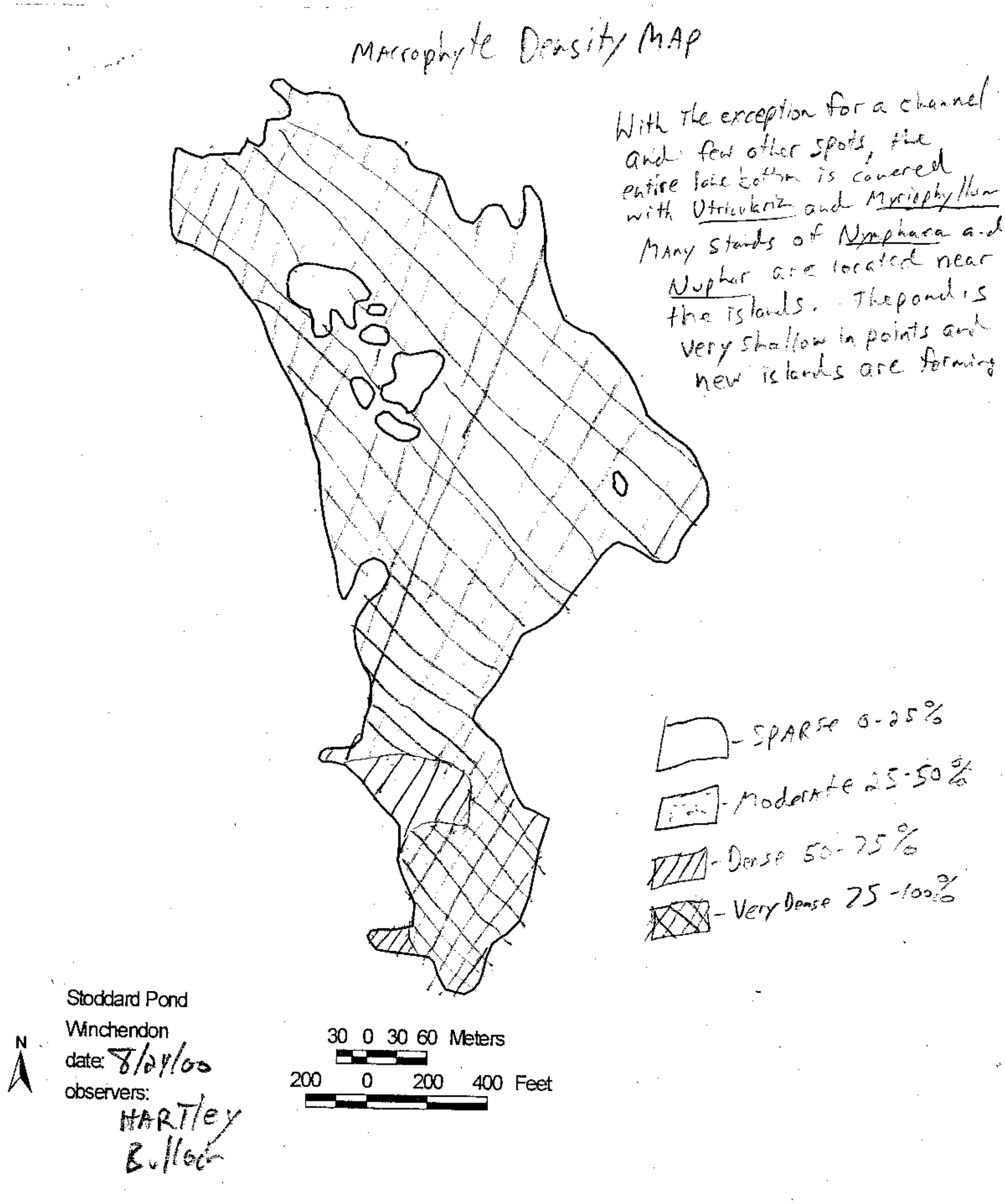


Figure 38. Stoddard Pond Macrophyte density distribution (2000).

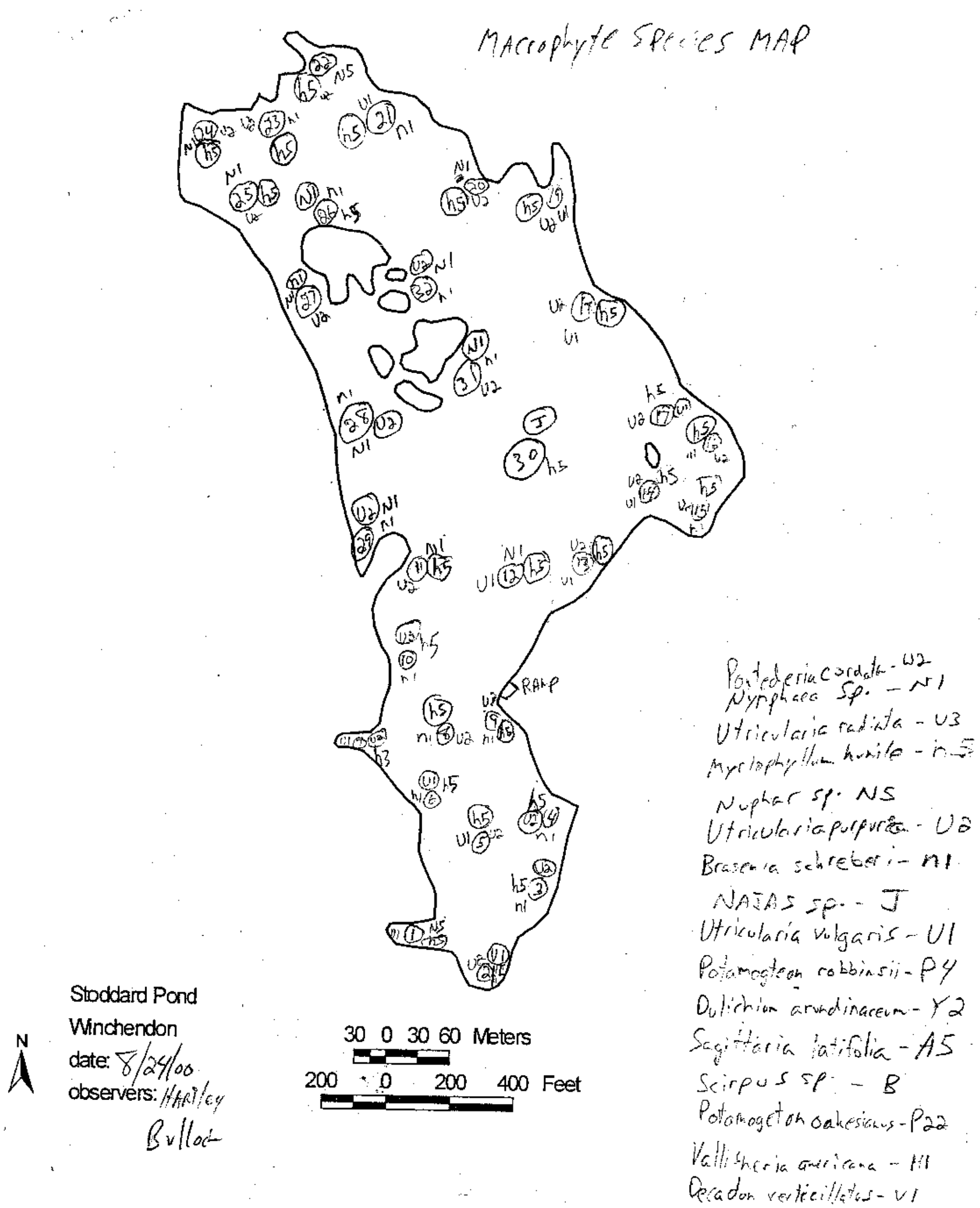


Figure 39. Stoddard Pond Macrophyte species distribution (2000).

Wallace Pond

in Ashburnham is a small pond of approximately 46 acres with a ten foot dam. The watershed is 94 percent forested and water and wetlands account for 4 percent. The remaining watershed consists of rural and agricultural landuse. Population in Ashburnham has been described above. MassHighways Route 119 crosses the watershed. Wallace Pond was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 30, 1995 synoptic survey indicated about 75% of the surface area covered with very dense growths of floating leaf vegetation.” A site visit in September of 2002 by DEP staff noted the conditions were unchanged and also noted a “tea” color in the water but otherwise good transparency.

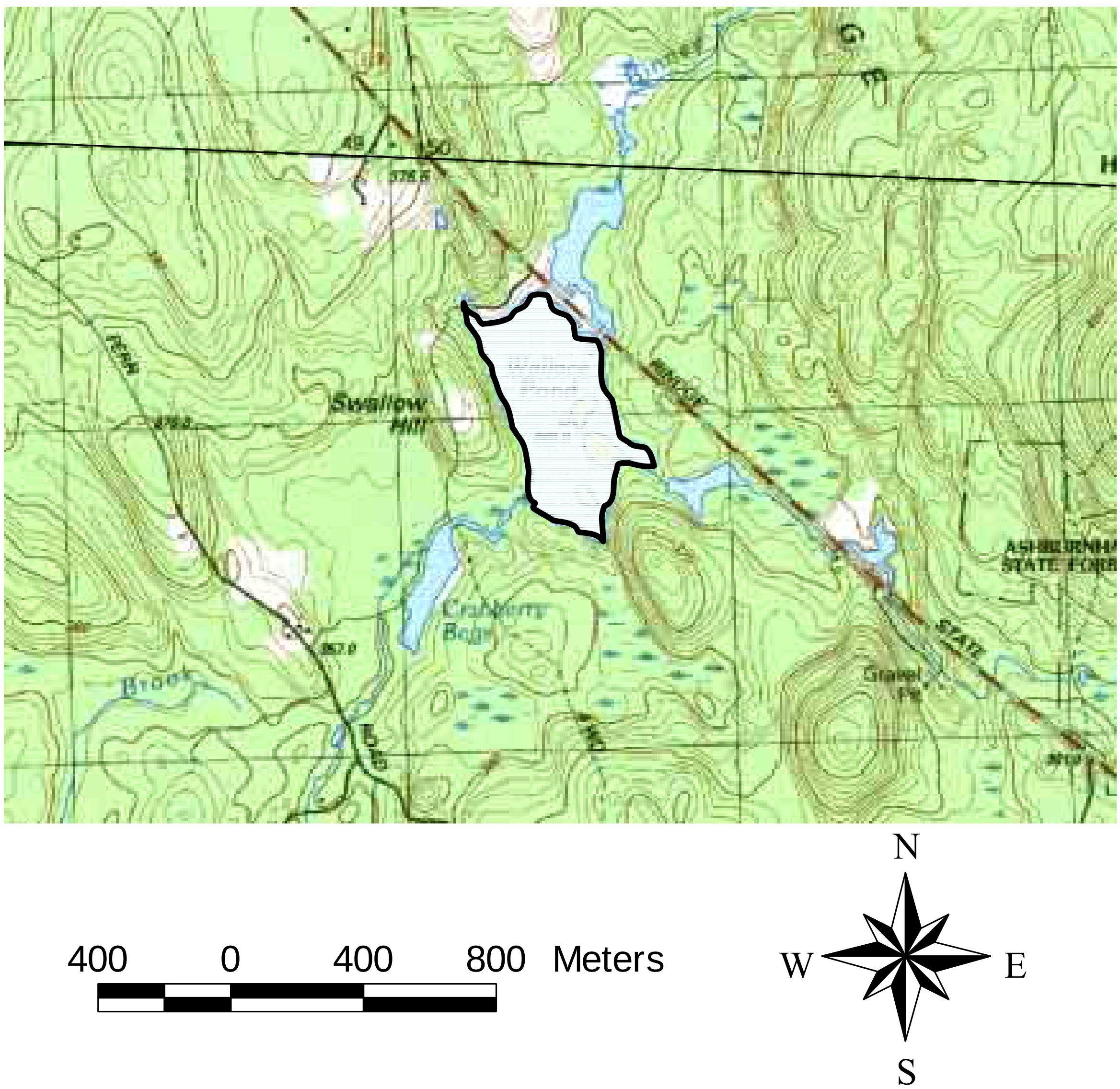


Figure 40. Wallace Pond Environs.

Ward Pond

in Athol is a small pond of approximately 6 acres. The watershed is 90 percent forested and low density residential landuse accounts for 6 percent. About 3 percent of the watershed consists of wetlands, agricultural landuse accounting for the remaining 1 percent. Population in Athol has been described above. Sections of MassHighways Route 2 and Route 202 are within the watershed. Ward Pond was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 15, 1995 synoptic survey indicated very dense cover of floating leaf plants over the entire pond." A site visit in September of 2002 by DEP staff noted the conditions were unchanged.

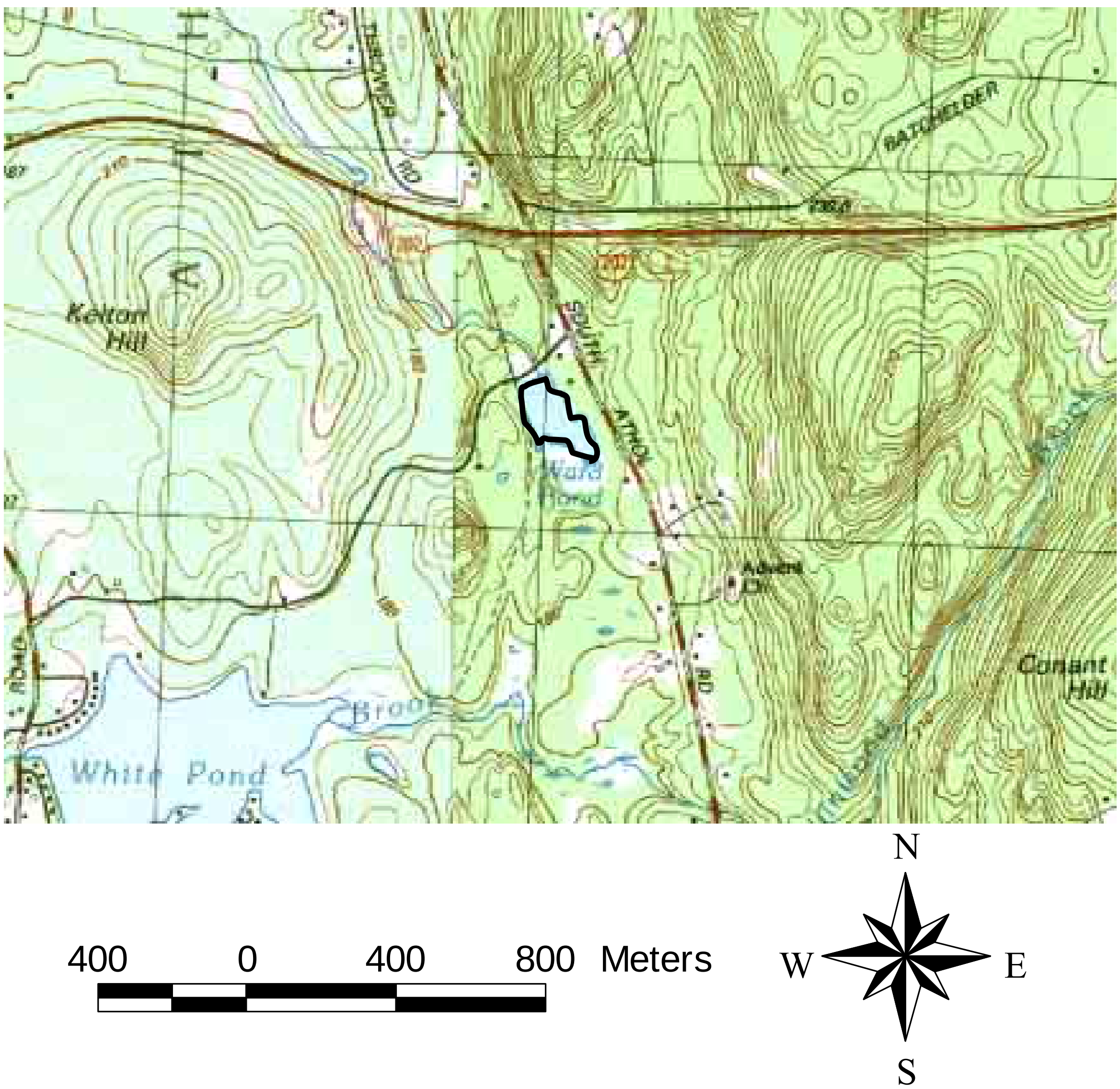


Figure 41. Ward Pond Environs.

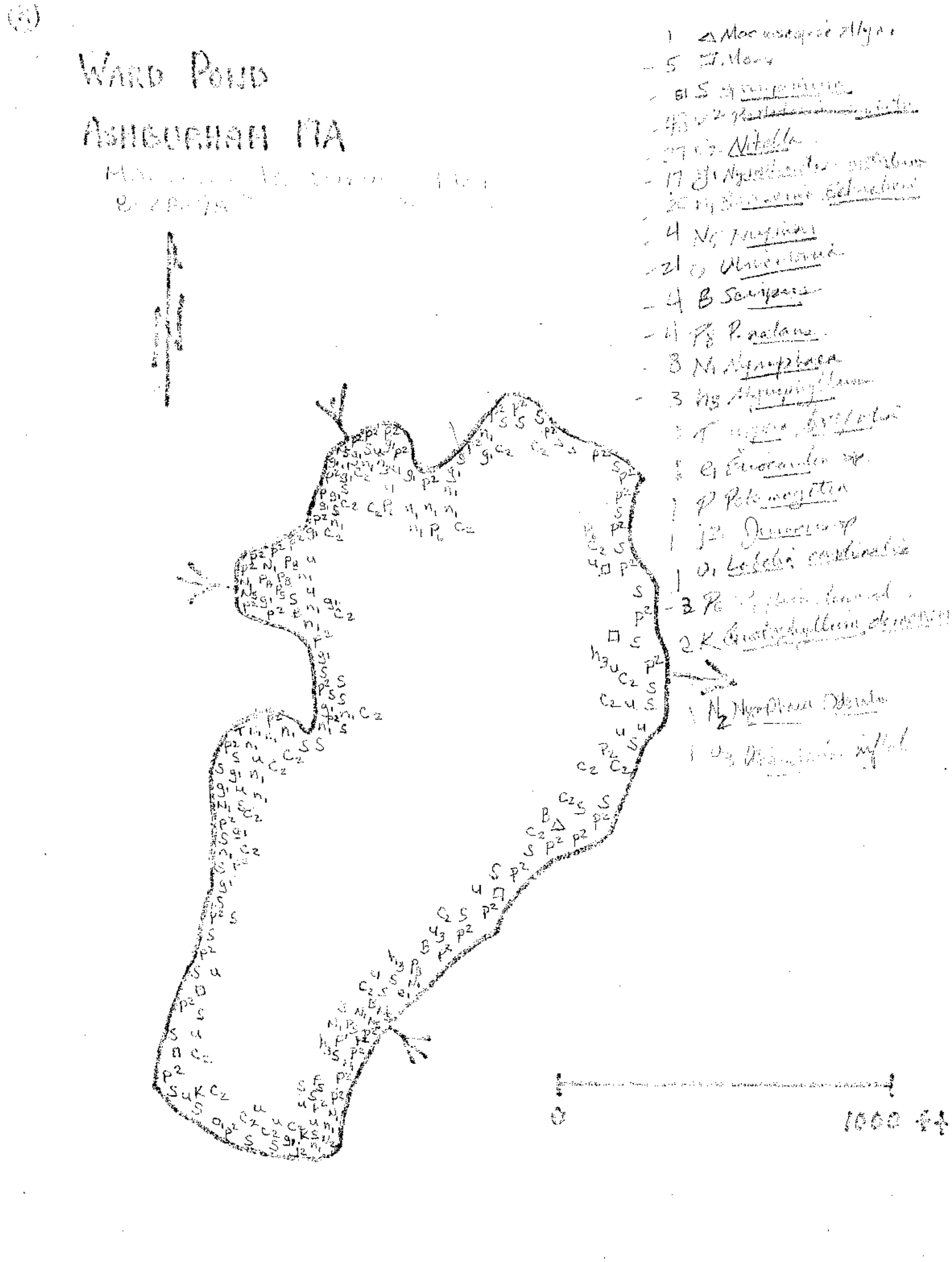


Figure 42. Ward Pond Macrophyte species distribution.

Whites Mill Pond

in Winchendon is a small reservoir of approximately 42 acres with a 16 foot dam located next to the Mylec Ray Plastic mill. The watershed is 81 percent forested and water and wetlands account for 10 percent. Approximately 8 percent of the watershed consists of low density residential landuse, open space accounting for the rest. Population in Winchendon has been described above. Whites Mill Pond was assessed by DEP in the summer of 1995 and the assessment comments reported: " August 22, 1995 synoptic survey indicated entire upper pond and most of the lower pond covered with very dense growths of floating, submergent and emergent vegetation." A site visit in September of 2002 by DEP staff noted the conditions were unchanged and many ducks on the pond.

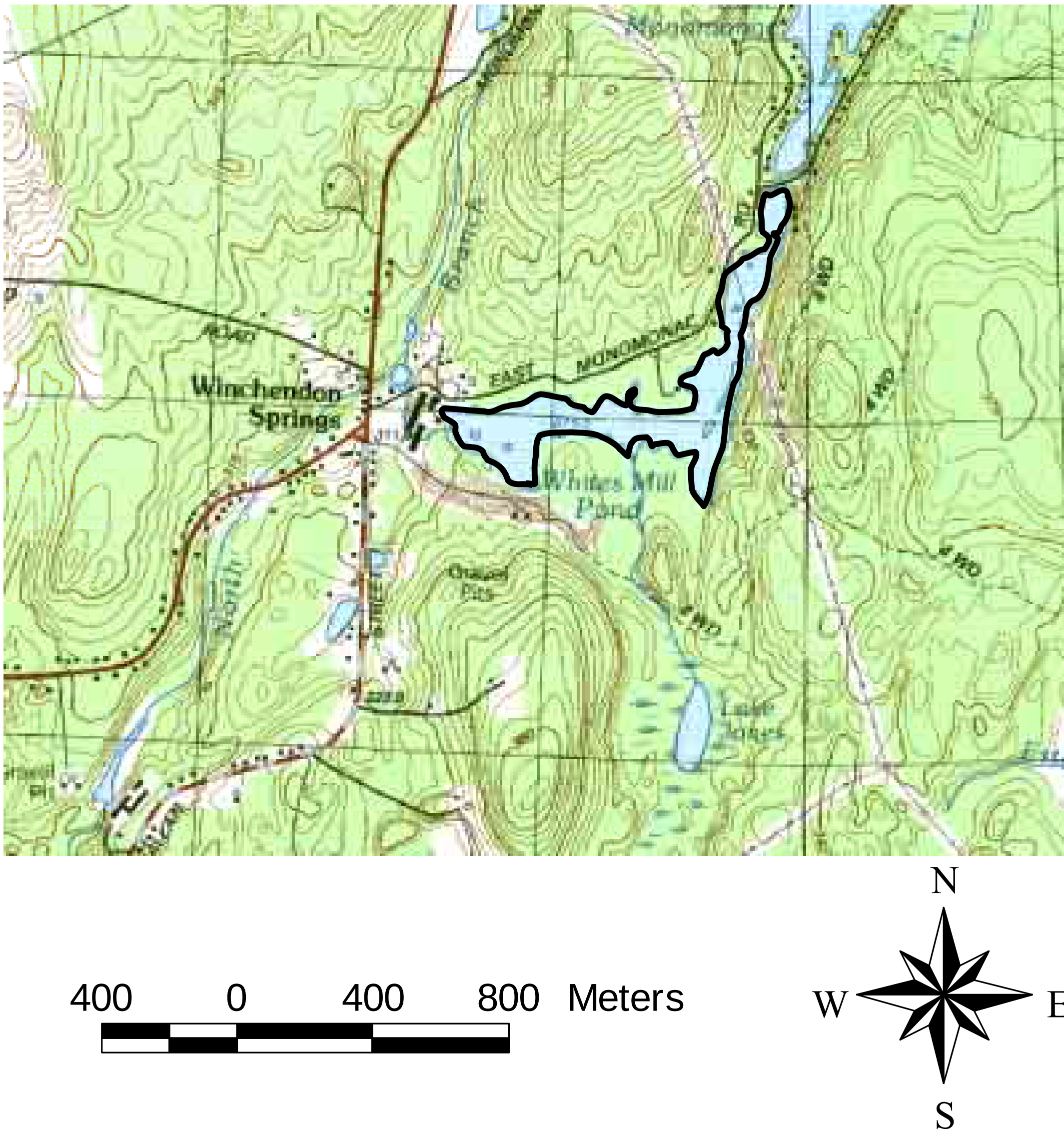


Figure 43. Whites Mill Pond Environs.

Whitney Pond

in Winchendon is a large pond of approximately 97 acres formed by a 21 foot high dam on the Millers River. The maximum depth is 5.6m or 18 feet). As such the lake is estimated to have an average residence time of approximately 7 days. The dominant landuses in the watershed are 87 percent forest, followed by 7 percent water and 3 percent agricultural landuse. The rest of the watershed consists of urban landuse. The Winchendon Country Club Golf Course is located near the pond. Population in Winchendon has been described above. A DEP baseline survey during June 1987 showed high total phosphorus in Whitney Pond and the assessment comments from 1994 reported: " Historically high total phosphorus levels and low hypolimnetic dissolved oxygen (3 to 5 meters), but these data are too old to use for making adequate assessments. Historically dense growths of aquatic macrophytes covered the entire littoral zone and fishing advisory due to mercury in fish tissue; these factors used to make current assessment." Data from a 3 month baseline survey conducted by DEP/MDFW during the summer of 2000 showed the pond does stratify and oxygen is nearly absent below 2.5 m (see figures below). Very dense native macrophytes covered about one half of the pond area with open water in the center. The average total phosphorus at the surface was 0.037mg/l. The average Secchi disk transparency ranged from 1.2 to 1.5 meters (average 1.3) but some of this low transparency was probably due to high levels of natural color that averaged 190 PCU. The chlorophyll a ranged between <1 and 4.3 ug/l. The Carlson trophic index of 51 indicates a eutrophic lake, with some indication of reduction in transparency due to natural color (See Appendix 1 and Appendix IV). A site visit in September of 2002 by DEP staff noted the pond had fairly transparent water but also noted evidence of people feeding bread to the ducks and geese on the pond.

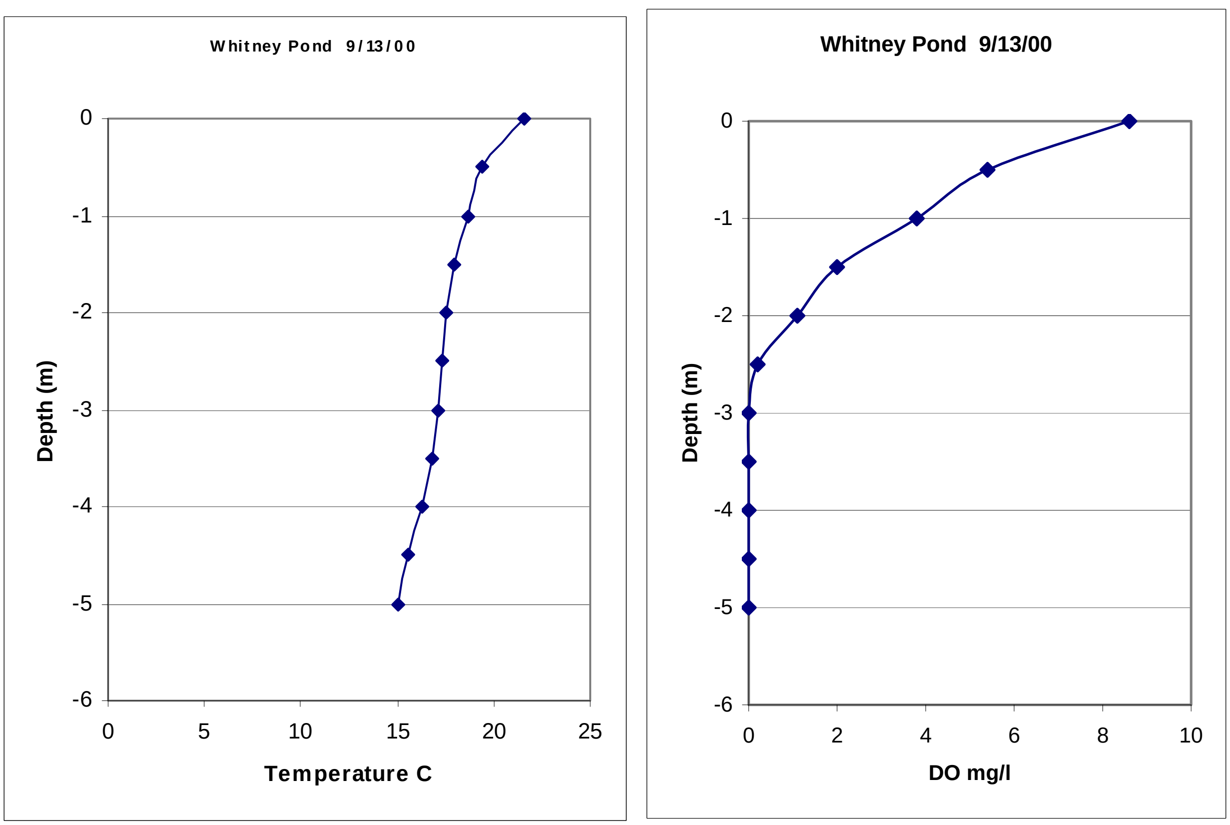


Figure 44. Whitney Pond Temperature and Oxygen Profile.

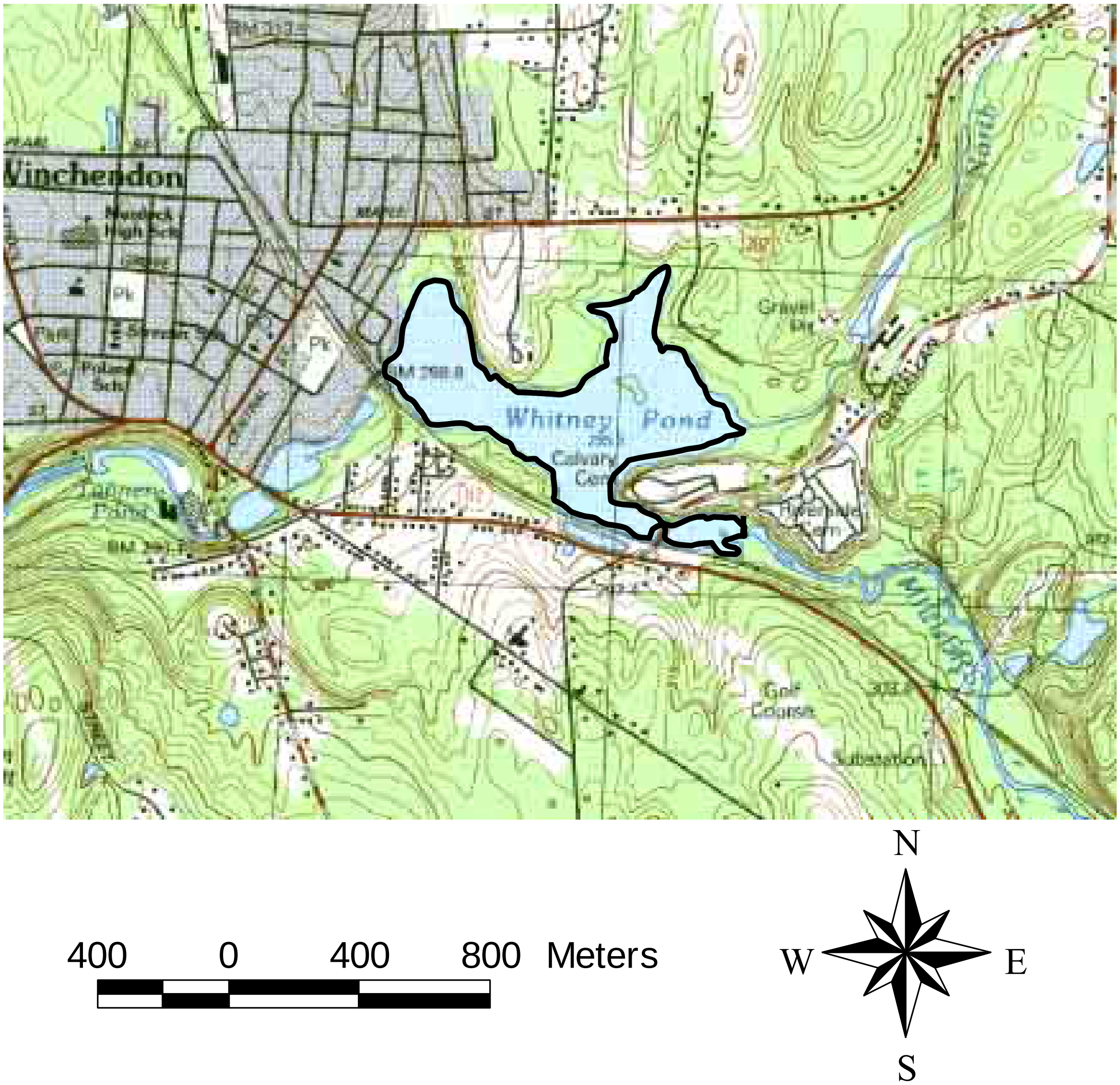


Figure 45. Whitney Pond Environs.

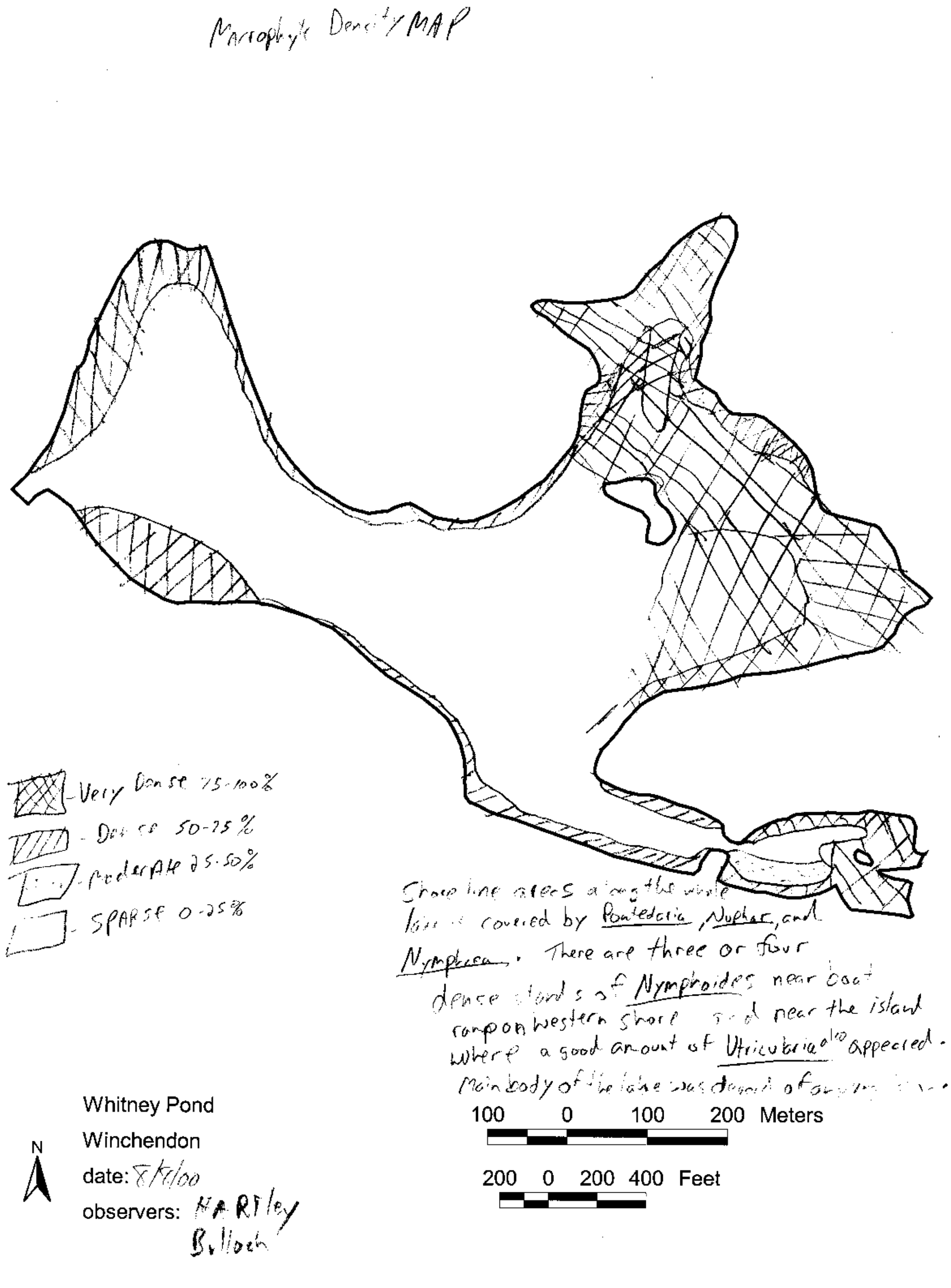


Figure 46. Whitney Pond Macrophyte density distribution (2000)

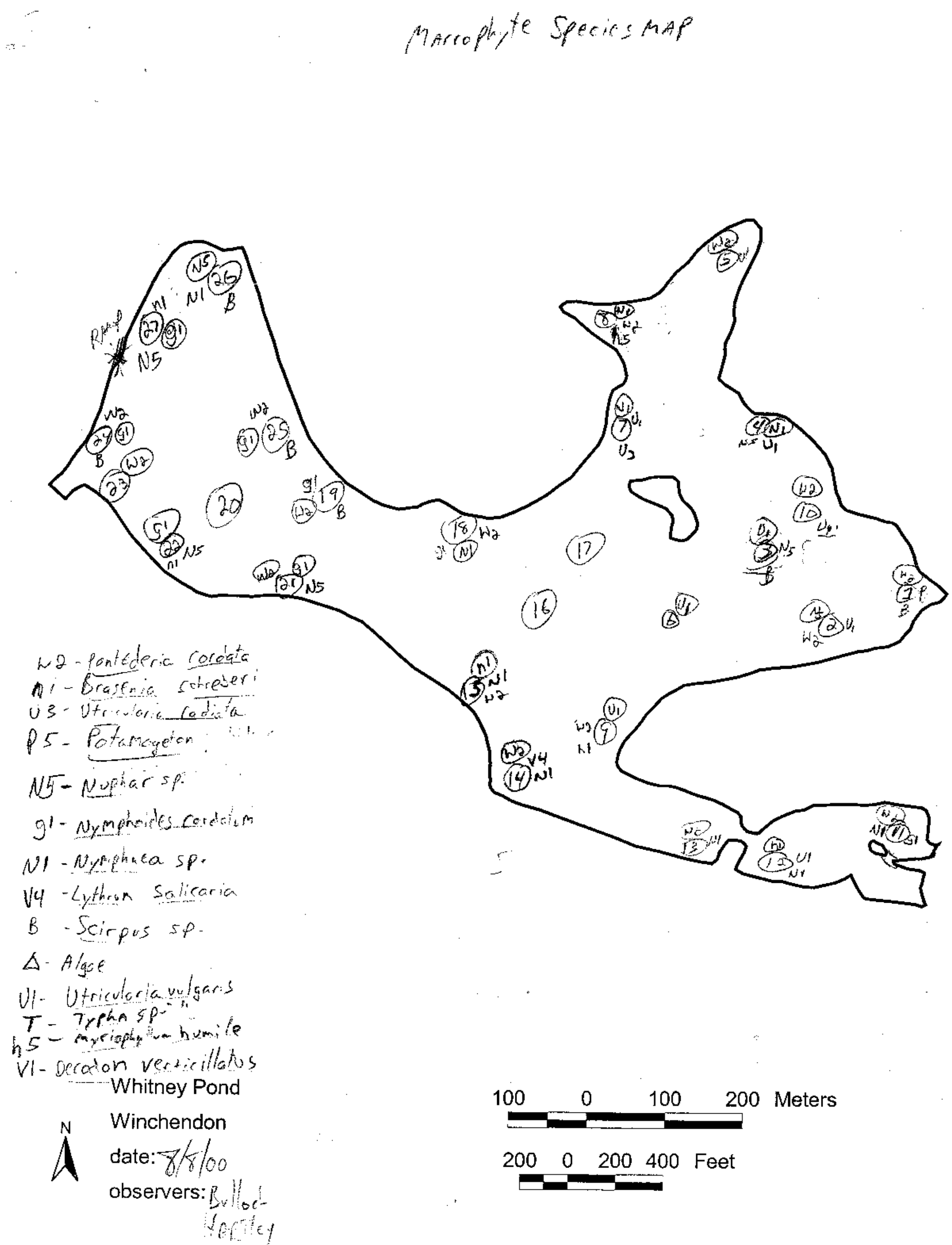


Figure 47. Whitney Pond Macrophyte species distribution (2000)

Wrights Reservoir

in Gardner/Westminster is a large pond of approximately 131 acres with a 14 foot dam. The dominant landuses in the watershed are 67 percent forest, followed by 17 percent rural and agricultural landuse and 15 percent water and wetlands. Urban landuse covers the remaining watershed. Population in Gardner and Westminster has been described above. A DEP baseline survey during September 1987 showed dense growths of macrophytes in Wrights Reservoir and the assessment comments from 1994 reported: " Very dense growths of aquatic macrophytes (primarily *Myriophyllum humile*) cover the littoral zone in the northwest and southeast portions. Historical information on high total phosphorus levels and transparency below safety criteria (4 ft. Secchi disc) was not considered adequate to make assessments.” A site visit in September of 2002 by DEP staff noted the pond water level was approximately 3 feet low and an algae scum was present on the shoreline.

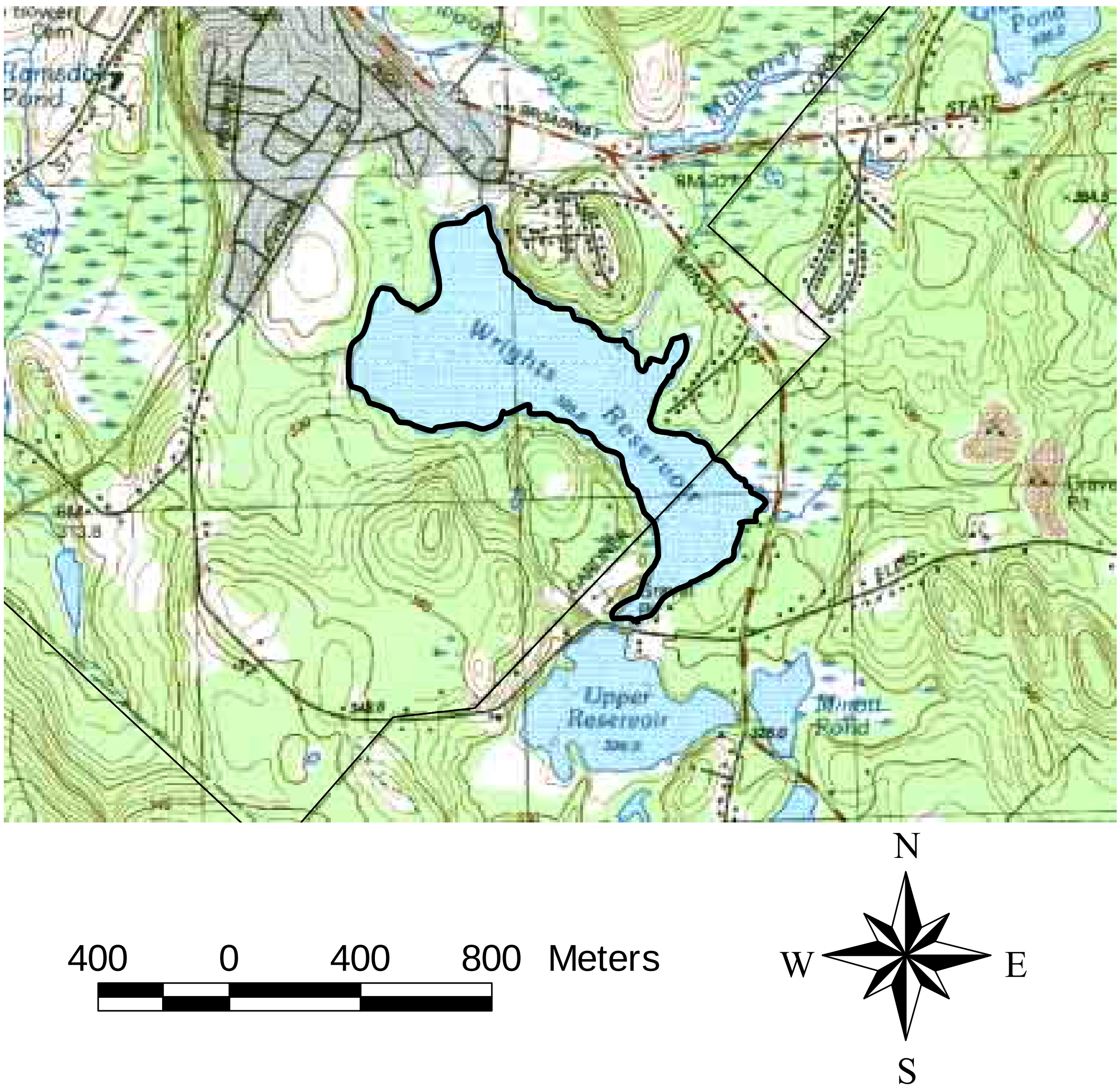


Figure 48. Wrights Reservoir Environs.

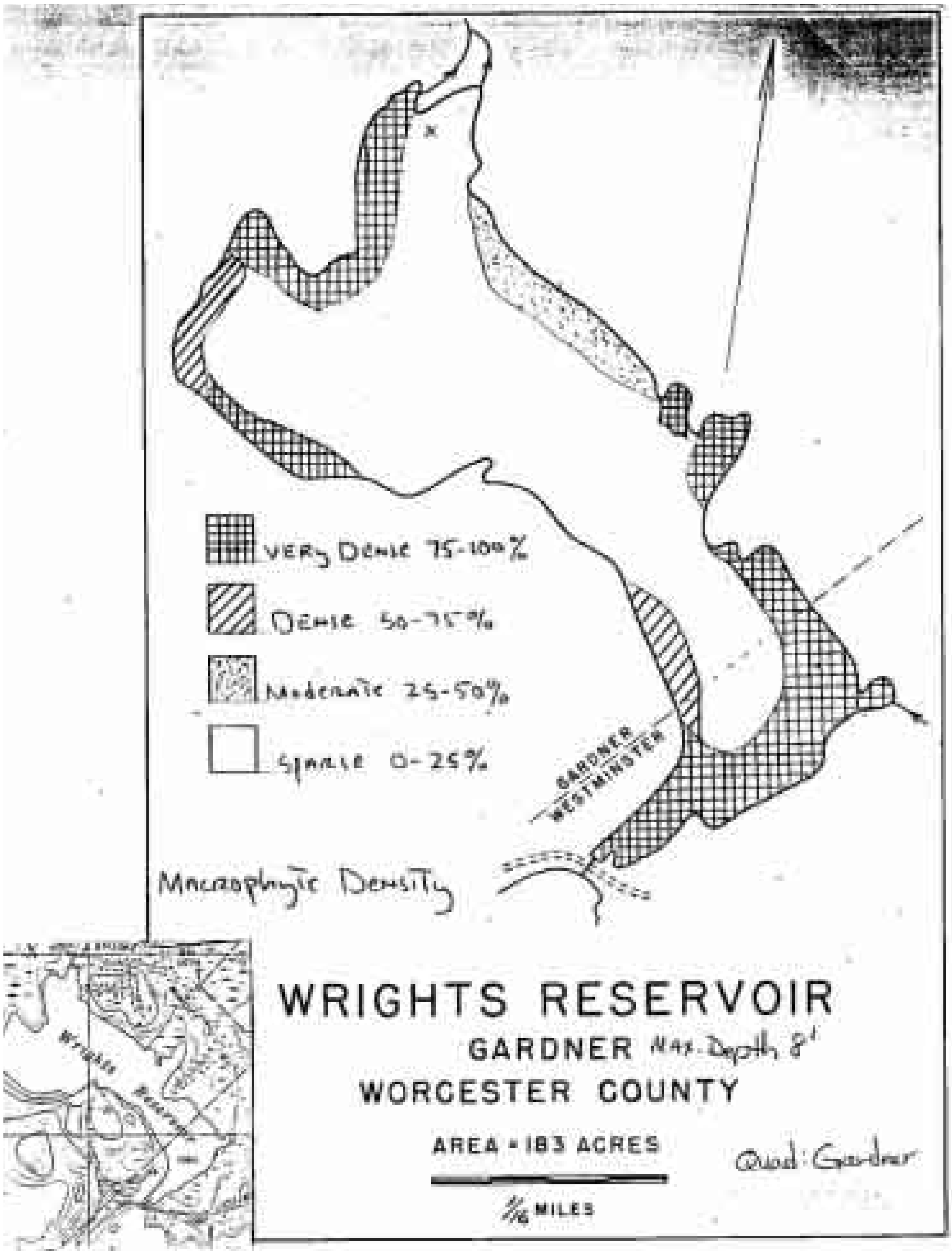


Figure 49. Wrights Reservoir Macrophyte density distribution (1987).

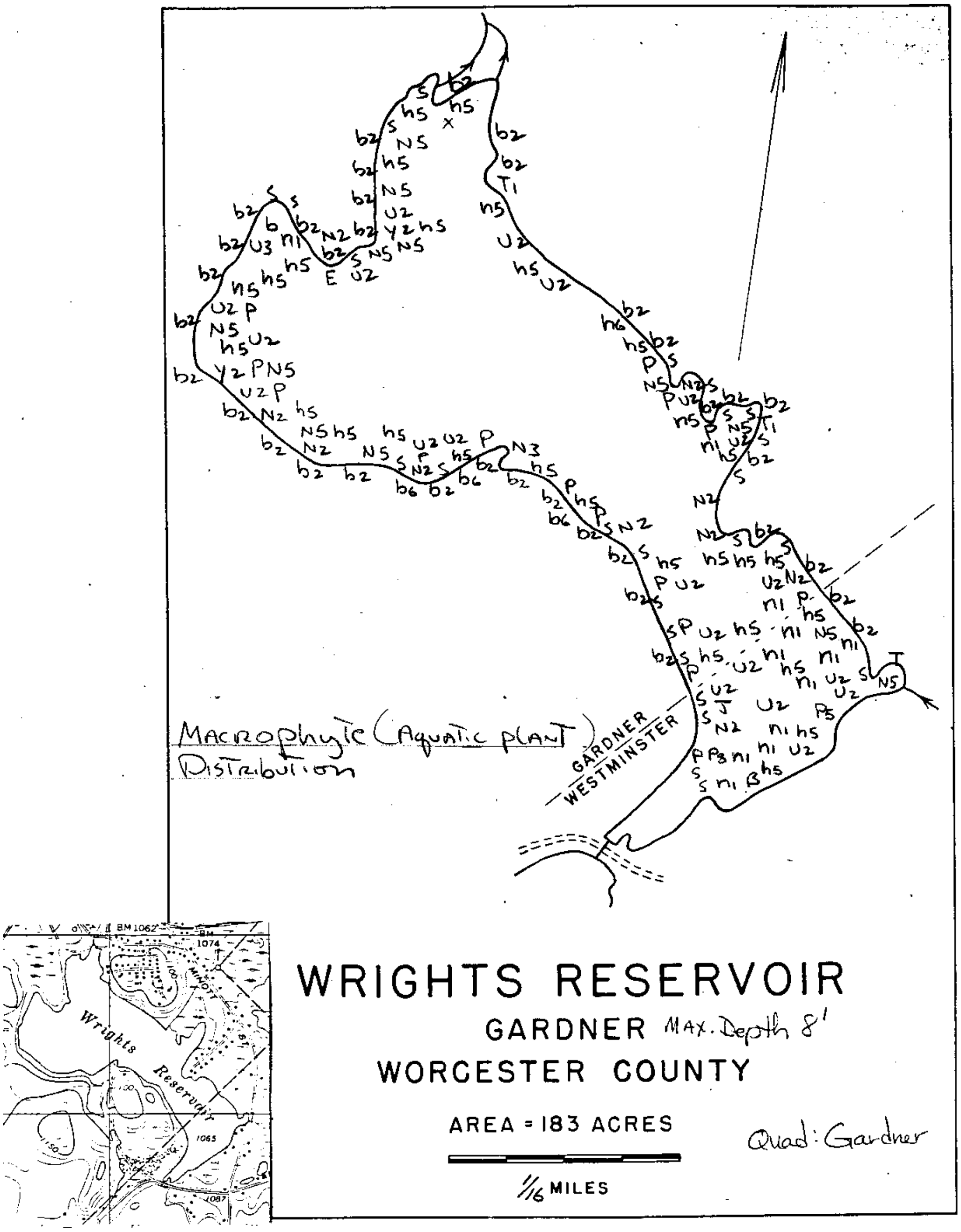


Figure 50. Wrights Reservoir Macrophyte Species distribution (1987).

Pollutant Sources and Background:

No detailed study of the nutrient sources within the lake watersheds has been conducted to date. Thus, nutrient sources were estimated based on land use modeling within the DEP's NPSLAKE model as discussed below (Mattson and Isaac, 1999). The NPSLAKE model of Mattson and Isaac (1999) was designed to estimate watershed loading rates of phosphorus to lakes. The phosphorus loading estimates from the model are used with estimates of water runoff and these are used as inputs into a water quality model of Reckhow (1979). A brief description of the NPSLAKE model and data inputs is given here. MassGIS digital maps of land use (1985 or 1999 when available) within the watershed were used to calculate areas of landuse within three major types: Forest, rural and urban landuse. This model takes the area in hectares of land use within each of three categories and applies an export coefficient to each to predict the annual external loading of phosphorus to the lake from the watershed. Because some of the landuse data is based on old (1985) aerial photographs, the current landuses within the watershed may be different today. This can be important in the development of the TMDL because different landuses can result in different phosphorus loadings to the waterbody in question. For many rural areas, landuse changes often result in conversion of open or agricultural lands to low density housing, in which case, the export coefficients of the NPSLAKE model are the same and no change in loading is predicted to occur. However, in cases where development changes forests to residential areas or rural landuses to urban landuses, phosphorus loadings are predicted to increase. In some cases, loadings are predicted to decrease if additional agricultural land is abandoned and forest regrowth occurs. To account for this uncertainty in landuse changes, a conservative target is chosen (see below). In addition, the MassGIS landuse maps are scheduled to be updated with current aerial photos and the TMDL can be modified as additional information is obtained.

Other phosphorus sources, such as septic system inputs of phosphorus, are estimated from an export coefficient multiplied by the number of homes within 100 meters of the lake. Point sources are estimated manually based on discharge information and site specific information for uptake and storage. Other sources such as atmospheric deposition to lakes was determined to be small and not significant in the NPSLAKE model, perhaps because lakes tend to be sinks rather than sources of phosphorus (Mattson and Isaac, 1999). For similar reasons, wetlands were also not considered to be significant sources of phosphorus following (see discussion and references in Mattson and Isaac, 1999). Other, non-landuse sources of phosphorus such as inputs from waterfowl were generally not included (except as noted below), but can be added as additional information becomes available. If large numbers of waterfowl are using the lake the total phosphorus budget may be an underestimate, and control measures should be considered.

An internal source (recycling) of phosphorus is not included because it is not considered as a net external load to the lake, but rather a seasonal recycling of phosphorus already present in the lake. In cases where this internal source is large it may result in surface concentrations higher than predicted from landuse loading models and may contribute to water quality violations during the critical summer period. As additional monitoring data become available, these lakes will be assessed for internal contributions and possibly control of these sources by alum or other means. The major sources according to the land use analysis are shown for each lake in Appendix V.

The NPSLAKE model assumes land uses are accurately represented by the MassGIS digital maps and that land use has not changed appreciably since the maps were compiled in 1985. The predicted loading is based on the equation:

$$\text{P Loading (kg/yr)} = 0.5 * \text{septics} + 0.13 * \text{forest ha} + 0.3 * \text{rural ha} + 14 * (\text{urban ha})^{0.5}$$

The coefficients of the model are based on a combination of values estimated with the aid of multiple regression on a Massachusetts data set and of typical values reported in previous diagnostic/feasibility studies in Massachusetts. All coefficients fall within the range of values reported in other studies such as Reckhow et al., (1980). Further details on the methods, assumptions, calibration and validation of the NPSLAKE model can be found in Mattson and Isaac (1999). The overall standard error of the model is approximately 172 kg/yr. If no data is available for internal loading a rough estimate of the magnitude of this source can be estimated from the Reckhow model (see below) by substitution of the in-lake concentration for TP. The difference in predicted loadings from this approach and the landuse approach is the best estimate of internal loading.

The NPSLAKE model also generates predictions of estimated yearly average water runoff to the lake based on total watershed area and runoff maps of Massachusetts (see Mattson and Isaac, 1999). Other estimates of nitrogen and total suspended solids (TSS) loading rates are estimates based on Reckhow et al.(1980) and EPA (1983) respectively, and are provided here for informational and comparison purposes only.

Because of the general nature of the landuse loading approach, natural background is included in land use based export coefficients. Natural background can be estimated based on the forest export coefficient of 0.13 kg/ha/yr multiplied by the hectares of the watershed assuming the watershed to be entirely forested. Without site specific information regarding soil phosphorus and natural erosion rates the accuracy of this estimate would be uncertain and would add little value to the analysis.

A recent report on nonpoint source pollution in the Millers basin used slightly different phosphorus coefficients based on the EPA Nationwide Urban Runoff Program (NURP) to estimate loads to several of the lakes (MRPC & FRCG, 2002).

Table 2a. Comparison of NPSLAKE to the NURP estimated phosphorus loads to lakes.

Lake	NURP estimated loads kg/yr	NPSLAKE estimated loads kg/yr
Bents Pond	173	501
Cowee Pond	41	38
Lake Dennison	342	210
Lower Naukeag Lake	345	506
Parker Pond	1455	432
Reservoir #2	70	16
Stoddard Pond	197	177
Wallace Pond	84	129
Whitney Pond	1070	1324

Although the two estimates are correlated there is no consistent difference (bias) between the models. The non-linear Urban landuse loading coefficient used in NPSLAKE may explain some of the variation between the models. Because the NPSLAKE model has been verified against measured loads to lakes (Mattson and Isaac, 1999), the NPSLAKE loads will be used as a basis for these TMDLs.

Water Quality Standards Violations:

With the exception of Cowee Pond, Reservoirs #1 and #2 and Lake Ellis that are Class A water supplies (discussed below), all lakes are listed are designated Class B waters under the Massachusetts Surface Water Quality Standards, the data listed above were judged sufficiently well documented to place the lake on the Massachusetts 303d list for 1998 (DEP, 1998) with Noxious Aquatic Plants listed for most lakes.
The Surface Water Quality Standards are described in the Code of Massachusetts Regulations under sections:

314CMR 4.04 subsection 5:
(5) Control of Eutrophication. From and after the date 314 CMR 4.00 become effective there shall be no new or increased point source discharge of nutrients, primarily phosphorus and nitrogen, directly to lakes and ponds. There shall be no new or increased point source discharge to tributaries of lakes or ponds that would encourage cultural eutrophication or the growth of weeds or algae in these lakes or ponds. Any existing point source discharge containing nutrients in concentrations which encourage eutrophication or growth of weeds or algae shall be provided with the highest and best practical treatment to remove such nutrients. Activities which result in the nonpoint source discharge of nutrients to lakes and ponds shall be provided with all reasonable best management practices for nonpoint source control.

and

314CMR 4.05 (3) b: “These waters are designated as a habitat for aquatic life, and wildlife, and for primary and secondary contact recreation...These waters shall have consistently good aesthetic value.

1. Dissolved Oxygen:

a. Shall not be less than 6.0 mg/l in cold water fisheries nor less than 5.0 mg/l in warm water fisheries unless background conditions are lower;
b. natural seasonal and daily variations above this level shall be maintained…

and

314CMR 4.05 (5) a: All surface waters shall be free from pollutants ......or produce undesirable or nuisance species of aquatic life".

Section 314 CMR 4.40(3) subsection 6 also states:

6. Color and Turbidity - These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class.

In addition, the Minimum Standards for Bathing Beaches established by the Massachusetts Department of Public Health which state that swimming and bathing are not permitted at public beaches when:

105CMR 445.10 (2b) A black disk, six inches in diameter, on a white field placed at a depth of at least 4 feet of water is not readily visible from the surface of the water; or when, under normal usage, such disk is not readily visible from the surface of the water when placed on the bottom where the water depth is less than four feet….

Cowee Pond is a Class A water supply. Reservoirs #1 and #2 and Lake Ellis are still listed as watersupplies and are thus Class A, but these latter reservoirs are no longer being used as water supplies and it is expected they will be moved to Class B above, in the near future. The Code of Massachusetts Regulations (CMR) for Class A waters include 314 CMR 4.05(3)(a):

Class A- These waters are designated as a source of public water supply. To the extent compatible with this use they shall be an excellent habitat for fish, other aquatic life and wildlife, and suitable for primary and secondary contact recreation. These waters shall have excellent aesthetic value. These waters are designated for protection as Outstanding Resource Waters under 314 CMR 4.40(3).

1. Dissolved Oxygen-
   a. Shall not be less than six mg/l unless background conditions are lower;
   b. natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 75% of saturation due to a discharge; and

Section 314 CMR 4.40(3) subsections 5-6 also state:

5. Solids- These waters shall be free from floating, suspended and settleable solids in concentrations or combinations that would impair any use assigned to this class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.
6. Color and Turbidity - These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class.

Because of its status as a water supply, Cowee Pond is classified as an Outstanding Resource Water (Rojko et al., 1995) and is placed in the Class A waters of the Commonwealth under 314 CMR 4.06. The Massachusetts antidegradation provisions of 314 CMR 4.04(3) state in part:

(3) Protection of Outstanding Resource Waters. Certain waters shall be designated for protection under this provision in 314 CMR 4.06(3) including Public Water Supplies (314 CMR 4.06(1)(d)1.) These waters constitute an outstanding resource as determined by their outstanding socio-economic, recreational, ecological and/or aesthetic values. The quality of these waters shall be protected and maintained.

The Water Quality Standards that are applicable to all surface waters also state in section 314CMR 4.05 (5)

a: All surface waters shall be free from pollutants ......or produce undesirable or nuisance species of aquatic life".

TMDL Analysis

Identification of Target: There is no loading capacity *per se* for nuisance aquatic plants. As the term implies, TMDLs are often expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs may be expressed in other terms when appropriate. For these cases, the TMDLs are expressed in terms of allowable annual loadings of phosphorus because the growth of phytoplankton and macrophytes responds to changes in annual rather than daily loadings of nutrients. The target in-lake total phosphorus concentration chosen is based on consideration of the typical concentrations expected in lakes in the region. The phosphorus ecoregion map of Griffith et al. (1994) is based on spring/fall concentrations, while the phosphorus ecoregion map of Rohm et al., (1995) is based on summer concentrations. Table 3.1 shows the ecoregion expected TP concentrations for both spring and summer, and the target TP that was chosen for each lake. The TP predicted by the NPSLAKE model and the surface TP concentrations are also shown for comparison. Note that according to the Carlson Trophic State analysis (Carlson,1977) a lake should have total phosphorus concentrations of about 40 ppb to meet the 4-foot transparency requirement for swimming beaches in Massachusetts. The target should be set lower than this to allow for a margin of safety. The lower phosphorus concentrations will lessen the chance of nuisance algal blooms, which may occur as macrophyte biomass is reduced by direct controls.

Shallow nutrient rich sediments offer an ideal habitat for natural growth of aquatic macrophytes, which provide habitat for fish and wildlife and as such complete elimination of macrophytes is neither possible nor desired. In many cases, the proliferation of aquatic macrophytes in the pond is a natural condition resulting from nutrient rich riparian soils being flooded when streams and lakes were dammed for hydropower. Thus reducing the supply of external phosphorus may not meet the goals of the TMDL without additional management in the lake as discussed below.

Table 3.1 TMDL Total Phosphorus Targets.

Griffith ecoregions are based on Griffith et al. (1994). Rohm ecoregions are based on Rohm et al., (1995). Latest surface total phosphorus concentrations are based on survey data (see text). Note: Recent surveys (Stoddard and Whitney Ponds conducted in 2000 have total phosphorus methods which can detect low concentrations accurately with a method detection limit of 5 ppb. The remaining early (pre-1990) survey TP concentrations have a detection limit of approximately 50 ppb, and values reported for these lakes that are less than this detection limit are suspect. In cases where the NPSLAKE model predicted current total phosphorus concentrations lower than the ecoregion targets, we chose to maintain the lower current total phosphorus concentrations as the final target. Lakes with higher TP than the model estimates may have unknown sources or internal sources of phosphorus.

WBID	Lake Name	TP (ppb) range in Griffith ecoregion	TP (ppb) range in Rohm ecoregion	NPSLAKE Predicted TP (ppb)	*Surface TP data (ppb)	Selected Target TP (ppb)
MA35005	Beaver Pond	5-9	15-19	12.5	NA	12.5
MA35007	Bents Pond	5-9	15-19	33.5	60	15
MA35008	Bourn-Hadley	5-9	15-19	31.1	NA	15
MA35010	Brazell Pond	5-9	15-19	42.1	NA	15
MA35013	Cowee Pond	5-9	15-19	12.7	NA	12.7
MA35015	Davenport Pond	5-9	15-19	12.7	60	12.7
MA35017	Lake Denison	5-9	15-19	20.1	32	15
MA35018	Depot Pond	5-9	15-19	32.2	NA	15
MA35023	Ellis Pond	5-9	15-19	17.5	50	15
MA35025	Greenwood Pond 1	5-9	15-19	13.9	NA	13.9
MA35026	Greenwood Pond 2	5-9	15-19	35.5	NA	15
MA35029	Hilchey Pond	5-9	15-19	27.4	NA	19
MA35041	Lower Naukeag	5-9	15-19	14.5	20	14.5
MA35045	Minott Pond South	5-9	15-19	11.0	NA	11.0
MA35046	Minott Pond	5-9	15-19	16.6	NA	15

MA35047	Lake Monomonac	5-9	15-19	13.3	14	13.3
MA35056	Parker Pond	5-9	15-19	30.0	NA	15
MA35062	Ramsdall Pond	5-9	15-19	32.4	NA	15
MA35063	Reservoir No. 1	5-9	15-19	21.1	NA	15
MA35064	Reservoir No. 2	5-9	15-19	5.1	NA	5.1
MA35065	Riceville Pond	5-9	15-19	15.1	NA	15
MA35078	South Athol Pond	5-9	15-19	17.5	20	15
MA35083	Stoddard Pond	5-9	15-19	21.1	25	15
MA35092	Wallace Pond	5-9	15-19	13.7	NA	13.7
MA35093	Ward Pond	5-9	15-19	15.4	50	15
MA35099	Whites Mill Pond	5-9	15-19	19.8	NA	15
MA35101	Whitney Pond	5-9	15-19	18.5	37	15
MA35104	Wrights Reservoir	5-9	15-19	13.5	60	13.5

NA=Not Available

Loading Capacity

Modeling Assumptions, Key Input, Calibration and Validation:
There are no numeric models available to predict the growth of rooted aquatic macrophytes as a function of nutrient loading estimates, therefore the control of nuisance aquatic plants is based on best professional judgment. However, as previously stated, the goal of the TMDL is to prevent future eutrophication from occurring, thus the nutrient loading still needs to be controlled. To control eutrophication, the Carlson Trophic State Index (TSI) (Carlson,1977) predicts a lake should have total phosphorus concentrations of about 40 ppb to meet the 4-foot transparency requirement for swimming beaches in Massachusetts and targets are set lower than this. Due to the lack of data on mean depth and other parameters, a simple water quality model was used to link watershed phosphorus loading to in-lake total phosphorus concentration targets. Based on the NPSLAKE model phosphorus loading output and predicted water runoff volumes, an estimated in-lake total phosphorus (TP) concentration was derived based on the Reckhow (1979) model:

$$TP=L/(11.6+1.2*q)*1000$$

where TP= the predicted average total phosphorus concentration (mg/l) in the lake.
L= Phosphorus loading in $g/m^2/yr$ (the total loading in grams divided by lake area in meters).
q= The areal water loading in m/yr from total water runoff in m^3/yr divided by lake area in m^2.

Similarly, by setting the TP to the target total phosphorus concentration, a target load was estimated by solving the equation above. As noted in Mattson and Isaac (1999) the Reckhow (1979) model was developed on similar, north temperate lakes and most Massachusetts lakes will fall within the range of phosphorus loading and hydrology of the calibration data set. Additional assumptions, and details of calibration and validation are given in Reckhow (1979).

Wasteload Allocations, Load Allocations and Margin of Safety:

For most lakes, point source wasteload allocation is zero since no point sources have been identified. For lakes with permitted point sources the loading is based on flow and concentrations reported in the DMR reports. The margin of safety is set by establishing a target that is below that expected to meet the 4-foot swimming standard (about 40 ppb). Thus, the TMDL is the same as the target load allocation to nonpoint sources as indicated in the right side of Table 4. Loading allocations are based on the NPSLAKE landuse modeled phosphorus budget. Note that some lakes have surface TP concentrations that are much larger than those predicted by the NPSLAKE. It is difficult to determine the cause of the discrepancy because only one data point was available for each lake and that one sample may not be representative of the lake. If further sampling confirms a discrepancy in these lakes, internal sources of phosphorus, such as the sediments, may also be a contributing source of phosphorus to the surface waters and should be considered for further evaluation and control.

Phosphorus loading allocations for each landuse category are shown (rounded to the nearest kg/yr) in the Tables 4.1-4.28. No reduction in forest loading is targeted, because other than logging operations, which are relatively rare and already have BMPs in place, this source is unlikely to be reduced by additional BMPs. The remaining load reductions are allocated as a proportional phosphorus loading reduction (except as noted below).

The TMDL is the sum of the wasteload allocations (WLA) from point sources (e.g., sewage treatment plants) plus load allocations (LA) from nonpoint sources (e.g., landuse sources) plus a margin of safety (MOS). Thus, the TMDL can be written as:

TMDL = WLA + LA + MOS

In some cases, such as Whites Mill Pond, some reduction in loading from the forest was required to attain the target TMDL. In the case of Whitney Pond the in-lake concentration was much higher than the NPSLAKE model predicted (0.037 mg/l vs. 0.018mg/l). This may be due to errors in the model and/or unmeasured sources of phosphorus to the lake such as internal sediment sources. Although there is a build up of high concentrations of phosphorus in the bottom waters in late summer (0.88 mg/l) it is unlikely this contributes to surface total phosphorus due to the quick flushing of water provided by the Millers River and the lack of any increase in surface TP during the summer. Thus an alum treatment is not warranted in this lake at this time. Further efforts should be put into controlling phosphorus inputs from the watershed. Although cold water (less than 20C or 68F) is present in the hypolimnion there is currently little or no dissolved oxygen present there to support trout during the summer.

Table 4.1. Beaver Pond MA35005 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	38	38
Agriculture	13	13
Open Land	3	3
Residential (Low den.)	3	3
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	0	0
Residential (High den.)	0	0
Total Inputs	56	56

Table 4.2. Bents Pond MA35007 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	160	160
Agriculture	15	3
Open Land	24	5
Residential (Low den.)	54	11
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	92	18
Residential (High den.)	158	31
Total Inputs	501	227

Table 4.3. Bourn-Hadley Pond MA35008 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	48	48
Agriculture	18	5
Open Land	4	1
Residential (Low den.)	17	5
Septic System	2	1
Other	0	0
Waste Load Allocation		
Comm. Indust.	76	21
Residential (High den.)	4	1
Total Inputs	168	81

Table 4.4. Brazell Pond MA35010 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	22	22
Agriculture	11	2
Open Land	1	0
Residential (Low den.)	11	2
Septic System	4	1
Other	0	0
Waste Load Allocation		
Comm. Indust.	62	12
Residential (High den.)	6	1
Total Inputs	117	41

Table 4.5. Cowee Pond MA35013 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	37	37
Agriculture	2	2
Open Land	0	0
Residential (Low den.)	0	0
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	0	0
Residential (High den.)	0	0
Total Inputs	39	39

Table 4.6. Davenport Pond MA35015 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	52	52
Agriculture	2	2
Open Land	1	1
Residential (Low den.)	4	4
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	0	0
Residential (High den.)	0	0
Total Inputs	59	59

Table 4.7. Lake Denison MA35017 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation		
Forest	86	86
Agriculture	8	5
Open Land	16	9
Residential (Low den.)	27	16
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	62	35
Residential (High den.)	12	7
Total Inputs	210	157

Table 4.8. Depot Pond MA35018 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation		
Forest	7	7
Agriculture	1	0
Open Land	3	1
Residential (Low den.)	2	1
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	0	0
Residential (High den.)	30	11
Total Inputs	43	20

Table 4.9. Ellis Pond MA35023 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation		
Forest	98	98
Agriculture	5	3
Open Land	8	5
Residential (Low den.)	21	15
Septic System	9	6
Other	0	0
Waste Load Allocation		
Comm. Indust.	33	23
Residential (High den.)	23	16
Total Inputs	195	167

Table 4.10. Greenwood Pond 1 MA35025 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	5	5
Agriculture	0	0
Open Land	0	0
Residential (Low den.)	5	5
Septic System	2	2
Other	0	0
Waste Load Allocation		
Comm. Indust.	0	0
Residential (High den.)	13	13
Total Inputs	25	25

Table 4.11. Greenwood Pond 2 MA35026 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	47	47
Agriculture	5	1
Open Land	3	0
Residential (Low den.)	21	3
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	15	2
Residential (High den.)	49	6
Total Inputs	140	58

Table 4.12. Hilchey Pond MA35029 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	96	96
Agriculture	2	1
Open Land	6	2
Residential (Low den.)	5	2
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	57	18
Residential (High den.)	8	3
Total Inputs	174	122

Table 4.13. Lower Naukeag Lake MA35041 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation		
Forest	285	285
Agriculture	12	12
Open Land	9	9
Residential (Low den.)	35	35
Septic System	57	57
Other	0	0
Waste Load Allocation		
Comm. Indust.	0	0
Residential (High den.)	108	108
Total Inputs	507	507

Table 4.14. Minott Pond South MA35045 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation		
Forest	22	22
Agriculture	2	2
Open Land	0	0
Residential (Low den.)	7	7
Septic System	1	1
Other	0	0
Waste Load Allocation		
Comm. Indust.	0	0
Residential (High den.)	0	0
Total Inputs	32	32

Table 4.15. Minott Pond MA35046 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation		
Forest	32	32
Agriculture	2	2
Open Land	0	0
Residential (Low den.)	9	6
Septic System	1	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	0	0
Residential (High den.)	0	0
Total Inputs	44	40

Table 4.16. Lake Monomonac MA35047 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation		
Forest	519	519
Agriculture	68	68
Open Land	4	4
Residential (Low den.)	0	0
Septic System	153	153
Other	0	0
Waste Load Allocation		
Comm. Indust.	0	0
Residential (High den.)	143	143
Total Inputs	887	887

Table 4.17. Parker Pond MA35056 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation		
Forest	168	168
Agriculture	6	1
Open Land	32	6
Residential (Low den.)	10	2
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	31	6
Residential (High den.)	185	34
Total Inputs	432	216

Table 4.18. Ramsdall Pond MA35062 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation		
Forest	188	188
Agriculture	19	4
Open Land	29	6
Residential (Low den.)	63	14
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	96	21
Residential (High den.)	166	36
Total Inputs	561	269

Table 4.19. Reservoir No. 1 MA35063 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	43	43
Agriculture	2	1
Open Land	2	1
Residential (Low den.)	7	2
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	16	4
Residential (High den.)	0	0
Total Inputs	71	50

Table 4.20. Reservoir No. 2 MA35064 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	13	13
Agriculture	0	0
Open Land	0	0
Residential (Low den.)	2	2
Septic System	2	2
Other	0	0
Waste Load Allocation		
Comm. Indust.	0	0
Residential (High den.)	0	0
Total Inputs	16	16

Table 4.21. Riceville Pond MA35065 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	173	173
Agriculture	4	4
Open Land	9	8
Residential (Low den.)	12	12
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	8	8
Residential (High den.)	0	0
Total Inputs	206	204

Table 4.22. South Athol Pond MA35078 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation		
Forest	279	279
Agriculture	13	6
Open Land	14	7
Residential (Low den.)	34	16
Septic System	2	1
Other	0	0
Waste Load Allocation		
Comm. Indust.	40	19
Residential (High den.)	4	2
Total Inputs	386	330

Table 4.23. Stoddard Pond MA35083 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation		
Forest	80	80
Agriculture	21	10
Open Land	14	7
Residential (Low den.)	11	5
Septic System	11	5
Other	0	0
Waste Load Allocation		
Comm. Indust.	36	17
Residential (High den.)	6	3
Total Inputs	179	127

Table 4.24. Wallace Pond MA35092 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation		
Forest	121	121
Agriculture	1	1
Open Land	6	6
Residential (Low den.)	1	1
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	0	0
Residential (High den.)	0	0
Total Inputs	129	129

Table 4.25. Ward Pond MA35093 TM DL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	16	16
Agriculture	0	0
Open Land	0	0
Residential (Low den.)	2	2
Septic System	1	1
Other	0	0
Waste Load Allocation		
Comm. Indust.	0	0
Residential (High den.)	0	0
Total Inputs	19	19

Table 4.26. Whites Mill Pond MA35099 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	556	500
Agriculture	68	27
Open Land	4	2
Residential (Low den.)	0	0
Septic System	4	2
Other	0	0
Waste Load Allocation		
Comm. Indust.	0	0
Residential (High den.)	144	58
Total Inputs	776	589

Table 4.27. Whitney Pond MA35101 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	1528	1528
Agriculture	116	7
Open Land	4	0
Residential (Low den.)	0	0
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	76	5
Residential (High den.)	194	12
Total Inputs	1918	1552

Table 4.28. Wrights Reservoir MA35104 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	64	64
Agriculture	5	5
Open Land	4	4
Residential (Low den.)	29	29
Septic System	4	4
Other	0	0
Waste Load Allocation		
Comm. Indust.	23	23
Residential (High den.)	29	29
Total Inputs	157	157

Seasonality: As the term implies, TMDLs are often expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs may be expressed in other terms when appropriate. For this case, the TMDL is expressed in terms of allowable annual loadings of phosphorus. Although critical conditions occur during the summer season when weed growth is more likely to interfere with uses, water quality in many lakes is generally not sensitive to daily or short term loading, but is more a function of loadings that occur over longer periods of time (e.g. annually). Therefore, seasonal variation is taken into account with the estimation of annual loads. In addition, evaluating the effectiveness of nonpoint source controls can be more easily accomplished on an annual basis rather than a daily basis.

For most lakes, it is appropriate and justifiable to express a nutrient TMDL in terms of allowable annual loadings. The annual load should inherently account for seasonal variations by being protective of the most sensitive time of year. The most sensitive time of year in most lakes occurs during summer, when the frequency and occurrence of nuisance algal blooms and macrophyte growth are usually greatest. Therefore, because the phosphorus TMDL was established to be protective of the most environmentally sensitive period (i.e., the summer season), it will also be protective of water quality during all other seasons. Additionally, the targeted reduction in the annual phosphorus load to lakes will result in the application of phosphorus controls that also address seasonal variation. For example, certain control practices such as stabilizing eroding drainage ways or maintaining septic systems will be in place throughout the year while others will be in effect during the times the sources are active (e.g., application of lawn fertilizer). In cases of rapidly flushing (less than 14 days) lakes or impoundments downstream of point sources it may be appropriate to set seasonal limits on phosphorus inputs based on the growing season (April-October). In such cases permit limits in the winter months could be relaxed (e.g. 1 mg/l total phosphorus), provided that permit limits on total suspended solids remain in effect.

Implementation

Considering the lack of information on discrete sources of phosphorus to the lake the implementation plan will of necessity include an organizational phase, an information gathering phase, and the actual remedial action phase. Phosphorus sources can not be reduced or eliminated until the sources of phosphorus are identified. Because many of the nutrient sources are not under regulatory control of the state, engagement and cooperation with local citizens groups, landowners, local officials and government organizations will be needed to implement this TMDL. The Massachusetts Department of Environmental Protection will use the EOEA Watershed Team as the primary means for obtaining public comment and support for this TMDL. The proposed tasks and responsibilities for implementing the TMDL are shown in Table 5. The local citizens within the watershed will be encouraged to participate in the information gathering phase. This phase may include a citizen questionnaire mailed to homeowners within the watershed to obtain information on use of the lake, identify problem areas in the lake and to survey phosphorus use and Best Management Practices in the watershed. The most important part of the information-gathering phase is to conduct a NPS watershed field survey to locate and describe sources of erosion and phosphorus within the watershed following methods described in the DEP guidebook "Surveying a Lake Watershed and Preparing and Action Plan" (DEP, 2001). For this survey volunteers are organized and assigned to subwatersheds to specifically identify, describe and locate potential sources of erosion and other phosphorus sources by driving the roads and walking the streams. Once the survey is completed, the Watershed Team will be asked to review and compile the data and make recommendations for implementation. Responsibility for remediation of each identified source will vary depending on land ownership, local jurisdiction and expertise as indicated in Table 6. For example, the lake association may organize a septic tank pumping program on a two to three year schedule for all lakeside homeowners. Usually a discount for the pumping fee can be arranged if a large number of homeowners apply together. Farmers can apply for money to implement BMPs as part of the NRCS programs in soil conservation. Town public works departments will generally be responsible for reduction of erosion from town roadways and urban runoff. The Conservation Commission will generally be responsible for ensuring the BMPs are being followed to minimize erosion from construction within the town. A description of potential funding sources for these efforts is provided in the Program Background section, above.

The major implementation effort would take place during the year 2006 as part of a rotating 5-year cycle, but would continue in the "off years" as well. The major components for each lake will focus on the major sources of nutrients as summarized in Table 7. This will usually include urban BMPs in urban areas and septic system inspections and other rural BMPs in rural areas. Additional nutrient and erosion control will focus on enforcement of the wetlands protection act by the local Conservation Commission and various Best Management practices supported by the National Resource Conservation Service (NRCS formerly SCS). Best Management Practices (BMPs) for logging are presented in Kittredge and Parker (1995) and BMPs for general nonpoint source pollution control are described in a manual by Boutiette and Duerring (1994), BMPs for erosion and sediment control are presented in DEP (1997). The Commonwealth has provided a strong framework to encourage watershed management through the recent modifications to on-site septic system regulations under Title 5 and by legislation requiring low phosphorus detergents. All of these actions will be emphasized during the outreach efforts of the Watershed Team.

The Department is recommending that the lake be monitored on a regular basis and if the lake does not meet the water quality standards additional implementation measures may be implemented. For example, if phosphorus concentrations remain high after watershed controls are in place, then in-lake control of sediment phosphorus recycling may be considered.

As new housing development expands within the watershed, additional measures are needed to minimize the associated additional inputs of phosphorus. A proactive approach to protecting the lake may include limiting development, particularly on steep slopes near the lake, changes in zoning laws and lot sizes, requirements that new developments and new roadways include BMPs for runoff management and more stringent regulation of septic systems. Examples of town bylaws for zoning and construction, as well as descriptions of BMPs are presented in the Nonpoint Source Management Manual by Boutiette and Duerring (1994), that was distributed to all municipalities in Massachusetts. Other voluntary measures may include encouraging the establishment of a vegetative buffer around the lake and along its tributaries, encouraging the use of non-phosphorus lawn fertilizers and controlling runoff from agriculture and timber harvesting operations. Such actions can be initiated in stages and at low cost. They provide enhancements that residents should find attractive and, therefore, should facilitate voluntary implementation. The National Resource Conservation Service is an ideal agency for such an effort and the residents will be encouraged to pursue NRCS' aid.

Reducing the supply of nutrients will not in itself result in achievement of all the goals of the TMDL and continued macrophyte management is an essential part of the implementation plan.

Table 5. Proposed Tasks and Responsibilities

Tasks	Responsible Group
TMDL development	**DEP**
Public comments on TMDL, Public meeting	**DEP and Watershed Team**
Response to public comments	**DEP**
Organization, contacts with Volunteer Groups	**Watershed Team**
Develop guidance for NPS watershed field survey.	**DEP**
Organize and implement NPS watershed field survey	**Watershed Team and Local Watershed Association**
Compile and prioritize results of NPS watershed surveys	**Watershed Team and Local Watershed Association**
Organize implementation; work with stakeholders and local officials to identify remedial measures and potential funding sources.	**Watershed Team and Local Watershed Association**
Write grant and loan funding proposals, develop lake management plan.	**Local Watershed Association, Towns, Planning Agencies, NRCS**
Organize and implement education, outreach programs	**Local Watershed Association,**
Implement remedial measures for discrete NPS pollution	**See Table 6 below.**
Include proposed remedial actions in the Watershed Management Plan	**Watershed Team**
Provide periodic status reports on implementation of remedial actions to DEP	**Watershed Team**
Monitoring of lake conditions	**Local Watershed Association annually, and DEP during year 2 of the cycle.**

Table 6. Guide to Nonpoint Source Control of Phosphorus and Erosion

Type of NPS Pollution	Whom to Contact	Types of Remedial Actions
Agricultural		
Erosion from Tilled Fields	**Landowner and NRCS**	**Conservation tillage (no-till planting); contour farming; cover crops; filter strips; etc.**
Fertilizer leaching	**Landowner and NRCS and UMass**	**Conduct soil P tests; apply no more fertilizer than required. Install BMPs to prevent runoff.**
Manure leaching	**Landowner and NRCS and UMass**	**Conduct soil P tests. Apply no more manure than required by soil P test. Install manure BMPs.**
Erosion and Livestock impacts	**Landowner and NRCS**	**Fence animals away from streams; provide alternate source of water.**
Construction		
Erosion, pollution from development and new construction.	**Conservation Commission, Town officials, planning boards**	**Enact bylaws requiring BMPs and slope restrictions for new construction, zoning regulations, strict septic regulations. Enforce Wetlands Protection Act**
Erosion at construction sites	**Contractors, Con.Comm.**	**Various techniques including seeding, diversion dikes, sediment fences, detention ponds etc.**
Resource Extraction		
Timber Harvesting	**Landowner, logger, Regional DEM forester**	**Check that an approved forest cutting plan is in place and BMPs for erosion are being followed**
Gravel Pits	**Pit owner, Regional DEP, Con.Comm.**	**Check permits for compliance, recycle wash water, install sedimentation ponds and berms.**
Residential, urban areas		
Septic Systems	**Homeowner, Town Board of Health, Town officials**	**Establish a septic system inspection program to identify and replace systems in non-compliance with Title 5. Discourage garbage disposals.**
Lawn and Garden fertilizers	**Homeowner, Lake associations**	**Establish an outreach and education program to encourage homeowners to eliminate the use of phosphorus fertilizers on lawns, encourage perennial plantings over lawns.**
Runoff from Housing lots	**Homeowner, Lake associations**	**Divert runoff to vegetated areas, plant buffer strips between house and lake**
Urban Runoff	**Landowner, Local Dept. Public Works**	**Reduce impervious surfaces, institute street sweeping, batch basin cleaning, detention basins.**
Highway Runoff	**MassHighway, Mass Turnpike**	**Better management of road sanding, salting, regular sweeping, and installation of BMPs.**
Unpaved Road runoff	**Town or city Dept. Public Works**	**Pave heavily used roads, divert runoff to vegetated areas, install riprap or vegetate eroded ditches.**
Other stream or lakeside erosion	**Landowner, Con. Comm.**	**Determine cause of problem; install riprap, plant vegetation.**

Table 7. Recommended Implementation by Lake

Recommended Implement-ation	Beaver Flowage	Bents	Bourn-Hadley	Brazell	Cowee	Davenport	Denison	Depot	Ellis	Greenwood1	Greenwood2	Hilchey	Lower Naukeag	Minott South	Minot	Monomonac	Parker	Ramsdall	Reservoir No.1	Reservoir No.2	Riceville	South Athol	Stoddard	Wallace	Ward	Whites Mill	Whitney	Wrights
Public Education	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Watershed Survey	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lake Management Plan	*	*	*	*	X	*	X	*	X	*	*	*	X	*	*	X	X	*	*	X	*	X	X	*	*	*	X	X
Forest BMPs	X				X	X								X	X	X			X	X	X	X		X	X	X	X	
Agriculture BMPs	X		X	X			X		X		X			X	X	X							X			X		
Residential BMPs		X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X
Septic System Inspection & Maintenance			X	X					X	X			X		X	X				X		X	X		X	X		
Urban stormwater BMPs		X	X	X					X	X	X	X	X			X	X	X	X								X	X
Highway BMPs		X	X	X					X		X					X		X	X					X			X	
In-Lake Management									X							X	X										X	
Other (Gravel pits, athletic fields, see text)			X						X								X					X					X	

*May need only town-wide NPS management plan focused on protection of these surface waters.

Specific implementation for some lakes and ponds is already underway. In Lake Ellis, aquatic macrophytes became a nuisance and the town initiated a program to treat the lake with herbicides. Although this was specifically not recommended in the BEC (1987) D/F study, the herbicides were effective in controlling the plants in the lake. At Parker Pond a 319 grant was awarded to Gardner to install a detention basin at the large stormwater inlet to the lake. However, due to problems with obtaining the necessary wetlands permits the grant was modified to install several large vortex sediment removal chambers.

Gravel pits are a concern for several ponds in the Millers basin. In some cases these are unregulated gravel operations operating close to surface waters. Bourn-Hadley Pond has one such gravel operation on the western shore and this site should be checked for BMPs and compliance with the Wetlands Protection Act as it appears some clearing of land has occurred within 50 feet of the shore of the pond and there is some evidence of erosion. South Athol Pond also has a gravel operation on the eastern shore that should be checked for BMPs.

Highway runoff should be investigated and BMPs implemented in at least ten ponds in this study (see table above). The BMPs should include at least twice yearly sweeping, catchbasin checking and cleaning on the sections of roads within the watersheds of these ponds. If sediment problems are observed the installation of swales or other infiltration BMPs should be considered as needed. Coordination with MassHighways is critical in regard to implementation of the BMPs in the targeted areas.

In-lake management of rooted aquatic plants is recommended for some recreational lakes that have public access and are deep enough to offer recreational opportunities such as swimming and boating. These may include Lake Ellis, as noted above, Lower Naukeag Lake, Lake Monomonac, Parker Pond and Whitney Pond. In these lakes designated use zoning is recommended to target areas for plant control. Under this approach, areas of the lake are designated in a management plan for different types of uses. Generally, deeper areas (> ten feet) of open water may be designated for boating and/or waterskiing if size permits. Boat access channels from boat launching areas and docks may be designated for access to the open water boating area. Other areas near shore or near residences are designated for swimming and each homeowner may be allowed to remove limited amounts of vegetation in front of their properties. Other shallow and vegetated areas are designated as wildlife habitat areas and are left undisturbed for fish and wildlife as spawning and feeding areas.

Reasonable Assurances

Reasonable assurances that the TMDL will be implemented include both enforcement of current regulations, availability of financial incentives, and the various local, state and federal program for pollution control. Enforcement of regulations includes enforcement of the permit conditions for point sources (as well as Stormwater Phase II permits) under the National Pollutant Discharge Elimination System (NPDES). Enforcement of regulations controlling nonpoint discharges include local enforcement of the states Wetlands Protection Act and Rivers Protection Act; the Title 5 regulations for septic systems and various local regulations including zoning regulations. Financial incentives include Federal monies available under the 319 NPS program and the 604 and 104b programs, which are provided as part of the Performance Partnership Agreement between DEP and the USEPA. Additional financial incentives include state income tax credits for Title 5 upgrades, low interest loans for Title 5 septic system upgrades, Clean Water Act State Revolving Fund (SFR) loans, and cost sharing for agricultural BMPs under the Federal NRCS program. Lake management grants are also provided by the State Department of Environmental Management Lakes and Ponds Program.

Water Quality Standards Attainment Statement

The proposed TMDL, if fully implemented, will result in the attainment of all applicable water quality standards, including designated uses and numeric criteria for each pollutant named in the Water Quality Standards Violations noted above.

Monitoring

Monitoring by DEP will be continued on a regular basis according to the five-year watershed cycle. Baseline surveys on the lake should include Secchi disk transparency, nutrient analyses, temperature and oxygen profiles and aquatic vegetation maps of distribution and density. At that time the strategy for reducing plant cover and reducing total phosphorus concentrations can be re-evaluated and the TMDL modified, if necessary. Additional monitoring by volunteer groups is encouraged.

Public Participation

A public meeting was announced in the Environmental Monitor and in local papers. The public meeting was held in the Millers River Environmental Center in Athol Massachusetts on the evening of November 14, 2002 to present the report to the public. The attendance list is included in Appendix VI.

Public Comment and Reply

During the public meeting much of the discussion focused on control of phosphorus from various sources. Public comments were received at the public meeting and comments were received in writing within a 15 day comment period following the public meeting. The following is a summary of comments and the Departmental replies.

1) Comment: Phosphorus Loading Assumptions - As I have commented on the prior TMDL reports (for three Worcester-area lakes and the French Basin Lakes), this report sets forth an assumption that highways are significant contributors of phosphorus to receiving waters. To our knowledge, the majority of contaminants contained in highway runoff (especially in particulate form) are associated with the sand used during winter maintenance operations, which is assumed to contain only minor amounts of nutrients. These sands have relatively large particle sizes, with correspondingly low surface area that would serve as phosphate adsorption sites. However, conditions may vary from highway to highway. This is one of the reasons that MassHighway is working toward developing a research study that would collect stormwater data and develop a contaminant loading model for highway runoff.

Reply: While sand may be considered low in nutrients, high concentrations of nutrients are known to be associated with highway runoff in both dissolved form and associated with fine sediments that run off the roadway. A review of many highway runoff studies conducted by the Federal Highway Administration (FHWA) reported the Event Mean Concentration for suspended solids was 143 mg/l and that the EMC for PO_4-P was 0.435 mg/l (Driscoll et al., 1990). These levels that are not considered "minor amounts" as EPA generally recommends that phosphorus inputs to lakes be less than 0.050 mg/l. A USGS review of dozens of other reports also indicated substantial biological impacts from highway runoff (Buckler and Granato, 1999). There are many lane miles of state highways (e.g. Route 2) that drain directly to many of the ponds in the Millers Basin. In addition, nutrients are not the sole focus of pollutant runoff from MassHighways. Highway sand and other solids discharged from roadways are a pollution source that also contributes to infilling of wetlands and lakes

We are pleased that you have developed scope of work for further research on highway runoff. As previously discussed, DEP would be happy to work with you on a revised scope to address these issues from a statewide prospective. However, DEP cannot delay the development of the TMDLs any further. The Federal Clean Water Act, Federal regulations and EPA policy require us to complete the TMDLs based on best available evidence and that is basis for this TMDL. In order to implement the TMDL in the absence of loading information for specific highways and city streets, DEP has established a set of performance standards for maintenance of all roadways within the affected watershed.

2) Comment: Maintenance Recommendations – MassHighway has very limited maintenance budgets and staff. The cost-effectiveness, and necessity of cleaning catch basins twice per year should be closely evaluated rather than arbitrarily set. Evaluation criteria includes sediment accumulation rates, and phosphorus concentrations in catch basin sediments. For example, catch basins at the sag of a hill will accumulate sediments at a greater rate than those at the crest of a hill. MassHighway's approach to monitoring catch basins will be included in its NPDES Stormwater Management Plan (to be submitted to EPA on 3/10/03).

Reply: The twice-yearly schedule was based on best available literature, however DEP is willing to work with MassHighway to establish site-specific schedules.

3) Comment: Improvements to Stormwater Quality – MassHighway believes that the most cost-effective approach to improving stormwater quality is to focus on source control measures, rather than end-of-pipe BMPs. Two important examples include reducing winter road sand application rates, and stabilizing shoulder areas that erode onto road surfaces.

Reply: Your comment is noted.

4) Comment: p.87, Table 6. This table pertains to remedial actions for controlling phosphorus and erosion. Therefore any reference to "salting," which has only trace amounts of phosphorus, should be omitted from the Remedial Actions for Highway Runoff. Also, "Better management of" should replace the term "Regulate," so as to avoid any confusion by the reader that actual laws will be promulgated which mandate specific maintenance requirements.

Reply: It is DEP's understanding that phosphorus is in some cases being added to roadsalt as a corrosion preventative agent. We would like to obtain further information from MassHighways about the phosphorus content of the salt and sand used before we modify the report. Regarding the term 'regulate', the change was made to the table as it refers to actions taken by MassHighway and MassTurnpike, however, DEP reserves the right to establish additional policies to regulate stormwater runoff and protect surface waters.

5) Comment: p.89, paragraph 2. As described above, MassHighway has very limited maintenance budgets. MassHighway is developing a realistic Operation and Maintenance approach to its road system – which will be incorporated into our NPDES Stormwater Management Plan. MassHighway currently believes that, unless extraordinary conditions exist, that catch basins cannot be practicably cleaned more often than once every one or two years, and quite often the lack of sediment accumulations does not warrant this effort. (At present, MassHighway's road network contains approximately 83,000 catch basins.)

Reply: The availability of funding may help set priorities but does not relieve a community or an agency from achieving water quality goals. We are not targeting all 83,000 of MassHighways catch basins for twice yearly cleaning. We will however target catch basins and highway BMPs in watersheds of critical 303d listed waters.

6)Comment: The only activity seen in recent years on any of the four ponds in Templeton would be Bourn-Hadley and Brazell. Bourne-Hadley has an extensive gravel removal operation taking place adjacent to the north-west quadrant of the pond. Orders of Conditions were issued just this year providing for a buffer strip along the edge of the pond, mitigation to prevent siltation from entering the pond, and final reclamation of the site. A 'Request for Determination of Applicability' is currently pending for the upgrade of a septic system on a lot bordering the north end of Brazell Pond.

We are uncertain as to the differentiation between Greenwood Ponds (35025) and (35026). Can we assume that the one with the higher predicted load is just south of Route 2A? This pond is bordered by several businesses. The Greenwood Pond identified on our quad map just south of Route 2 shows no activity. Also the Town of Templeton has no wetland bylaw.

Reply: Your comments are noted. In regard to Greenwood Ponds, please refer to Figure 19 and 20 which show the two ponds. Both are located south of Route 2, but Greenwood Pond 2 in Templeton is actually bisected by Route 2 and has higher estimated loadings than Greenwood Pond 1 in Westminster.

7) Comment: The town of Winchendon has no bylaws relating to wetlands or lakes, but the Conservation Commission's regulatory authority, the Massachusetts Wetlands Act, is regarded with particular sensitivity. It can also be said, with a reasonable degree of certainty, that re-engineered septic systems for lakefront properties required under Title V are improving water quality in Lake Monomonac, Stoddard Pond and Whitney Pond. This is due, in part, to new septic systems replacing direct discharge into the Millers River which feeds Whitney Pond.

Lake Denison is within land owned by the Army Corps of Engineers and maintained by Department of Environmental Management, but hearings are still required under the Wetlands Act for any recreational area modifications. Very few private residences have been constructed on Whites Mill Pond in recent years and this pond is in the discharge chain for Lake Monomonac.

Reply: Your comments are noted.

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Appendix I Baseline Lakes Data

BASELINE LAKE SURVEYS

Two of the 303d listed lakes in the Millers River Basin were selected for baseline surveys. Lakes were preferentially targeted for sampling based on the severity of the nutrient-related problem and the size of the lake (MA DEP 1999a). Those lakes that were listed solely for non-nutrient related issues (e.g., lakes listed for fish consumption advisories) and those with previous diagnostic/feasibility studies were not selected. Baseline surveys were conducted to provide information on the current chemical, physical and biological conditions of the lake system (i.e., in-lake and in the surrounding watershed).

Each baseline lake survey included a macrophyte survey conducted once during the late summer at the peak of macrophyte growth (generally in July/August/September). The survey data are used in several ways: 1) to determine if the macrophyte growth causes nuisance conditions such that the lake would be listed or delisted on the state's 303d list for violations of water quality standards; 2) to determine if the lake meets designed uses in the 305b assessments; 3) to monitor changes in density of plant growth following implementation of a TMDL; 4) to document invasive species distributions in the state; and 5) to suggest macrophyte management options for the lake. The data are used to validate Total Maximum Daily Load (TMDL) phosphorus loading models and to document the present trophic conditions as well as assessing the status of lake's designated uses. The total phosphorus data are used to evaluate accuracy of land use loading estimates (Mattson and Isaac 1999) of total phosphorus to lakes by comparing predictions of lake concentrations based on modeling to actual measured lake concentrations. These may be used as a basis for estimation of internal loading or other unmeasured phosphorus sources. Concurrently a lake database will be developed for both 303d development and for 305b evaluation based on lakes that are on the current 303d list. The data contained in this database along with the other data collected are used in TMDL development or to monitor lakes for changes in water quality and nuisance plant growth after TMDL implementation.

In the Millers River Basin, baseline lake surveys were conducted between July and October 2000 to coincide with maximum growth of aquatic vegetation, highest recreational use, and highest lake productivity. Lakes (Figure B2) were sampled three times each (monthly intervals). The deep hole in Stoddard Pond, Winchendon were sampled 18-July, 17 August and 13 September 2000. The deep hole of Whitney Pond, Winchendon was sampled 18 July, 17 August and 13 September 2000.

In situ measurements using the Hydrolab® (measures dissolved oxygen, water temperature, pH, conductivity, and depth and calculates total dissolved solids and % oxygen saturation) were recorded. At deep hole stations measurements were recorded at various depths creating profiles. In-lake (as well as unnamed tributary) samples were also collected for alkalinity, total phosphorus, apparent color, and chlorophyll *a* (an integrated sample). Procedures used for water sampling and sample handling are described in the *Grab Collection Techniques for DWM Water Quality Sampling Standard Operating Procedure* and the *Hydrolab® Series 3 Multiprobe Standard Operating Procedure* (MA DEP 1999b and MA DEP 1999c). The hydrdolab used was provided by Massachusetts Division of Fisheries and Wildlife, whose staff also collected the samples. In some cases hydrolab data was censored because of insufficient documentation of calibration procedures. The Wall Experiment Station (WES), the Department's analytical laboratory, supplied all sample bottles and field preservatives, which were prepared according to the WES *Laboratory Quality Assurance Plan and Standard Operating Procedures* (MA DEP 1995). Samples were preserved in the field as necessary, transported on ice to WES, and analyzed according to the WES Standard Operating Procedure (SOP). The quality control protocol that was followed for field and equipment blank samples is described in Appendix I of this report. Both quality control samples (field blanks, trip blanks, and split samples) and raw water quality samples were transported on ice to WES on each sampling date; they were subsequently analyzed according to the WES SOP. Information about data quality objectives (accuracy, precision, detection limits, holding times, representativeness and comparability) is also presented in Appendix I. Apparent color and chlorophyll *a* were measured according to standard procedures at the DEP DWM office in Worcester (MA DEP 1999d and MA DEP 1999e). An aquatic macrophyte survey was conducted at each lake. The aquatic plant cover (native and non-native) and species distribution was mapped and recorded. Details on procedures used can be found in the *Baseline Lake Survey Quality Assurance Project Plan* (DEP DWM 1999a).

The *in-situ* Hydrolab® lake data are provided in Table B13. Alkalinity, total phosphorus, apparent color, chlorophyll *a*, and Secchi depth data are provided in Table B14. These data are managed and maintained in DWM's *Water Quality Data Access Database*.

Table B13. 2001 MA DEP DWM Millers River Basins *in-situ* Hydrolab® lake data.

Date	OWMID	OWMID QA/QC	Time (24hr)	Depth (m)	Temp (°C)	pH (SU)	Cond @ 25 °C (µS/cm)	TDS (mg/l)	DO (mg/l)	SAT (%)
Millers River Basin										
Stoddard Pond (Palis: 35083)										
Station: A Descript ion: deep hole in northern end, Winchendon										
09/13/00	LB-1107		10:30	0	21.0	5.7	39.7	23.8	7.6	84
			10:34	0.5	20.8	5.7	39.6	23.8	7.5	82
			10:39	1.0	18.9	5.3	40.7	24.4	2.3	24
			10:43	1.5	17.6	5.2	41.7	25.0	0.4	4
			10:48	2.0	16.6	5.5	51.5	30.9	<0.2	<2
Whitney Pond (Palis: 35101)										
Station: A Description: deep hole in western quadrant of pond, Winchendon										
09/13/00	LB-1103		12:15	0	21.6	6.3	86.5	51.9	8.6	97
			12:18	0.5	19.4	5.6	87.1	52.3	5.4	58
			12:25	1.0	18.7	5.5	86.1	51.7	3.8	40
			12:30	1.5	17.9	5.4	85.5	51.3	2.0	20
			12:33	2.0	17.5	5.3	85.4	51.2	1.1	11
			12:38	2.5	17.3	5.3	85.0	51.0	0.2	2
			12:42	3.0	17.1	5.3	85.4	51.2	<0.2	<2
			12:46	3.5	16.8	5.5	86.5	51.9	<0.2	<2
			12:49	4.0	16.3	6.0	101.3	60.8	<0.2	<2
			12:53	4.5	15.6	6.5	127.6	76.6	<0.2	<2
			12:56	5.0	15.0	6.8	150.0	90.0	<0.2	<2

"**i**" = **i**naccurate readings from Hydrolab® multiprobe likely; may be due to significant pre-survey calibration problems, post-survey calibration readings outside typical acceptance range for the low ionic check and for the deionized blank water check, or lack of calibration of the depth sensor prior to use.

"**m**" = **m**ethod not followed; one or more protocols contained in the DWM Hydrolab® SOP not followed, ie. operator error (eg. less than 3 readings per station (rivers) or per depth (lakes), or instrument failure not allowing method to be implemented.

"**u**" = **u**nstable readings, due to lack of sufficient equilibration time prior to final readings, non-representative location, highly-variable water quality conditions, etc. (See Section 4.1 for acceptance criteria.)

Table B14. 2000 MA DEP DWM Millers River Basin in-lake Secchi depth, alkalinity, color, total phosphorus and chlorophyll *a* data.

Date	Time (24hr)	Secchi Depth (m)	Station Depth (m)	OWMID	OWMID QA/QC	Sample Depth (m)	Alkalinity (mg/l)	Apparent Color (PCU)	Total Phosphorus mg/l	Chlorophyll *a* (mg/m^3)
Millers River Basin										
Stoddard Pond (Palis: 35083)										
Station: A				**Description: deep hole in northern end, Winchendon**						
07/18/00	13:33	1.8	1.8							
				LB-1019		0.5	<0.2	65**m**	0.028	--
				LB-1020		1.3	2	65**m**	0.024	--
				LB-1021		1.3	--	--	--	8.6
Station: A				**Description: deep hole in northern end, Winchendon**						
08/17/00	11:53	1.4	2.1							
				LB-1062		0.5	4	140	0.027	--
				LB-1063		1.6	3	170	0.037	--
				LB-1064		1.6	--	--	--	2.9
Station: A				**Descript ion: deep hole in northern end, Winchendon**						
09/13/00	10:27	1.5	2.7							
				LB-1104		0.5	5	160**b**	0.02**b**	--
				LB-1105		2.2	3	260**b**	0.4**b**	--
				LB-1106		2.2	--	--	--	4.6**h**

Whitney Pond (Palis: 35101)

Station: A **Description deep hole in western quadrant of pond, Winchendon**

Date	Time (24hr)	Secchi Depth (m)	Station Depth (m)	OWMID	OWMID QA/QC	Sample Depth (m)	Alkalinity (mg/l)	Apparent Color (PCU)	Total Phosphorus mg/l	Chlorophyll *a* (mg/m^3)
07/18/00	10:25	1.5	0.8							
				LB-1013	LB-1014	0.5	3	--	0.034	--
				LB-1014	LB-1013	0.5	<0.2	130	0.038	--
				LB-1015	BLANK		<0.2	<15	<0.005	--
				LB-1016		4.5	--	--	--	4.3
				LB-1017		4.5	3	360	0.057	--
				LB-1018		only one pH taken at surface				

Station: A **Description deep hole in western quadrant of pond, Winchendon**

Date	Time (24hr)	Secchi Depth (m)	Station Depth (m)	OWMID	OWMID QA/QC	Sample Depth (m)	Alkalinity (mg/l)	Apparent Color (PCU)	Total Phosphorus mg/l	Chlorophyll *a* (mg/m^3)
08/17/00	10:27	1.2	5.3							
				LB-1055	LB-1056	0.5	2	160	0.039	--
				LB-1056	LB-1055	0.5	3	--	0.045	--
				LB-1057	DUP	0.5	4	--	0.042	--
				LB-1058	BLANK		<0.2	---	0.005	--
				LB-1059		4.8	10	260	0.092	--
				LB-1060		3.6	--	--	--	0.1

Station: A **Description deep hole in western quadrant of pond, Winchendon**

Date	Time (24hr)	Secchi Depth (m)	Station Depth (m)	OWMID	OWMID QA/QC	Sample Depth (m)	Alkalinity (mg/l)	Apparent Color (PCU)	Total Phosphorus mg/l	Chlorophyll *a* (mg/m^3)
09/13/00	12:11	1.2	5.6							
				LB-1097	LB-0198	0.5	3	340**b**	0.031**b**	--
				LB-1098	LB-0197	0.5	3	190**b**	0.033**b**	--
				LB-1099	DUP	0.5	< 0.2	320**b**	0.032**b**	--
				LB-1100	BLANK	--	<0.2	21**b**	0.031**b**	--
				LB-1101		5.1	12	**580bm**	0.88**b**	
				LB-1102		3.6	--	--	--	2.7

“ ** ” = Censored or missing data

“ -- ” = No data

“ b ” = **b**lank Contamination in lab reagent blanks and/or field blank samples (indicating possible bias high and false positives).

“ **d** ” = precision of field **d**uplicates (as RPD) did not meet project data quality objectives identified for program or in QAPP; batch samples may also be affected

“ **h** ” = **h**olding time violation (usually indicating possible bias low)

“ **m ”** = **m**ethod SOP not followed, only partially implemented or not implemented at all, due to complications with sample matrix (e.g. sediment in sample, floc formation), lab error (e.g., cross-contamination between samples), additional steps taken by the lab to deal with matrix complications, and lost/unanalyzed samples.

“ **p** ” = samples not **p**reserved per SOP or analytical method requirements.

Appendix II. Macrophyte Species Codes.

Plant species (common name)	Code	Plant species (common name)	Code
Macroscopic algae (mats, clumps, etc.)	Δ	Najas sp. “Bushy Pondweed” or Naiad”	J
Chara sp. “Muskgrass”	Δ1	Ruppia maritima “Widgeon Grass”	J1
Nitella sp. “Stonewort”	Δ2	Najas flexilis “Slender Naiad”	J2
Bryozoan	Δ3	Najas minor “European Naiad”	J3
		Najas guadalupensis “Naiad”	J4
Moss		Najas gracillima	J5
Riccia fluitans “Slender Riccia”	M1		
Ricciocarpus natans “Purple-fringed Riccia”	M2		
		Alisma sp. “Water-Plantain”	A1
Other aquatic ferns	N	Echinodorus sp. “Burhead”	A2
Osmunda regalis “Royal Fern”	N1	Sagittaria sp. “Arrowhead” or “Duck Potato”	A3
Marsilea quadrofolia “Pepperwort”	N2	Sagittaria sp. (submerged form only)	A4
Azolla caroliniana “Water-velvet”	N3	S. latifolia “Common Arrowhead”	A5
Salvinia rotundifolia “Floating Moss”	N4	S. rigida “Stiff Arrowhead”	A6
		S. teres “Dwarf Wapato	A7
Isoetes sp. “Quillwort”	I	S. graminea “Grassy Arrowhead”	A8
I. tuckermani “Quillwort”	I1		
		Vallisneria americana “Wild Celery” or “Tape Grass”	H1
Typha latifolia “Common Cattail”	T	Elodea sp. “Waterweed”	H2
Typha angustifolia “Narrow-leaved Cattail”	T1	E. nattallii “Waterweed”	H3
Typha glauca “Hybrid Cattail”	T2	E. canadensis “Canadian Waterweed”	H4
		Egeria densa “Brazilian elodea”	H5
Sparganium sp. “Bur Reed”	S	Gramineae (Grass Family)	G
S. fluctuans “Water Bur Reed”	S1		
S. eurycarpum “Giant Bur Reed”	S2	Cyperus sp. “Flat Sedge”	Y1
S. americanum “Bur Reed”	S3	Dulichium arundinaceum “Three-way Sedge”	Y2
		Fimbristylis sp. “Fimbristylis”	Y3
Potamogeton sp. “Pondweed”	P	Rynchospora sp. “Beak Rush”	Y4
P. amplifolias “Largeleaf Pondweed”	P1	Cladium sp. “Twig Rush” or “Sawgrass”	Y5
P. crispus “Curlyleaf Pondweed”	P2		
P. richardsonii “Richardson Pondweed”	P3	Carex sp.	X
P. robbinsii “Flatleaf Pondweed”	P4		
P. epihydrus “Ribbonleaf Pondweed”	P5	Scirpus sp. “Bulrush”	B
P. sp. “Thin-leaved Pondweed”	P6	S. validus “Softstem Bulrush”	B1
P. gramineus “Grassleaf Pondweed”	P7	S. cyperinus “Woolgrass Bulrush”	B2
P. natans “Floatingleaf Pondweed”	P8	S. americanus “American Bulrush”	B3
P. vaseyi “Vasey’s Pondweed”	P9	S. atrovirens “Dark-green Bulrush”	B4
P. capillaceus “Pondweed”	P10	S. subterminalis	B5
P. folisus “Leafy Pondweed”	P11		
P. tenuifolius “Pondweed”	P12	Eleocharis sp. “Spike Rush”	E
P. perfoliatus “Redhead Grass”	P13	E. acicularis “Needle Spike Rush”	E1
P. pusillus “Slender Pondweed” or “Baby Pondweed”	P14	E. smallii “Spike Rush”	E2
P. spirillus “Snailseed Pondweed”	P15	E. palustris “Common Spike Rush”	E3

P. pectinatus “Sago Pondweed” P16
P. illinoensis “Illinois Pondweed” P17
P. pulcher “Heartleaf Pondweed” P18
P. bicupulatus “Snailseed Pondweed” P19
P. zosteriformis “Flatstem Pondweed” P20
P. nodosus P21
P. oakesianus P22
Spirodela polyrhiza “Big Duckweed” L1
Wolffia sp. “Watermeal” L2
Wolffiella floridana “Florida Wolffiella” L3
Lemna sp. “Duckweed” L4
L. minor “Common Duckweed” L5
L. trisulca “Star Duckweed” L6

Xyris sp. “Yellow-eyed Grass” e
Eriocaulon sp. “Pipewort” e1
E. septangulare “Pipewort” e2
Heteranthera dubia “Mud Plantain” W1
Pontederia cordata “Pickerelweed” W2
P. cordata forma taenia “Pickerelweed” W3

Iris sp. “Iris” j1
Juncus sp. “Rush” j2
Saururus cernuus “Lizard’s tail” j3

Rumex sp. “Dock” Q1
Polygonum sp. “Smartweed” Q2

Salix sp. “Willow” b1
Myrica gale “Sweet Gale” b2
Alnus sp. “Alder” b3
Nyssa sp. “Sour Gum” or “Tupelo” b4
Cornus sp. “Dogwood” b5
Chamaedaphne calyculata “Leatherleaf” b6
Fraxinus sp. “Ash” b7
Cephalanthus occidentalis “Buttonbush” b8
Ilex verticillata “Virginia Winterberry” or “Black Alder” b9
Clethra alnifolia “Sweet Pepperbush” b10

Ceratophyllum sp. “Coontail” C
Ceratophyllum demersum “Coontail” C1
C. echinatum C2

Nymphaea sp. “Water Lily” N1
N. odorata “Fragrant Water Lily” N2
N. tuberosa “White Water Lily” N3
Nuphar sp. “Yellow Water Lily”, or “Spatterdock” N5
N. variegatum “Painted Cow Lily” N6

Brasenia schreberi “Water Shield” n1
Nelumbo lutea “American Lotus” n2

Peltandra virginica “Arrow Arum” a1
Calla palustris “Water Arum” a2
Orontium aquaticum “Golden Club” a3
Acorus calamus “Sweet Flag” a4

Subularia aquatica “Awlwort” M1
Neobeckia aquatica “Lake Cress” M2
Cardamine sp. “Bitter Cress” M3
Rorippa sp. “Water Cress” M4

Podostenum sp. “River Weed” r

Callitriche sp. “Water Starwort” k1
Elatine sp. “Waterwort” k2
Viola sp. “Violet” k3
Hypericum sp. “St. John’s-wort” k4
H. boreale f. callitrichoides “St. John’s-wort” k5

Decodon verticillatus “Swamp Loosestrife” V1
Trapa natans “Water Chestnut” V2
Ludwigia sp. “False Loosestrife” V3
Lythrum salicaria “Purple or Spiked Loosestrife” V4
Rhexia virginica “Virginia Meadow-beauty” V5
Hippuris vulgaris “Mare’s-tail” h1
Prosperinaca sp. “Mermaid Weed” h2
Myriophyllum sp. “Water Milfoil h3
M. heterophyllum “Broadleaf Water Milfoil” h4
M. humile “Water Milfoil” h5
M. tenellum “Leafless Milfoil” h6
M. spicatum h7

Sium suave “Water Parsnip” f1
Hydrocotyle sp. “Water Pennywort” f2
Cicuta sp. “Water Hemlock” f3

Hottonia inflata “Featherfoil” m1
Samolus sp. “Water Pimpernel” m2
Lysimachia sp. “Loosestrife” m3
L. ciliata “Loosestrife” m4

Nymphoides cordatum “Floating Heart” g1
Asclepias sp. “Milkweed” g2
Myosotis sp. “Forget-me-not” g3

Stachys sp. “Hedge Nettle” t1
Scutellaria sp. “Skullcap” t2
Physostegia sp. “False Dragonhead” t3
Lycopus sp. “Water Horehound” t4
Mentha sp. “Mint” t5

Cabomba caroliniana "Fanwort" n3

Caltha palustris "Marsh Marigold" R1
Myosurus minimus "Mousetail" R2
Ranunculus sp. "Buttercup" or "Crowfoot" R3

Bacopa sp. "Water Hyssop" F1
Limosella sp. "Mudwort" F2
Veronica sp. "Speedwell" F3
Chelone sp. "Turtlehead" F4
Mimulus sp. "Monkey Flower" F5
Lindernia sp. "False Pimpernel" F6
Gratiola sp. "Hedge Hyssop" F7
G. virginiana "Hedge Hyssop" F8

Lobelia sp. O
L. cardinalis "Cardinal Flower" O1
L. dortmanna "Water Lobelia" O2

Solanum dulcamara "Nightshade" t6

Utricularia sp. "Bladderwort" U
U. vulgaris "Common Bladderwort" U1
U. purpurea "Purple Bladderwort" U2
U. radiata "Floating Bladderwort" U3
U. intermedia "Flat-leaved Bladderwort" U4
Megalodonta beckii "Water Marigold" Z1
Eupatorium sp. "Joe-pye Weed" Z2
Bidens sp. "Bur Marigold", "Beggar-ticks", Z3
Helenium sp. "Sneezeweed" Z4
Solidago sp. "Goldenrod" Z5
Aster sp. "Aster" Z6
Coreopis rosea "Pink Tickseed" Z7

Equisetum sp. "Horsetail" i
E. fluviatile "Swamp or Water Horsetail" i1

Drosera rotundifolia "Roundleaf Sundew" D

Vaccinium sp. "Cranberry" d

Phragmites sp. "Reed Grass" q

Appendix III Carlson Trophic State Index (TSI)

Carlson's Trophic State Index and Attributes of Lakes.
(Modified from http://dipin.kent.edu/tsi.htm and Carlson and Simpson (1996).

A list of possible changes that might be expected in a north temperate lake as the amount of algae changes along the trophic state gradient.

TSI	Chl (ug/L)	SD (m)	TP (ug/L)	Attributes	Water Supply	Fisheries & Recreation
<30	<0.95	>8	<6	**Oligotrophy:** Clear water, oxygen throughout the year in the hypolimnion	Water may be suitable for an unfiltered water supply.	Salmonid fisheries dominate
30-40	0.95-2.6	8-4	6-12	Hypolimnia of shallower lakes may become anoxic		Salmonid fisheries in deep lakes only
40-50	2.6-7.3	4-2	12-24	**Mesotrophy:** Water moderately clear; increasing probability of hypolimnetic anoxia during summer	Iron, manganese, taste, and odor problems worsen. Raw water turbidity requires filtration.	Hypolimnetic anoxia results in loss of salmonids. Walleye may predominate
50-60	7.3-20	2-1	24-48	**Eutrophy:** Anoxic hypolimnia, macrophyte problems possible		Warm-water fisheries only. Bass may dominate.
60-70	20-56	0.5-1	48-96	Blue-green algae dominate, algal scums and macrophyte problems	Episodes of severe taste and odor possible.	Nuisance macrophytes, algal scums, and low transparency discourage swimming and boating.
70-80	56-155	0.25-0.5	96-192	**Hypereutrophy:** (light limited). Dense algae & macrophytes		
>80	>155	<0.25	192-384	Algal scums, few macrophytes		Rough fish dominate; summer fish kills possible

Reference:
Carlson, R.E. and J. Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. 96 pp.

Appendix IV Summer Carlson Trophic State Index (TSI) Calculations.

Table IV Average Summer Trophic Status of Millers Basin Lakes Surveyed in 2000.

Pond Name	Secchi M	Chl a ppb	TP ppb	PCU color	Secchi TSI	Chl a TSI	TP TSI	Average TSI	Trophic State
Stoddard*	1.6	5.4	25	150	53	47	50	50	Eutrophic
Whitney*	1.3	2.6	37	190	56	39	56	51	Eutrophic

Appendix V NPSLAKE model results.

Table V.1. Beaver Pond MA35005

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	373.4 Ha (1.4 mi2)
Average Annual Water Load =	2276475.9 m3/yr (2.6 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	15.4 Ha. (38.0ac)
Areal water loading to lake: q=	14.8 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	290.3 (77.7)	37.7 (66.8)	725.7	6966.6
Rural category				
Agriculture:	43.1 (11.5)	12.9 (22.9)	267.4	7086.7
Open land:	8.8 (2.3)	2.6 (4.7)	45.6	131.4
Residential Low:	10.7 (2.9)	3.2 (5.7)	58.9	4157.8
Other Landuses				
Water:	14.9 (4.0)	0.0 (0.0)	0.0	0.0
Wetlands:	5.7 (1.5)	0.0 (0.0)	0.0	302.6
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Urban category				
Residential High:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Total	373.4 (100.0)	56.5(100)	1097.6	18645.2

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.4 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 12.5 ppb.
Predicted transparency = 3.8 meters.

Table V.2. Bents Pond MA35007

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	2020.3 Ha (7.8 mi2)
Average Annual Water Load =	12315962.7 m3/yr (13.9 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	2.5 Ha. (6.2ac)
Areal water loading to lake: q=	494.2 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	1227.0 (60.7)	159.5 (31.8)	3067.5	29448.0
Rural category				
Agriculture:	48.9 (2.4)	14.7 (2.9)	383.1	12179.8
Open land:	78.9 (3.9)	23.7 (4.7)	410.2	9446.5
Residential Low:	180.1 (8.9)	54.0 (10.8)	990.7	69889.1
Other Landuses				
Water:	111.6 (5.5)	0.0 (0.0)	0.0	0.0
Wetlands:	56.7 (2.8)	0.0 (0.0)	0.0	3006.0
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Urban category				
Residential High:	200.5 (9.9)	157.6 (31.5)	1351.4	104037.3
Comm - Ind:	116.6 (5.8)	91.7 (18.3)	1162.7	82885.9
Total	2020.3 (100.0)	501.2(100)	7392.1	311245.0

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 20.1 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 33.3 ppb.
Predicted transparency = 1.4 meters.

Table V.3. Bourn-Hadley Pond MA35008

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	572.7 Ha (2.2 mi2)
Average Annual Water Load =	3491251.9 m3/yr (4.0 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	10.4 Ha. (25.8ac)
Areal water loading to lake: q=	33.5 m/yr.
Homes with septic systems within 100m of lake.=	4.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	368.0 (64.3)	47.8 (28.5)	919.9	8831.3
Rural category				
Agriculture:	59.5 (10.4)	17.8 (10.6)	579.2	19681.6
Open land:	13.4 (2.3)	4.0 (2.4)	69.6	592.4
Residential Low:	56.2 (9.8)	16.8 (10.0)	308.9	21788.6
Other Landuses				
Water:	17.5 (3.1)	0.0 (0.0)	0.0	0.0
Wetlands:	25.9 (4.5)	0.0 (0.0)	0.0	1371.5
Other P inputs:	NA	0.0 (0.0)		
4.0 Septics:	NA	2.0 (1.2)		
Urban category				
Residential High:	1.5 (0.3)	3.6 (2.1)	8.1	683.8
Comm - Ind:	30.8 (5.4)	76.0 (45.2)	307.5	23067.6
Total	572.7 (100.0)	168.1(100)	2193.2	76016.7

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 1.6 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 31.1 ppb.
Predicted transparency = 1.5 meters.

Table V.4. Brazell Pond MA35010

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	286.5 Ha (1.1 mi2)
Average Annual Water Load =	1746712.8 m3/yr (2.0 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	5.9 Ha. (14.7ac)
Areal water loading to lake: q=	29.4 m/yr.
Homes with septic systems within 100m of lake.=	7.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	171.9 (60.0)	22.3 (19.1)	429.7	4124.7
Rural category				
Agriculture:	36.0 (12.6)	10.8 (9.2)	313.0	10143.0
Open land:	4.0 (1.4)	1.2 (1.0)	20.8	451.6
Residential Low:	38.0 (13.3)	11.4 (9.7)	208.8	14733.2
Other Landuses				
Water:	6.2 (2.2)	0.0 (0.0)	0.0	0.0
Wetlands:	7.0 (2.4)	0.0 (0.0)	0.0	369.2
Other P inputs:	NA	0.0 (0.0)		
7.0 Septics:	NA	3.5 (3.0)		
Urban category				
Residential High:	2.0 (0.7)	5.8 (4.9)	11.0	931.9
Comm - Ind:	21.6 (7.5)	62.2 (53.1)	214.9	18181.3
Total	286.5 (100.0)	117.2(100)	1198.2	48935.0

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 2.0 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 42.1 ppb.
Predicted transparency = 1.1 meters.

Table V.5. Cowee (Mamjohn) Pond MA35013

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	296.6 Ha (1.1 mi2)
Average Annual Water Load =	1807775.1 m3/yr (2.0 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	7.4 Ha. (18.3ac)
Areal water loading to lake: q=	24.5 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	282.1 (95.1)	36.7 (95.3)	705.2	6770.3
Rural category				
Agriculture:	4.9 (1.7)	1.5 (3.8)	25.6	575.4
Open land:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Residential Low:	1.1 (0.4)	0.3 (0.9)	6.3	444.7
Other Landuses				
Water:	8.4 (2.8)	0.0 (0.0)	0.0	0.0
Wetlands:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Urban category				
Residential High:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Total	296.6 (100.0)	38.5(100)	737.1	7790.4

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.5 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 12.7 ppb.
Predicted transparency = 3.8 meters.

Table V.6. Davenport Pond MA35015

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	434.1 Ha (1.7 mi2)
Average Annual Water Load =	2646452.7 m3/yr (3.0 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	12.3 Ha. (30.4ac)
Areal water loading to lake: q=	21.5 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	397.6 (91.6)	51.7 (88.2)	994.0	9542.9
Rural category				
Agriculture:	8.1 (1.9)	2.4 (4.1)	42.2	948.8
Open land:	2.8 (0.7)	0.9 (1.5)	14.7	184.4
Residential Low:	12.2 (2.8)	3.6 (6.2)	66.9	4720.0
Other Landuses				
Water:	12.8 (2.9)	0.0 (0.0)	0.0	0.0
Wetlands:	0.6 (0.1)	0.0 (0.0)	0.0	32.7
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Urban category				
Residential High:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Total	434.1 (100.0)	58.6(100)	1117.9	15428.7

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.5 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 12.7 ppb.
Predicted transparency = 3.8 meters.

Table V.7. Lake Denison MA35017

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	895.4 Ha (3.5 mi2)
Average Annual Water Load =	5458283.7 m3/yr (6.2 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	33.8 Ha. (83.5ac)
Areal water loading to lake: q=	16.2 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	658.4 (73.5)	85.6 (40.7)	1645.9	15801.1
Rural category				
Agriculture:	27.0 (3.0)	8.1 (3.9)	133.5	3002.8
Open land:	52.1 (5.8)	15.6 (7.4)	270.7	10959.1
Residential Low:	91.2 (10.2)	27.3 (13.0)	501.4	35369.6
Other Landuses				
Water:	33.8 (3.8)	0.0 (0.0)	0.0	0.0
Wetlands:	5.5 (0.6)	0.0 (0.0)	0.0	292.5
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Urban category				
Residential High:	4.4 (0.5)	11.6 (5.5)	24.0	2032.9
Comm - Ind:	23.2 (2.6)	61.8 (29.4)	230.9	5688.5
Total	895.4 (100.0)	210.1(100)	2818.1	73302.2

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.6 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 20.1 ppb.
Predicted transparency = 2.4 meters.

Table V.8. Depot Pond MA35018

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	86.3 Ha (0.3 mi2)
Average Annual Water Load =	526172.1 m3/yr (0.6 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	6.2 Ha. (15.2ac)
Areal water loading to lake: q=	8.5 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	54.1 (62.7)	7.0 (16.2)	135.2	1298.1
Rural category				
Agriculture:	4.4 (5.1)	1.3 (3.0)	54.9	2023.9
Open land:	9.7 (11.3)	2.9 (6.7)	50.7	2192.1
Residential Low:	5.4 (6.3)	1.6 (3.7)	29.7	2098.3
Other Landuses				
Water:	6.8 (7.8)	0.0 (0.0)	0.0	0.0
Wetlands:	1.2 (1.4)	0.0 (0.0)	0.0	62.7
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Urban category				
Residential High:	4.7 (5.5)	30.4 (70.2)	49.3	3480.7
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Total	86.3 (100.0)	43.3(100)	319.8	11155.9

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.7 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 32.2 ppb.
Predicted transparency = 1.5 meters.

Table V.9. Ellis Pond MA35023

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	962.9 Ha (3.7 mi2)
Average Annual Water Load =	5869792.6 m3/yr (6.6 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	35.4 Ha. (87.5ac)
Areal water loading to lake: q=	16.6 m/yr.
Homes with septic systems within 100m of lake.=	17.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	755.7 (78.5)	98.2 (50.4)	1889.2	18136.0
Rural category				
Agriculture:	15.0 (1.6)	4.5 (2.3)	100.3	2510.0
Open land:	25.0 (2.6)	7.5 (3.8)	130.0	5692.9
Residential Low:	68.4 (7.1)	20.5 (10.5)	376.1	26533.6
Other Landuses				
Water:	65.6 (6.8)	0.0 (0.0)	0.0	0.0
Wetlands:	17.3 (1.8)	0.0 (0.0)	0.0	916.4
Other P inputs:	NA	0.0 (0.0)		
17.0 Septics:	NA	8.5 (4.4)		
Urban category				
Residential High:	6.5 (0.7)	22.9 (11.7)	35.8	3034.8
Comm - Ind:	9.4 (1.0)	32.9 (16.9)	93.5	8382.0
Total	962.9 (100.0)	195.1(100)	2624.9	65205.7

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.6 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 17.5 ppb.
Predicted transparency = 2.7 meters.

Table V.10. Greenwood Pond #1 MA35025

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	69.3 Ha (0.3 mi2)
Average Annual Water Load =	422387.9 m3/yr (0.5 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	10.9 Ha. (27.0ac)
Areal water loading to lake: q=	3.9 m/yr.
Homes with septic systems within 100m of lake.=	3.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	35.8 (51.7)	4.7 (18.8)	89.5	859.4
Rural category				
Agriculture:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Open land:	1.1 (1.6)	0.3 (1.4)	5.9	51.5
Residential Low:	17.4 (25.0)	5.2 (21.1)	95.4	6733.0
Other Landuses				
Water:	10.9 (15.7)	0.0 (0.0)	0.0	0.0
Wetlands:	3.3 (4.7)	0.0 (0.0)	0.0	172.8
Other P inputs:	NA	0.0 (0.0)		
3.0 Septics:	NA	1.5 (6.1)		
Urban category				
Residential High:	0.9 (1.2)	13.0 (52.6)	4.7	402.1
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Total	69.3 (100.0)	24.7(100)	195.6	8218.9

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.2 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 13.9 ppb.
Predicted transparency = 3.4 meters.

Table V.11. Greenwood Pond #2 MA35026

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	502.8 Ha (1.9 mi2)
Average Annual Water Load =	3065121.4 m3/yr (3.5 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	2.2 Ha. (5.5ac)
Areal water loading to lake: q=	138.0 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	357.4 (71.1)	46.5 (33.3)	893.6	8578.4
Rural category				
Agriculture:	17.1 (3.4)	5.1 (3.7)	169.2	5778.2
Open land:	10.8 (2.2)	3.2 (2.3)	56.3	1150.1
Residential Low:	69.8 (13.9)	20.9 (15.0)	383.8	27078.7
Other Landuses				
Water:	20.0 (4.0)	0.0 (0.0)	0.0	0.0
Wetlands:	6.8 (1.4)	0.0 (0.0)	0.0	362.3
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Urban category				
Residential High:	15.9 (3.2)	48.8 (34.9)	87.3	7394.0
Comm - Ind:	4.9 (1.0)	15.0 (10.8)	48.8	2005.8
Total	502.8 (100.0)	139.6(100)	1638.9	52347.5

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 6.3 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 35.5 ppb.
Predicted transparency = 1.4 meters.

Table V.12. Hilchey Pond MA35029

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	822.6 Ha (3.2 mi2)
Average Annual Water Load =	5014426.9 m3/yr (5.7 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	3.1 Ha. (7.6ac)
Areal water loading to lake: q=	162.8 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	741.7 (90.2)	96.4 (55.3)	1854.3	17800.9
Rural category				
Agriculture:	6.5 (0.8)	2.0 (1.1)	44.5	765.6
Open land:	19.3 (2.3)	5.8 (3.3)	100.2	3162.6
Residential Low:	17.4 (2.1)	5.2 (3.0)	95.6	6746.2
Other Landuses				
Water:	4.6 (0.6)	0.0 (0.0)	0.0	0.0
Wetlands:	11.6 (1.4)	0.0 (0.0)	0.0	612.2
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Urban category				
Residential High:	2.8 (0.3)	8.3 (4.8)	15.2	1289.5
Comm - Ind:	18.8 (2.3)	56.6 (32.5)	187.2	890.8
Total	822.6 (100.0)	174.4(100)	2297.1	31267.8

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 5.7 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 27.4 ppb.
Predicted transparency = 1.8 meters.

Table V.13. Lower Naukeag Lake MA35041

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	2880.8 Ha (11.1 mi2)
Average Annual Water Load =	17561231.7 m3/yr (19.9 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	119.6 Ha. (295.4ac)
Areal water loading to lake: q=	14.7 m/yr.
Homes with septic systems within 100m of lake.=	114.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	2193.8 (76.2)	285.2 (56.3)	5484.4	52650.4
Rural category				
Agriculture:	40.9 (1.4)	12.3 (2.4)	251.8	5538.1
Open land:	29.2 (1.0)	8.8 (1.7)	151.9	1180.2
Residential Low:	117.8 (4.1)	35.3 (7.0)	648.0	45710.8
Other Landuses				
Water:	317.4 (11.0)	0.0 (0.0)	0.0	0.0
Wetlands:	122.1 (4.2)	0.0 (0.0)	0.0	6470.8
Other P inputs:	NA	0.0 (0.0)		
114.0 Septics:	NA	57.0 (11.3)		
Urban category				
Residential High:	59.5 (2.1)	108.0 (21.3)	327.4	27740.0
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Total	2880.8 (100.0)	506.6(100)	6863.5	139290.4

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.4 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 14.5 ppb.
Predicted transparency = 3.3 meters.

Table V.14. Minott Pond South MA35045

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	217.0 Ha (0.8 mi2)
Average Annual Water Load =	1323136.4 m3/yr (1.5 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	11.1 Ha. (27.3ac)
Areal water loading to lake: q=	12.0 m/yr.
Homes with septic systems within 100m of lake.=	1.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	170.1 (78.4)	22.1 (70.1)	425.2	4081.8
Rural category				
Agriculture:	7.3 (3.4)	2.2 (7.0)	38.9	859.5
Open land:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Residential Low:	22.4 (10.3)	6.7 (21.3)	123.2	8691.7
Other Landuses				
Water:	12.5 (5.8)	0.0 (0.0)	0.0	0.0
Wetlands:	4.7 (2.2)	0.0 (0.0)	0.0	250.6
Other P inputs:	NA	0.0 (0.0)		
1.0 Septics:	NA	0.5 (1.6)		
Urban category				
Residential High:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Total	217.0 (100.0)	31.5(100)	587.3	13883.7

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.3 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 11.0 ppb.
Predicted transparency = 4.4 meters.

Table V.15. Minott Pond MA35046

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	310.0 Ha (1.2 mi2)
Average Annual Water Load =	1889665.2 m3/yr (2.1 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	3.4 Ha. (8.4ac)
Areal water loading to lake: q=	55.3 m/yr.
Homes with septic systems within 100m of lake.=	2.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	246.6 (79.5)	32.1 (72.4)	616.4	5917.7
Rural category				
Agriculture:	8.1 (2.6)	2.4 (5.5)	42.9	950.2
Open land:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Residential Low:	29.2 (9.4)	8.8 (19.8)	160.7	11337.7
Other Landuses				
Water:	16.3 (5.3)	0.0 (0.0)	0.0	0.0
Wetlands:	9.7 (3.1)	0.0 (0.0)	0.0	516.2
Other P inputs:	NA	0.0 (0.0)		
2.0 Septics:	NA	1.0 (2.3)		
Urban category				
Residential High:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Total	310.0 (100.0)	44.3(100)	820.0	18721.8

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 1.3 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 16.6 ppb.
Predicted transparency = 2.9 meters.

Table V.16. Lake Monomonac MA35047

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	4794.1 Ha (18.5 mi2)
Average Annual Water Load =	29224671.0 m3/yr (33.1 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	271.8 Ha. (671.3ac)
Areal water loading to lake: q=	10.8 m/yr.
Homes with septic systems within 100m of lake.=	305.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	3993.8 (83.3)	519.2 (58.5)	9984.6	95852.2
Rural category				
Agriculture:	227.4 (4.7)	68.2 (7.7)	2842.8	104842.0
Open land:	12.5 (0.3)	3.8 (0.4)	65.1	187.8
Residential Low:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	455.2 (9.5)	0.0 (0.0)	0.0	0.0
Wetlands:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other P inputs:	NA	0.0 (0.0)		
305.0 Septics:	NA	152.5 (17.2)		
Urban category				
Residential High:	105.1 (2.2)	143.5 (16.2)	577.9	48964.7
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Total	4794.1 (100.0)	887.2(100)	13470.4	249846.8

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.3 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 13.3 ppb.
Predicted transparency = 3.6 meters.

If all land were primeval forest P export would be 564.1 kg/yr
And the forested condition lake TP would be 8.5 ppb.
Thus anthropogenic inputs increase lake TP by 57.3 percent.
The Trophic State Index has increased from 35.0 to 41.5
The Lake is predicted to be mesotrophic and in a natural condition.

Table V.17. Parker Pond MA35056

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	1762.6 Ha (6.8 mi2)
Average Annual Water Load =	10745106.9 m3/yr (12.2 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	13.0 Ha. (32.2ac)
Areal water loading to lake: q=	82.5 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	1290.2 (73.2)	167.7 (38.8)	3225.5	30964.4
Rural category				
Agriculture:	21.1 (1.2)	6.3 (1.5)	177.0	5502.8
Open land:	107.9 (6.1)	32.4 (7.5)	561.2	17626.1
Residential Low:	32.6 (1.9)	9.8 (2.3)	179.5	12664.2
Other Landuses				
Water:	49.0 (2.8)	0.0 (0.0)	0.0	0.0
Wetlands:	23.8 (1.4)	0.0 (0.0)	0.0	1263.7
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Urban category				
Residential High:	204.2 (11.6)	185.3 (42.9)	1776.8	118846.6
Comm - Ind:	33.7 (1.9)	30.6 (7.1)	336.5	26049.2
Total	1762.6 (100.0)	432.2(100)	6256.5	212917.0

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 3.3 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 30.0 ppb.
Predicted transparency = 1.6 meters.

Table V.18. Ramsdall Pond MA35062

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	2348.5 Ha (9.1 mi2)
Average Annual Water Load =	14316250.3 m3/yr (16.2 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	0.9 Ha. (2.1ac)
Areal water loading to lake: q=	1649.3 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	1445.1 (61.5)	187.9 (33.5)	3612.7	34682.2
Rural category				
Agriculture:	64.8 (2.8)	19.4 (3.5)	494.0	14391.0
Open land:	95.2 (4.1)	28.6 (5.1)	495.0	10719.3
Residential Low:	211.2 (9.0)	63.4 (11.3)	1161.7	81950.7
Other Landuses				
Water:	117.5 (5.0)	0.0 (0.0)	0.0	0.0
Wetlands:	66.0 (2.8)	0.0 (0.0)	0.0	3497.1
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Urban category				
Residential High:	221.0 (9.4)	165.7 (29.5)	1542.6	116392.5
Comm - Ind:	127.8 (5.4)	95.8 (17.1)	1273.9	90140.6
Total	2348.5 (100.0)	560.7(100)	8579.9	351773.4

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 64.6 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 32.4 ppb.
Predicted transparency = 1.5 meters.

Table V.19. Reservoir No. 1 MA35063

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	410.4 Ha (1.6 mi2)
Average Annual Water Load =	2501573.8 m3/yr (2.8 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	3.1 Ha. (7.7ac)
Areal water loading to lake: q=	80.4 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	327.1 (79.7)	42.5 (59.9)	817.6	7849.3
Rural category				
Agriculture:	8.1 (2.0)	2.4 (3.4)	64.2	1720.7
Open land:	8.1 (2.0)	2.4 (3.4)	42.1	1780.4
Residential Low:	24.5 (6.0)	7.3 (10.3)	134.5	9489.0
Other Landuses				
Water:	36.9 (9.0)	0.0 (0.0)	0.0	0.0
Wetlands:	4.4 (1.1)	0.0 (0.0)	0.0	235.2
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Urban category				
Residential High:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Comm - Ind:	1.3 (0.3)	16.2 (22.9)	13.4	1178.2
Total	410.4 (100.0)	71.0(100)	1071.9	22252.7

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 2.3 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 21.1 ppb.
Predicted transparency = 2.3 meters.

Table V.20. Reservoir No.2 MA35064

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	129.3 Ha (0.5 mi2)
Average Annual Water Load =	788332.0 m3/yr (0.9 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	19.6 Ha. (48.3ac)
Areal water loading to lake: q=	4.0 m/yr.
Homes with septic systems within 100m of lake.=	3.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	100.3 (77.5)	13.0 (80.0)	250.7	2406.3
Rural category				
Agriculture:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Open land:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Residential Low:	5.9 (4.6)	1.8 (10.8)	32.4	2285.4
Other Landuses				
Water:	21.2 (16.4)	0.0 (0.0)	0.0	0.0
Wetlands:	2.0 (1.5)	0.0 (0.0)	0.0	104.3
Other P inputs:	NA	0.0 (0.0)		
3.0 Septics:	NA	1.5 (9.2)		
Urban category				
Residential High:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Total	129.3 (100.0)	16.3(100)	283.1	4796.0

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.1 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 5.1 ppb.
Predicted transparency = 9.5 meters.

Table V.21. Riceville Pond MA35065

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	1472.1 Ha (5.7 mi2)
Average Annual Water Load =	8974126.7 m3/yr (10.2 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	24.8 Ha. (61.3ac)
Areal water loading to lake: q=	36.1 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	1326.7 (90.1)	172.5 (83.8)	3316.8	31841.4
Rural category				
Agriculture:	13.3 (0.9)	4.0 (1.9)	69.3	1559.1
Open land:	28.9 (2.0)	8.7 (4.2)	150.4	5695.5
Residential Low:	41.0 (2.8)	12.3 (6.0)	225.5	15905.1
Other Landuses				
Water:	42.7 (2.9)	0.0 (0.0)	0.0	0.0
Wetlands:	19.1 (1.3)	0.0 (0.0)	0.0	1014.0
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Urban category				
Residential High:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Comm - Ind:	0.4 (0.0)	8.4 (4.1)	3.6	228.0
Total	1472.1 (100.0)	205.9(100)	3765.6	56242.9

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.8 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 15.1 ppb.
Predicted transparency = 3.2 meters.

Table V.22. South Athol Pond MA35078

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	2477.3 Ha (9.6 mi2)
Average Annual Water Load =	15101532.1 m3/yr (17.1 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	33.5 Ha. (82.8ac)
Areal water loading to lake: q=	45.1 m/yr.
Homes with septic systems within 100m of lake.=	3.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	2146.6 (86.6)	279.1 (72.4)	5366.4	51517.3
Rural category				
Agriculture:	42.8 (1.7)	12.8 (3.3)	283.8	7590.0
Open land:	47.8 (1.9)	14.3 (3.7)	248.5	6783.3
Residential Low:	114.5 (4.6)	34.4 (8.9)	629.9	44435.8
Other Landuses				
Water:	74.2 (3.0)	0.0 (0.0)	0.0	0.0
Wetlands:	41.9 (1.7)	0.0 (0.0)	0.0	2219.8
Other P inputs:	NA	0.0 (0.0)		
3.0 Septics:	NA	1.5 (0.4)		
Urban category				
Residential High:	0.8 (0.0)	3.7 (0.9)	4.4	376.7
Comm - Ind:	8.8 (0.4)	39.7 (10.3)	87.6	617.0
Total	2477.3 (100.0)	385.4(100)	6620.6	113540.0

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 1.2 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 17.5 ppb.
Predicted transparency = 2.7 meters.

Table V.23. Stoddard Pond MA35083

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	814.7 Ha (3.1 mi2)
Average Annual Water Load =	4966628.6 m3/yr (5.6 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	21.0 Ha. (51.8ac)
Areal water loading to lake: q=	23.7 m/yr.
Homes with septic systems within 100m of lake.=	21.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	616.3 (75.6)	80.1 (45.2)	1540.6	14790.2
Rural category				
Agriculture:	70.4 (8.6)	21.1 (11.9)	484.2	14026.7
Open land:	46.5 (5.7)	13.9 (7.9)	241.7	2010.3
Residential Low:	35.0 (4.3)	10.5 (5.9)	192.6	13585.5
Other Landuses				
Water:	24.6 (3.0)	0.0 (0.0)	0.0	0.0
Wetlands:	13.4 (1.6)	0.0 (0.0)	0.0	710.2
Other P inputs:	NA	0.0 (0.0)		
21.0 Septics:	NA	10.5 (5.9)		
Urban category				
Residential High:	1.2 (0.1)	5.5 (3.1)	6.3	537.7
Comm - Ind:	7.5 (0.9)	35.6 (20.1)	74.3	303.4
Total	814.7 (100.0)	177.2(100)	2555.0	46166.1

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.8 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 21.1 ppb.
Predicted transparency = 2.3 meters.

Table V.24. Wallace Pond MA35092

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	1004.4 Ha (3.9 mi2)
Average Annual Water Load =	6123139.3 m3/yr (6.9 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	17.4 Ha. (42.9ac)
Areal water loading to lake: q=	35.2 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	933.9 (93.0)	121.4 (94.4)	2334.9	22414.6
Rural category				
Agriculture:	3.1 (0.3)	0.9 (0.7)	16.1	361.2
Open land:	18.5 (1.8)	5.6 (4.3)	96.2	277.6
Residential Low:	2.5 (0.3)	0.8 (0.6)	13.8	975.4
Other Landuses				
Water:	24.1 (2.4)	0.0 (0.0)	0.0	0.0
Wetlands:	22.3 (2.2)	0.0 (0.0)	0.0	1181.6
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Urban category				
Residential High:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Total	1004.4 (100.0)	128.6(100)	2461.0	25210.3

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.7 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 13.7 ppb.
Predicted transparency = 3.5 meters.

If all land were primeval forest P export would be 124.5 kg/yr
And the forested condition lake TP would be 13.3 ppb.
Thus anthropogenic inputs increase lake TP by 3.3 percent.
The Trophic State Index has increased from 41.5 to 41.9
The Lake is predicted to be mesotrophic and in a natural condition.

Table V.25. Ward Pond MA35093

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	134.3 Ha (0.5 mi2)
Average Annual Water Load =	818913.5 m3/yr (0.9 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	2.4 Ha. (5.9ac)
Areal water loading to lake: q=	34.3 m/yr.
Homes with septic systems within 100m of lake.=	2.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	121.2 (90.2)	15.8 (81.4)	303.1	2909.3
Rural category				
Agriculture:	1.3 (0.9)	0.4 (2.0)	6.6	148.1
Open land:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Residential Low:	7.4 (5.5)	2.2 (11.5)	40.7	2872.9
Other Landuses				
Water:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Wetlands:	4.4 (3.3)	0.0 (0.0)	0.0	235.5
Other P inputs:	NA	0.0 (0.0)		
2.0 Septics:	NA	1.0 (5.2)		
Urban category				
Residential High:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Total	134.3 (100.0)	19.4(100)	350.4	6165.8

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.8 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 15.4 ppb.
Predicted transparency = 3.1 meters.

Table V.26. Whites Mill Pond MA35099

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	5087.6 Ha (19.6 mi2)
Average Annual Water Load =	31013805.6 m3/yr (35.1 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	17.2 Ha. (42.4ac)
Areal water loading to lake: q=	180.6 m/yr.
Homes with septic systems within 100m of lake.=	9.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	4273.3 (84.0)	555.5 (71.6)	10683.3	102560.0
Rural category				
Agriculture:	227.4 (4.5)	68.2 (8.8)	2842.8	104842.0
Open land:	12.5 (0.2)	3.8 (0.5)	65.1	187.8
Residential Low:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	469.2 (9.2)	0.0 (0.0)	0.0	0.0
Wetlands:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other P inputs:	NA	0.0 (0.0)		
9.0 Septics:	NA	4.5 (0.6)		
Urban category				
Residential High:	105.1 (2.1)	143.5 (18.5)	577.9	48964.7
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Total	5087.6 (100.0)	775.5(100)	14169.1	256554.5

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 4.5 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 19.8 ppb.
Predicted transparency = 2.4 meters.

If all land were primeval forest P export would be 600.4 kg/yr
And the forested condition lake TP would be 15.3 ppb.
Thus anthropogenic inputs increase lake TP by 29.2 percent.
The Trophic State Index has increased from 43.5 to 47.2
The Lake is predicted to be mesotrophic and in a natural condition.

Table V.27. Whitney Pond MA35101

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	13517.7 Ha (52.2 mi2)
Average Annual Water Load =	82404328.9 m3/yr (93.3 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	41.0 Ha. (101.3ac)
Areal water loading to lake: q=	201.0 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	11750.8 (86.9)	1527.6 (79.7)	29377.0	282019.2
Rural category				
Agriculture:	386.7 (2.9)	116.0 (6.1)	4833.9	178273.6
Open land:	12.5 (0.1)	3.8 (0.2)	65.1	187.8
Residential Low:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	996.6 (7.4)	0.0 (0.0)	0.0	0.0
Wetlands:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Urban category				
Residential High:	266.6 (2.0)	193.8 (10.1)	1466.4	124241.9
Comm - Ind:	104.5 (0.8)	75.9 (4.0)	1041.4	70499.8
Total	13517.7 (100.0)	1917.1(100)	36783.8	655222.3

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 4.7 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 18.5 ppb.
Predicted transparency = 2.6 meters.

Table V.28. Wrights Reservoir MA35104

Total Estimated Pollution loads based on GIS Landuse

Watershed Area=	741.3 Ha (2.9 mi2)
Average Annual Water Load =	4518702.9 m3/yr (5.1 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	53.0 Ha. (130.8ac)
Areal water loading to lake: q=	8.5 m/yr.
Homes with septic systems within 100m of lake.=	7.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	493.6 (66.6)	64.2 (41.0)	1234.1	11847.3
Rural category				
Agriculture:	16.0 (2.2)	4.8 (3.1)	112.1	2725.2
Open land:	12.2 (1.6)	3.7 (2.3)	63.4	1393.0
Residential Low:	96.3 (13.0)	28.9 (18.5)	529.8	37377.1
Other Landuses				
Water:	86.0 (11.6)	0.0 (0.0)	0.0	0.0
Wetlands:	23.6 (3.2)	0.0 (0.0)	0.0	1252.7
Other P inputs:	NA	0.0 (0.0)		
7.0 Septics:	NA	3.5 (2.2)		
Urban category				
Residential High:	7.5 (1.0)	28.8 (18.4)	67.0	4426.7
Comm - Ind:	5.9 (0.8)	22.6 (14.4)	59.0	962.4
Total	741.3 (100.0)	156.4(100)	2065.4	59984.4

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.3 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 13.5 ppb.
Predicted transparency = 3.5 meters.

Appendix VI Millers Lakes TMDL Public Meeting Attendance List.

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Division of Watershed Management, 627 Main Street, Worcester, MA 01608

JANE SWIFT, Governor — LAUREN A. LISS, Commissioner — BOB DURAND, Secretary

MEETING ATTENDEES LIST

Meeting: Millers Basin Lakes TMDL public meeting
Presenters: Mark Mattson Russell Issac
Date: Nov 14 2002 Place: Athol Environmental Center Athol

Name	Affiliation or address	phone or email
1) Brian Duval	MA DEP WORC.	(508) 849-4027 brian.duval@state.ma.us
2) Rick Wilkey	126 Horton Rd Orange	rdwilkey@trysb.net
3) Doug Walsh	Athol DPW	978-249-4542
4) Keith R. Newton	Royalston DPW	978-249-4223
5) Earl Baldwin	Athol	earlcbaldwin@yahoo.com
6) Jim White	Athol	978-249-0116
7) Shelley Hight	Athol	978-249-9731 shelleyh@forwild.umass.edu
8) Brian Nason	Rt #2, Secret Lake	(978) 249-0483 BNason@Bradley.com
9) Ron Cloutier	Millers River Env. Ctr	(H) 978 544-7500
10) Sue Cloutier	Millers River Env Ctr.	(W) 978 248-9491
11) Dave Small	Millers River Watershed Council	dhsmall@gis.net
12) Scott Maslansky	New England Forestry Foundation	smaslansky@neforestry.org
13) David Romanowski	Winchendon Springs Lake Assn.	dromanowski@nn3b.com
14) Amanda Emery	MRPC R1427 Water St. Fitchburg	aemery@mrpc.org
William Benoit	Winchendon Springs Lake Assn.	978 297-1282
Carol Lovuciat	Recorder	978 544-8361

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COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Division of Watershed Management, 627 Main Street, Worcester, MA 01608

JANE SWIFT
Governor

LAUREN A. LISS
Commissioner

BOB DURAND
Secretary

MEETING ATTENDEES LIST

Meeting: Millers Basin Lakes TMDL Public meeting
Presenters: Mark Mattson Russell Isaac
Date: Nov 14 2002 Place: Millers River Environmental Center Athol MA

Name	Affiliation or address	phone or email
1) ELWIN E. BACON	441 BEARSDEN Rd.	978-249-2004
2) Alice Rojko	EOEA Millers River Team Leader	508 792 7423 ext 505
3)		
4)		
5)		
6)		
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11)		
12)		
13)		
14)		

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