Total Maximum Daily Loads of Phosphorus for Selected Chicopee Basin Lakes

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Front Cover
Photograph of Wickaboag Pond in West Brookfield

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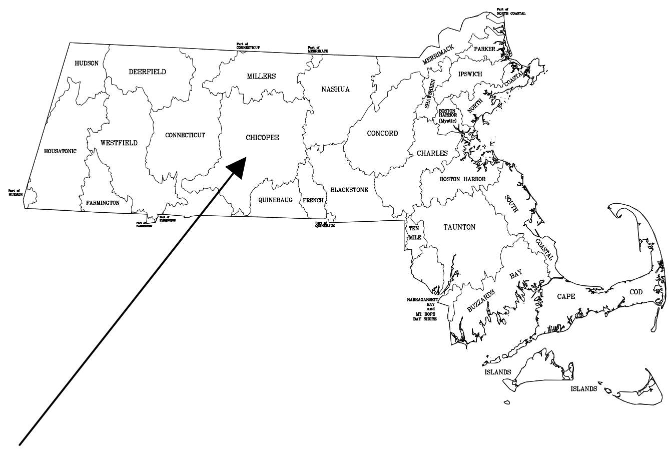
DEP, DWM TMDL Report MA36025-2002-2 January 4, 2002



Location of Chicopee Basin in Massachusetts.

Key Feature:	TMDL assessment Total Phosphorus for Chicopee Basin Lakes.
Locations:	Browning Pond (MA36025), Oakham; Long Pond (MA36083), Springfield; Minechoag Pond (MA36093), Ludlow; Mona Lake (MA36094), Springfield; Spectacle Pond (MA36142), Wilbraham; Sugden Reservoir (MA36150), Spencer; and Wickaboag Pond (MA36166), West Brookfield.
Land Type:	New England Upland
303d Listings:	Seven Lakes with 10 stressors on 303d list including: Noxious Plants; Organic enrichment/low DO; Nutrients; and Turbidity
Data Sources:	Synoptic lake surveys, Land use information.
Data Mechanisms:	NPSLAKE phosphorus loading model, Reckhow water quality model, Best Professional Judgment
Monitoring Plan:	Volunteer groups and DEP Five-Year Cycle.
Control Measures:	Watershed Management, Septic system maintenance, In-lake 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 Water Quality Standards. The list of impaired waters, better known as the “303d 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 Chicopee Watershed. The lakes were listed on the state “303d” list for a variety of pollutants and stressors including low dissolved oxygen, turbidity, nutrients, and 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. Russ Isaac of DEP (1999).

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

WBID	Lake Name	NPSLAKE Predicted TP (ppb)	NPSLAKE Predicted Load (kg/ha/yr)	Selected Target TP (ppb)	Selected Target Load (kg/ha/yr)
MA36025	Browning Pond	15.1	200	15	200
MA36083	Long Pond	73.3	163	30	68
MA36093	Minechoag Pond	62.4	110	30	53
MA36094	Mona Lake	76.6	47	30	19
MA36142	Spectacle Pond	35.6	16.8	20	8.7
MA36150	Sugden Reservoir	24.4	372	15	230
MA96331	Wickaboag Pond	21.6	1049	15	729

In the case of lakes dominated by rooted aquatic plants, watershed nutrient controls alone are not expected to control plant growth, and thus additional in-lake plant management programs are recommended. Because of the limited data available on discrete sources of nutrients within a given watershed, a locally organized watershed

survey may be recommended to target reductions in nonpoint sources of nutrients and sediments. Suggested implementation is provided in the following table:

Lake Name WBID=> Implementation Suggested	Browning Pond MA36025	Long Pond MA36083	Minechoag Pond MA36093	Mona Lake MA36094	Spectacle Pond MA36142	Sugden Reservoir MA36150	Wickaboag Pond MA36166
Public Education	X	X	X	X	X	X	X
NPS Survey	X	X	X	X	X	X	X
Lake Management Plan	X	X	X	X	X	X	X
Forest BMPs	X					X	X
Agriculture BMPs						X	X
Residential BMPs						X	X
Septic System Maintenance	X					X	X
Urban BMPs		X	X	X	X	X	
Highway BMPs			X		X		X
In-Lake Management	X	X	X	X	X	X	X
Other (Gravel pits, golf courses, see text)							

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 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 will be created a Watershed Community Council that may 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 web at http://www.state.ma.us/envir/watershd.htm.

The proposed Total Maximum Daily Loads (TMDLs) for the Chicopee Basin 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 a preventative total phosphorus TMDL is established to slow the rate of eutrophication and various plant management options are discussed. For lakes impaired by algae and non-rooted macrophytes a total phosphorus TMDL is established to meet Massachusetts 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 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) and Cooke et al., (1993). 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 7:1 by weight or 16:1 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. 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 changes 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 and the modeling is done on a yearly basis.

There are three basic approaches to estimating current nutrient loading rates: the measured mass balance approach and the landuse export approach and modeling 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. In this report, the NPSLAKE model was used to estimate loading.

Target Load: Once the current nutrient loading rate is established, a new, lower rate of nutrient loading must be established which will restore water quality. 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 (ecoregions). 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 Reckhow (1979) method was used to model lake concentrations in this report. 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. This margin of safety can be specifically included, and/or included in the selection of a conservative 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 which may include point sources as well as private septic systems and various land uses within the watershed. In Massachusetts, few, if any, lakes receive direct point source discharges of nutrients. River impoundments often have upstream point sources, but these will be addressed as part of the appropriate river system. 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. 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.

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 sources in rural areas are leaching from failed or inadequate septic systems and phosphorus associated with soil erosion. 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'. 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. 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.

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 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 Basin Teams. In some cases, structural controls, such as detention ponds, may be used to reduce pollution loads to surface waters.

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 a Draft Generic Environmental Impact Report (Mattson et al., 1998). The Massachusetts Department of Environmental Protection will endorse in-lake remediation efforts that meet all environmental concerns, however, instituting such measures will rest with communities and the Clean Lakes Program now administered by EPA and, in Massachusetts, the 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 as well as the Massachusetts Watershed Inititative (MWI) Monitoring grants and MWI Priority Grants. 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 will be essential. This can be accomplished through a variety of mechanisms including volunteer efforts. Recommended monitoring will 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

Landuse information for each watershed is based on MassGIS digital maps derived from aerial photography taken in 1985. 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 1990's Baseline surveys were conducted on lakes by the Department. These Baseline surveys typically were conducted 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. 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 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	Acres	303d list pollutant/stressor
MA36025	Browning Pond	Oakham/Spencer	106	Low DO; Noxious plants
MA36083	Long Pond	Springfield	18	Noxious plants
MA36093	Minechoag Pond	Ludlow	21	Noxious plants
MA36094	Mona Lake	Springfield	11	Noxious plants
MA36142	Spectacle Pond	Wilbraham	16	Noxious plants
MA36150	Sugden Reservoir	Spencer	83	Nutrients; Low DO
MA36166	Wickaboag Pond	West Brookfield	320	Noxious plants; Turbidity

The locations of the seven lakes are shown in Figure 1. below. The local environs of the ponds are shown in Figures 2a-g below.

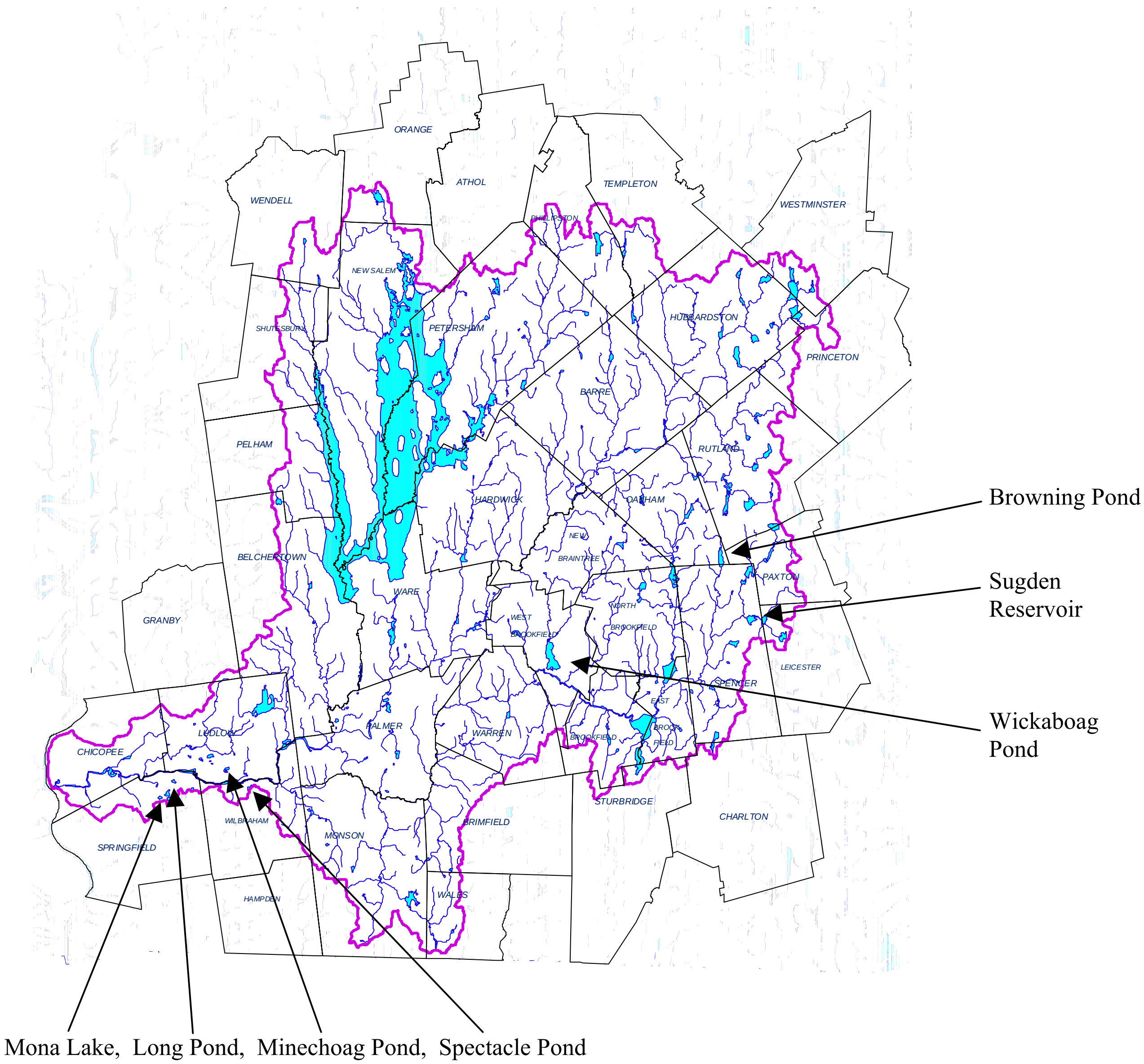


Figure 1. Locations of Lakes within Chicopee Basin.

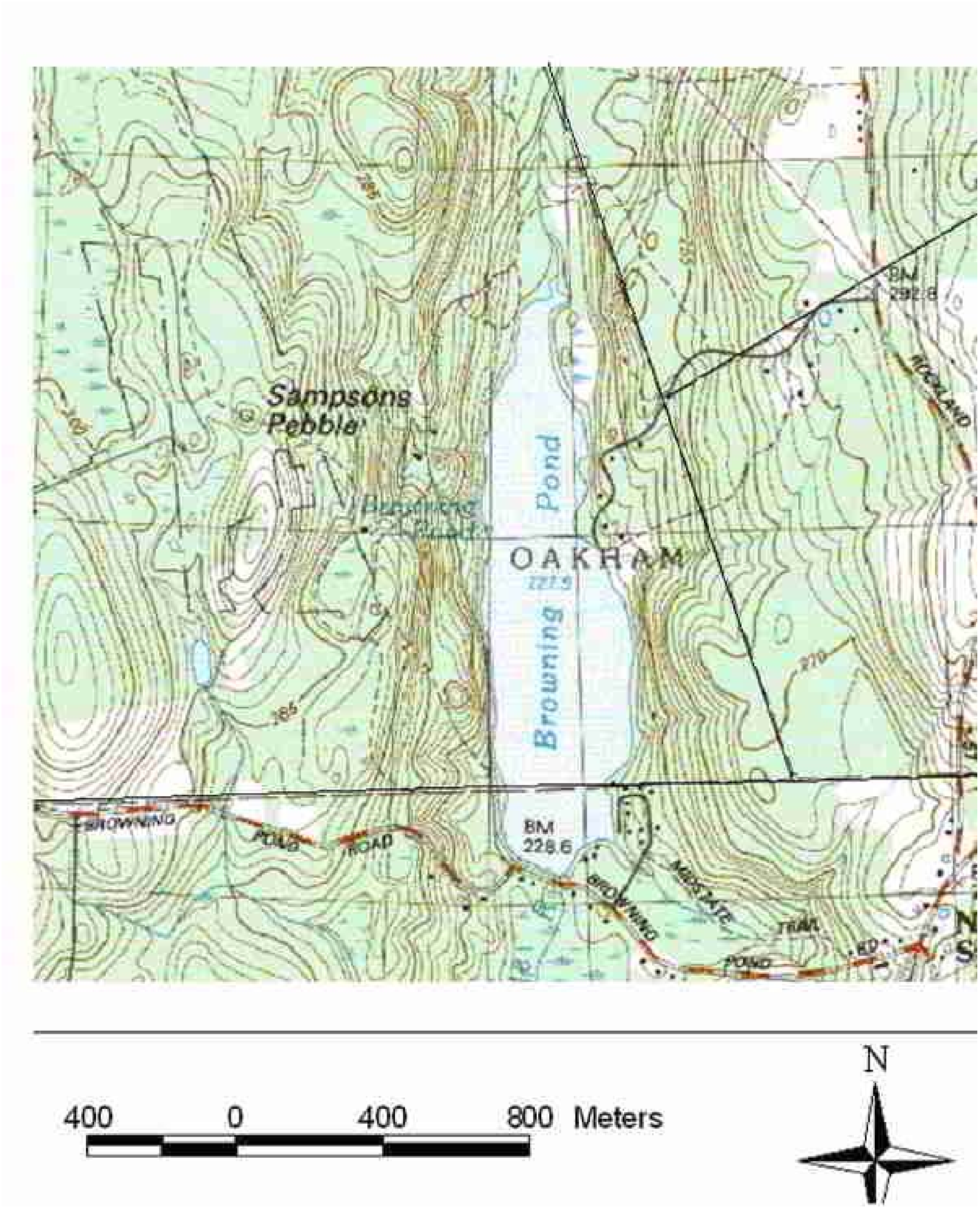


Figure 2a. Browning Pond Environs.

Figure 2b. Long Pond Environs.

Figure 2c. Minechoag Pond Environs.

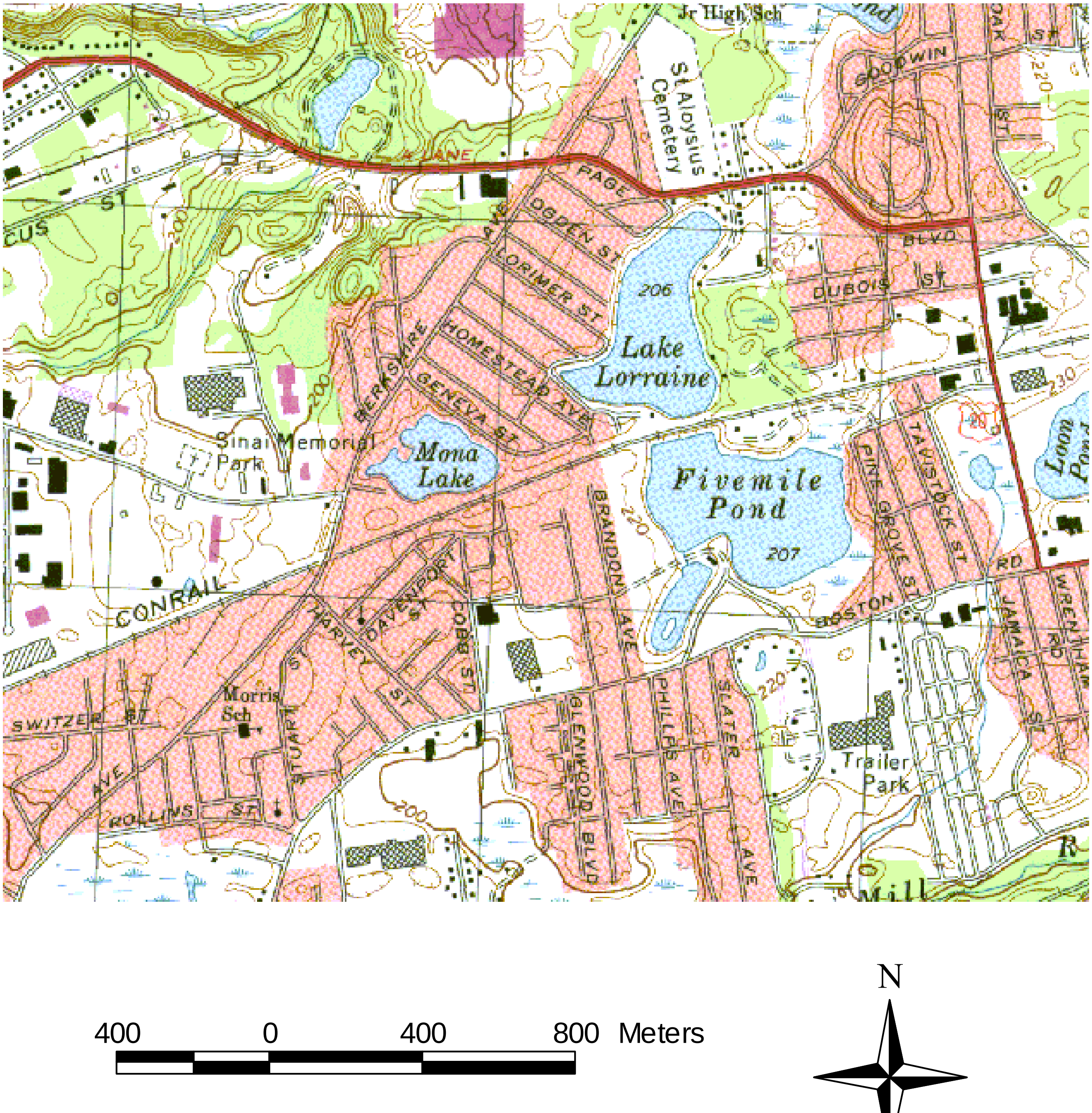


Figure 2d. Mona Lake Environs.

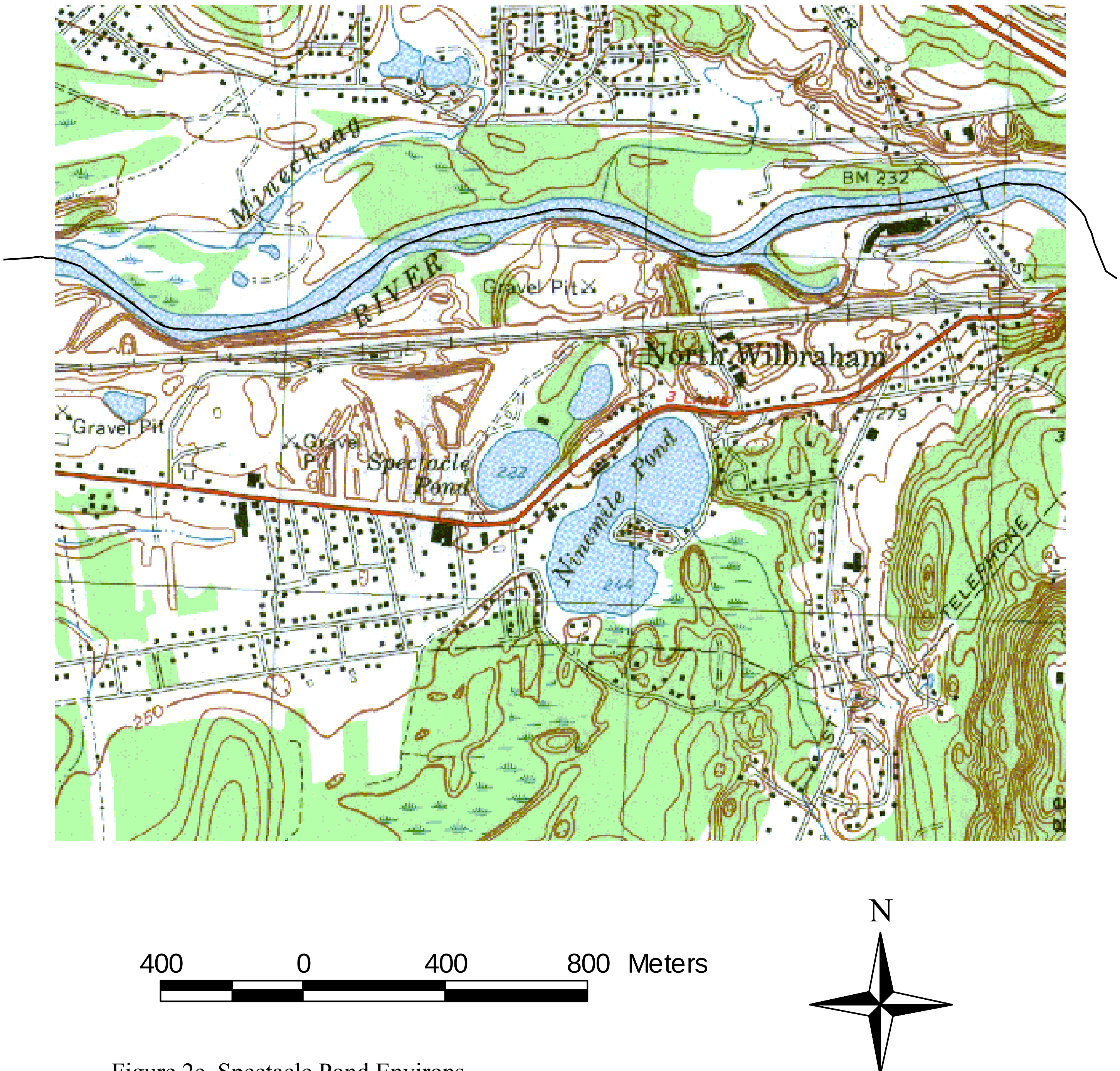
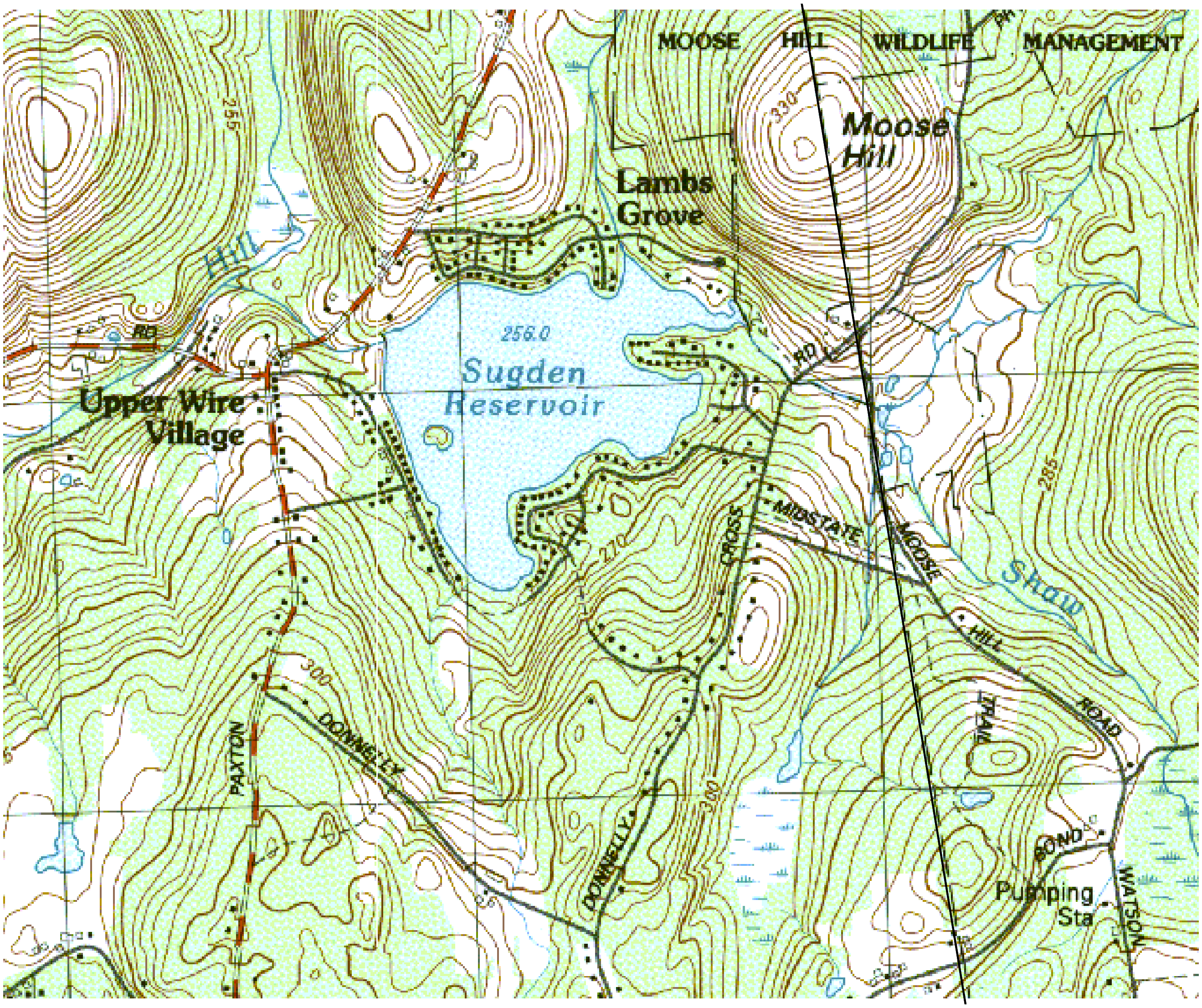
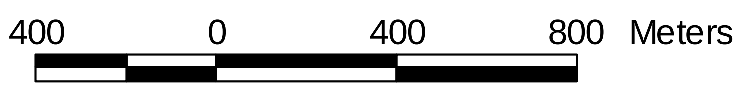


Figure 2e. Spectacle Pond Environs.





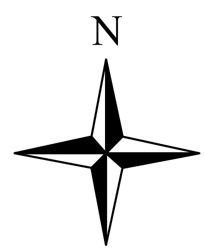
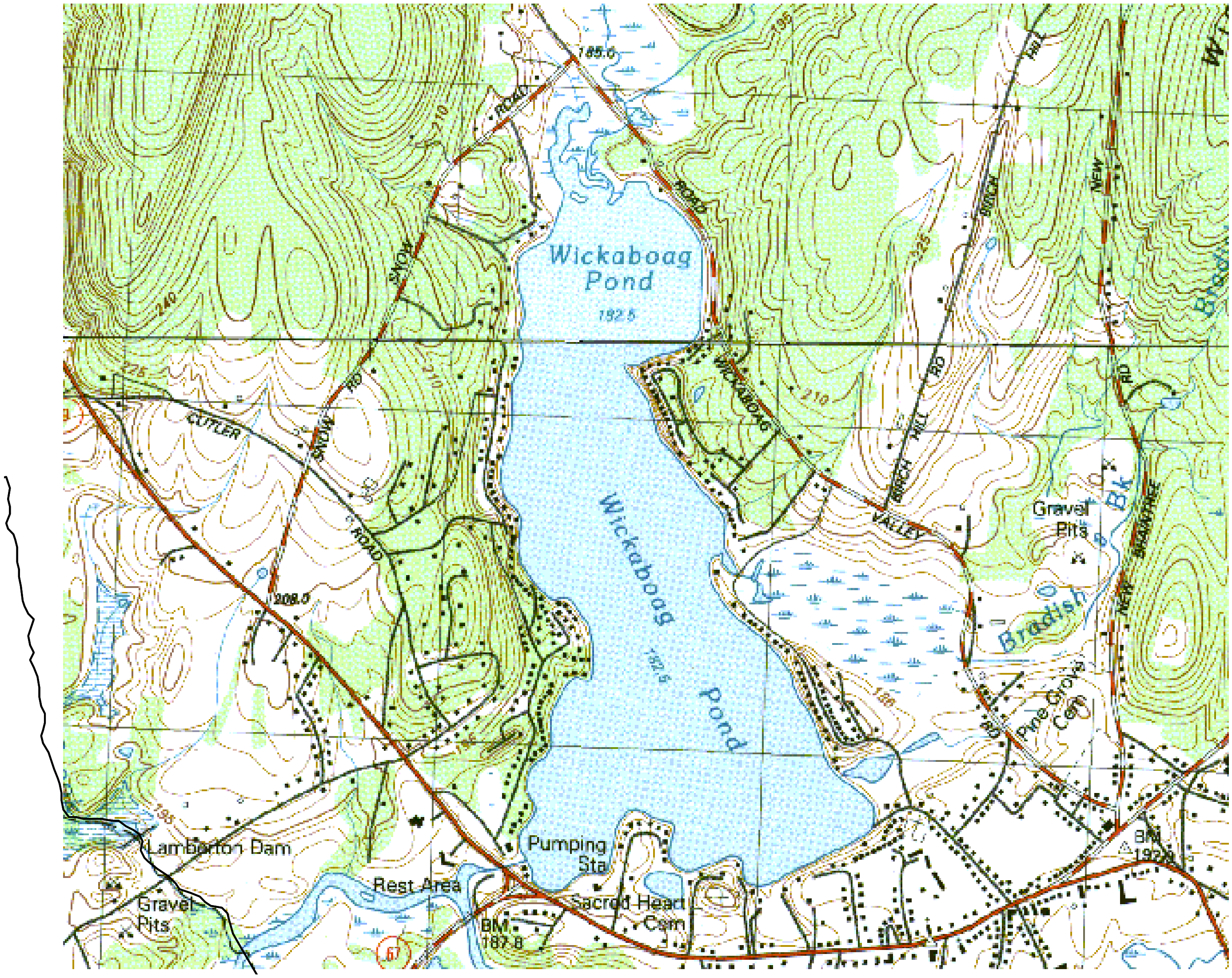
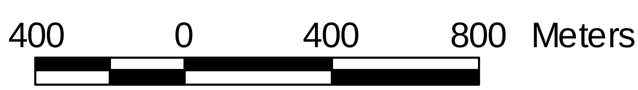


Figure 2f. Sugden Reservoir Environs.





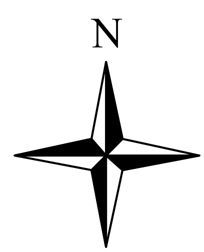


Figure 2g. Wickaboag Pond Environs.

Description:

Browning Pond in Oakham is a medium sized lake of approximately 97 acres and a maximum depth of approximately forty feet (12 meters). The lake is used by local anglers and swimmers. The watershed (4.6 squarer miles) is largely forested with some agriculture and low-density residential housing. Populations in Oakham ranged between 994 and 1,503 from 1980 to the 1990 census. MISER predictions on growth are 1,834 for the year 2000 and 2,592 for the year 2010 with an estimated 20 year growth rate of about 72 percent. Browning Pond was assessed by DEP in the summer of 1993 and the assessment comments reported: "Very dense growths of aquatic macrophytes (many native species) are encroaching from the north end of the pond; dissolved oxygen depletion was detected below 6.0 meters and it fell to <1 mg/l below 7.0 meters. A small population of a non-native macrophyte (*Myriophyllum heterophyllum*) noted at the north end of the pond threatens to spread throughout the littoral zone." This information was used to establish the low dissolved oxygen condition and noxious aquatic plants condition. Percent cover of dense macrophyte beds over the lake was not reported in the assessment comments but appears to be about 25% from the plant density map. The total phosphorus was reported at 0.02 mg/l (20 ppb) but this was below the detection limit of 0.05mg/l of the method used. The Secchi disk transparency was reported at 5.2 meters.

Long Pond in Springfield is a small pond of approximately 14 acres (26 acres according to BEC and Purcell Asso., (1980.) with a maximum depth of approximately one meter located in the city of Springfield. The watershed (0.8 square miles) is mostly high density residential and commercial landuse (45%) and forested landuse (31%) and most of the rest being open space and water. The pond is probably not used for either boating or swimming. Populations in Springfield ranged between 152,319 and 156,983 from 1980 to the 1990 census. MISER predictions on growth are 144,272 for the year 2000 and 143,474 for the year 2010 with an estimated 20 year growth rate of about –8.6 percent. Long Pond was assessed in the summer of 1987 and the assessment comments were: "Very dense growths of aquatic macrophytes (primarily *Elodea* sp., *Ceratophyllum demersum,* and *Brasenia schreberi*) cover the entire pond, high total phosphorus levels, and algal blooms were recorded." This information was used to establish a noxious aquatic plants condition. Total phosphorus concentrations were reported to be 0.21mg/l (210 ppb), which is very high. The Secchi disk transparency was recorded at one meter (on the bottom). This lake is also part of an earlier report (BEC and Purcell Asso., 1980).

Minechoag Pond is an urban pond in Ludlow (just east of Springfield) of approximately 22 acres and maximum depth of about 13 feet (4 meters). The dominant landuses in the watershed(0.4 square miles) are 50 percent urban, followed by 23 percent rural, 18 percent forest and about 9 percent water. Populations in Ludlow ranged between 18,150 and 18,820 from 1980 to the 1990 census. MISER predictions on growth are 20,189 for the year 2000 and 21,178 for the year 2010 with an estimated 20 year growth rate of about 12 percent. Minechoag Pond was assessed in the summer of 1987 and the assessment comments were: "Very dense growths of aquatic macrophytes (primarily *Utricularia* spp., *Nymphaea* sp., and *Elodea* sp.) cover the southeastern portion of the pond and the remaining littoral zone, moderate total phosphorus levels, and low oxygen recorded in hypolimnion." This information was used to establish a noxious aquatic plants condition. Total phosphorus concentrations were reported to be 0.04mg/l (40 ppb) and Secchi disk transparency was reported to be 2.6 meters.

Mona Lake is another urban lake in Springfield with an area of about 10 acres and maximum depth of approximately 10 feet (17 feet according to BEC and Purcell Asso., 1980). The dominant landuses in the watershed (21 Ha) are 52 percent urban with high density residential housing, followed by 30 percent forest and the rest of the watershed consists of water. It is probably not used for boating or swimming. Population in the town of Springfield has been described above. Mona Lake was assessed in the summer of 1987 and the assessment comments were: " Very dense growths of aquatic macrophytes (primarily *Brasenia schreberi*) cover littoral zone, DO.(3.0 PPM at surface) was < 50% saturation, blue-green "blooms" reduce the transparency below the safety criteria (4 ft. Secchi disc), and high total phosphorus levels." This information was used to establish a noxious aquatic plants condition. Total phosphorus concentrations were reported to be 0.13mg/l (130 ppb) and Secchi disk transparency was reported to be 0.7 meters. This lake is also part of an earlier report (BEC and Purcell Asso., 1980.)

Spectacle Pond in Wilbraham is a small pond of about 9 acres and maximum depth of about 46 feet, which is very deep for such a small lake. The watershed is tiny, (only 10.1 Ha) and the lake is for the most part a seepage lake. The dominant landuses in the watershed are 44 percent water, followed by 33 percent forest and 13 percent urban, which includes medium-high density housing along with urban transportation (roads and railroads). The remaining 10 percent of the watershed consists of open land. The NPSLAKE model in this case overestimated observed in-lake phosphorus concentrations, mostly likely due to the seepage nature of Spectacle Pond and some retention of phosphorus in the smaller pond just north of the main basin. Populations in Wilbraham ranged between 12,053 and 12,635 from 1980 to the 1990 census. MISER predictions on growth are 13,687 for the year 2000 and 14,041 for the year 2010 with an estimated 20 year growth rate of about 11 percent. Spectacle Pond was assessed in the summer of 1986 and the assessment comments were: "Historically very dense growths of aquatic macrophytes cover most of the littoral zone and oxygen depletion below 7 meters (anoxia below 9 meters to 14 meters). No management efforts implemented to date." This information was used to establish a noxious aquatic plants condition. Total phosphorus concentrations were reported to be 0.02 mg/l (20 ppb) and Secchi disk transparency was reported to be 4.6 meters.

Sugden Reservoir is a medium sized reservoir of approximately 83 acres and maximum depth of 21 feet (6.4 meters) in the town of Spencer. The watershed (6.0 square miles) is largely forested accounting for 71 percent, followed by about 14 percent in agricultural land and approximately 8 percent in water and wetlands. About 5 percent of the watershed consists of open land and residential areas with many residences on the shoreline and the remaining 2 percent is in the urban landuse category. Populations in Spencer ranged between 10,774 and 11,645 from 1980 to the 1990 census. MISER predictions on growth are 11,944 for the year 2000 and 12,332 for the year 2010 with an estimated 20 year growth rate of about 6 percent, however other towns in the watershed (Paxton and Leicester) have higher projected growth rates of 24 and 18% respectively. Sugden Reservoir was assessed in the summer of 1987 and the assessment comments were: "High total phosphorus levels and low hypolimnetic oxygen levels." This information was used to establish nutrients and organic enrichment/low dissolved oxygen as conditions. Total phosphorus concentrations were reported to be 0.06 mg/l (60 ppb) and Secchi disk transparency was reported to be 2.3 meters.

Wickaboag Pond is a large pond of 320 acres and maximum depth of only 11 feet in the town of West Brookfield. The lake is heavily used for boating, fishing and swimming. The dominant landuses in the watershed (17.7 square miles) are 63 percent forest, followed by 23 percent agricultural and about 6 percent water and wetlands. The rest of the watershed consists of both rural and urban landuse category including some open land and residential areas, with many residences on the shoreline. Populations in West Brookfield ranged between 3,026 and 3,532 from 1980 to the 1990 census. MISER predictions on growth are 3,783 for the year 2000 and 4,163 for the year 2010 with an estimated 20 year growth rate of about 18 percent. Wickaboag Pond was assessed in the summer of 1988 and the assessment comments were: "Very dense growths of aquatic macrophytes at the north end and along the northwestern shore. Occasional transparency below the safety criteria (4 ft. Secchi disk) noted historically and confirmed by citizen monitoring. Historically moderately high total phosphorus levels not used for assessments." Total phosphorus concentrations were reported to be 0.05 mg/l (50 ppb) and Secchi disk transparency was reported to be 1.2 meters.

Macrophytes density and species distributions were mapped during each DEP survey noted above. The maps for each pond are shown in Figures 3a-g, below.

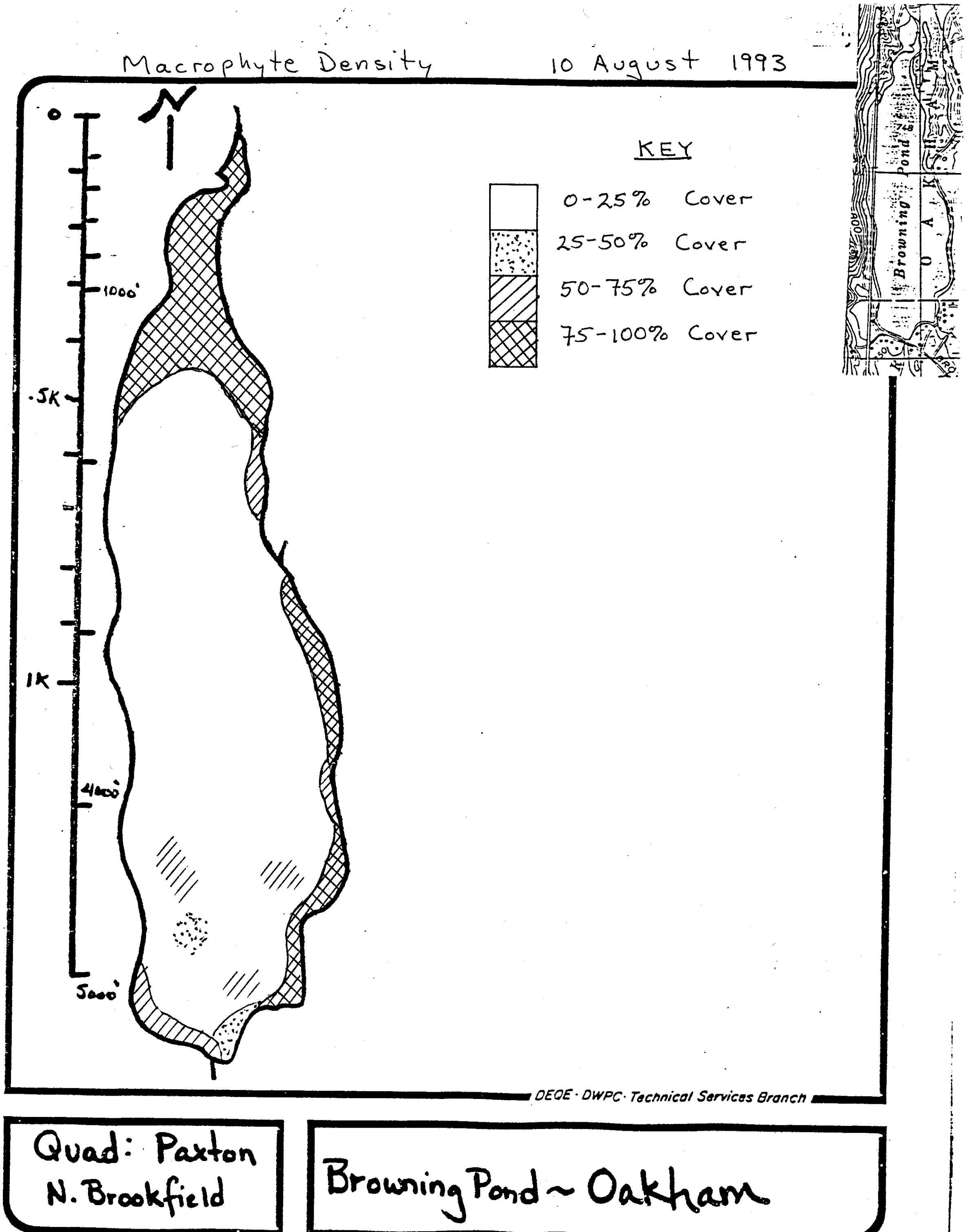


Figure 3a. Browning Pond Macrophyte density distribution.

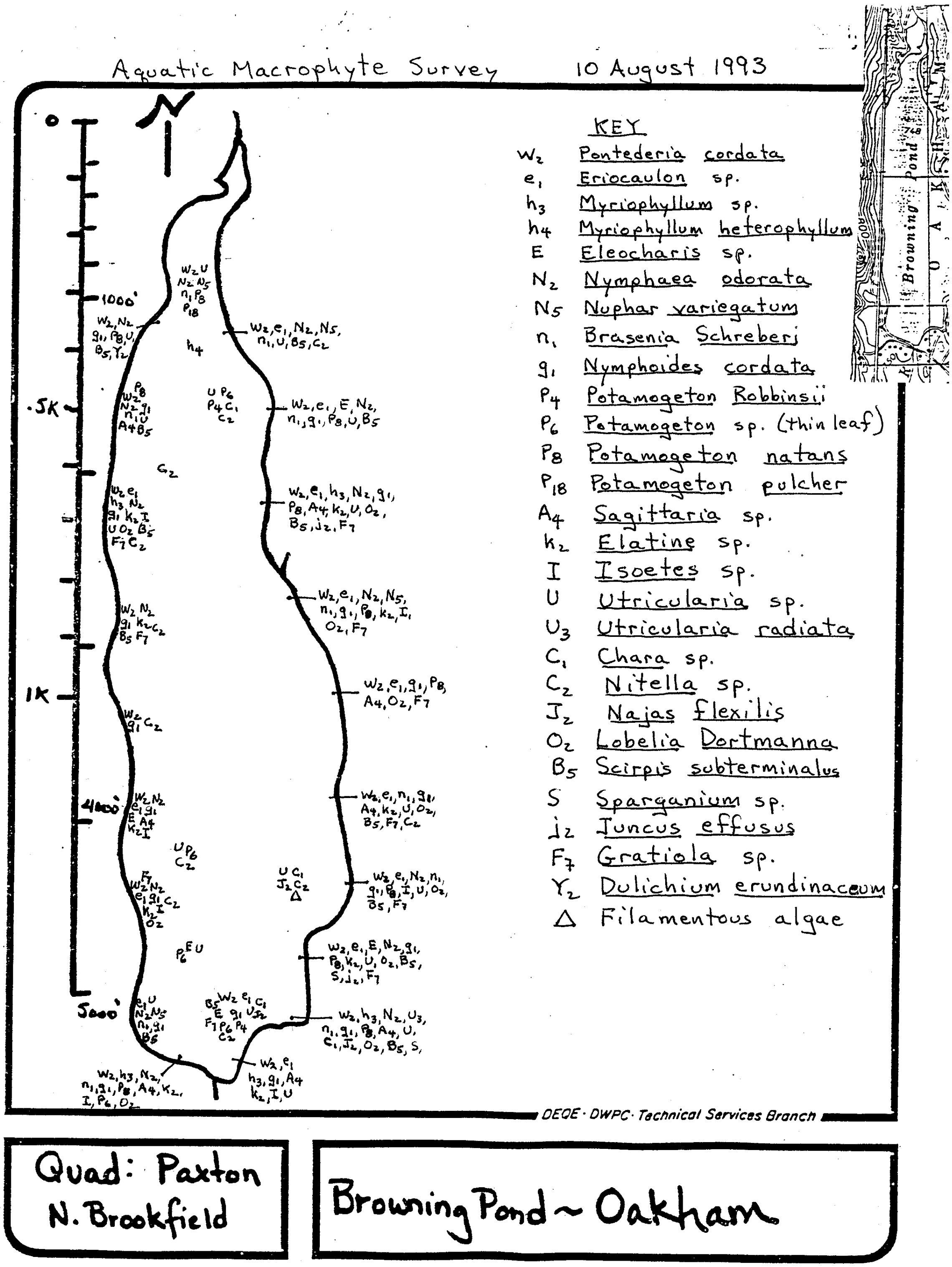


Figure 3b. Browning Pond Macrophyte species distribution.

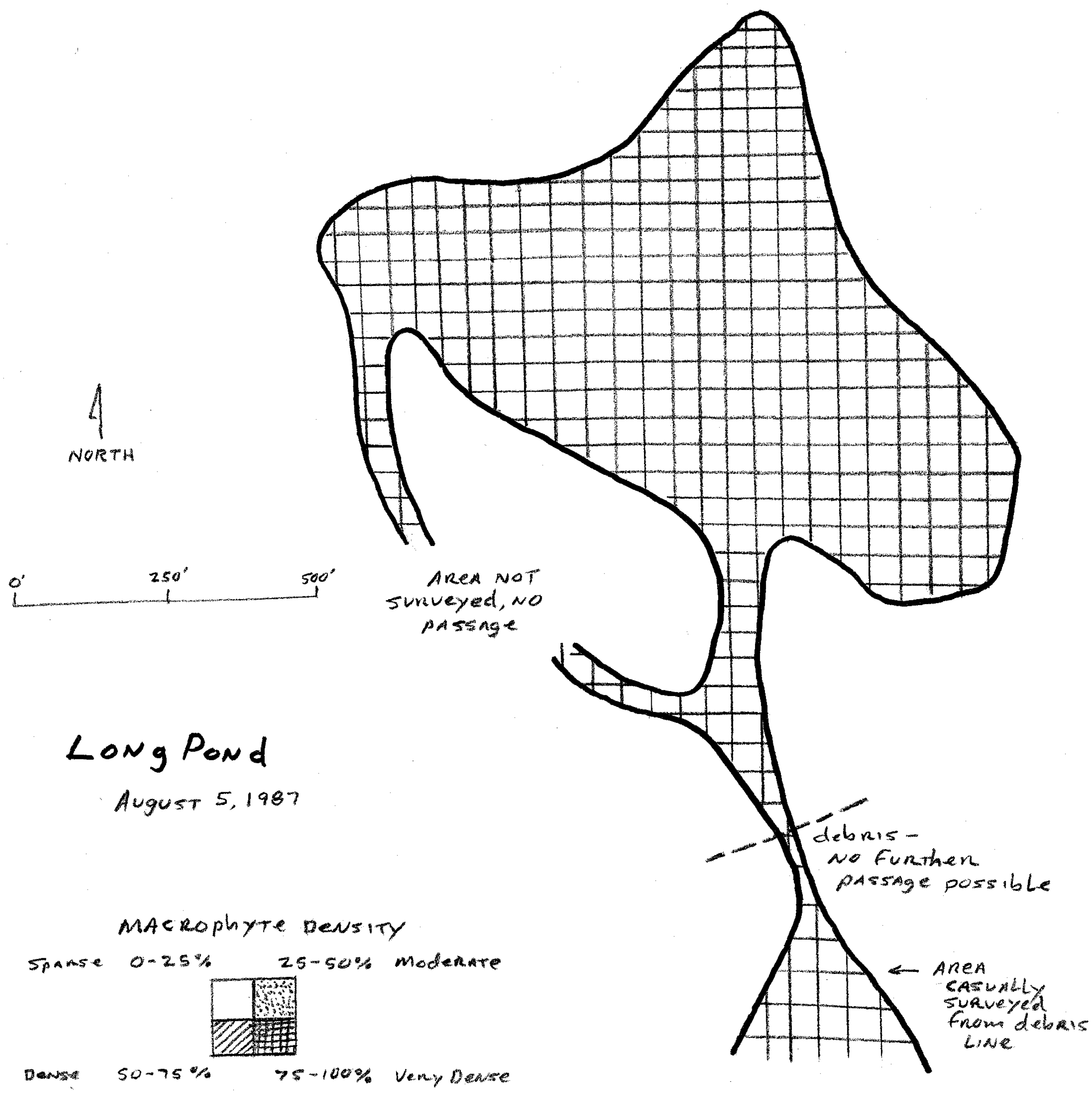


Figure 3c. Long Pond Macrophyte density distribution.

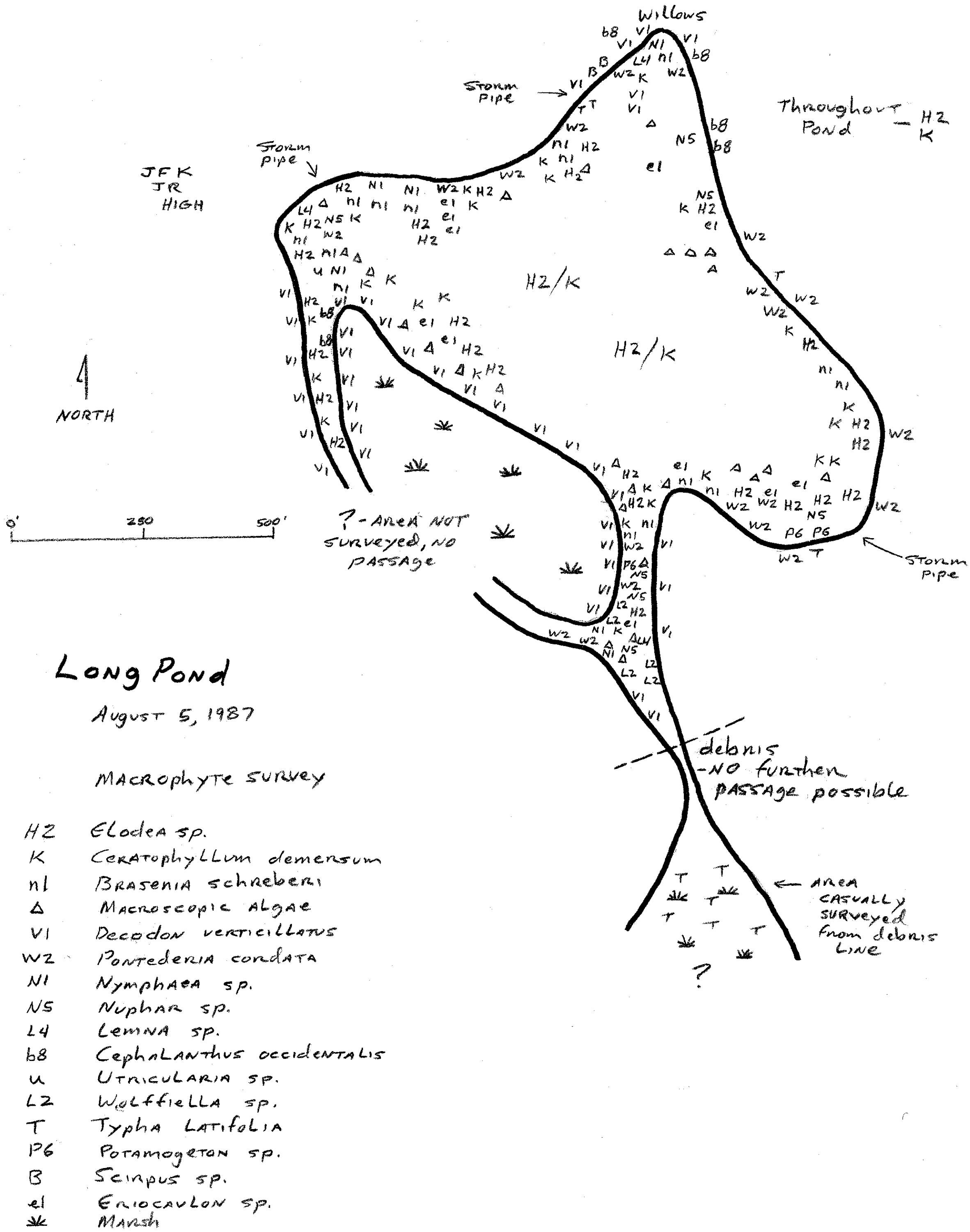


Figure 3d. Long Pond Macrophyte species distribution.

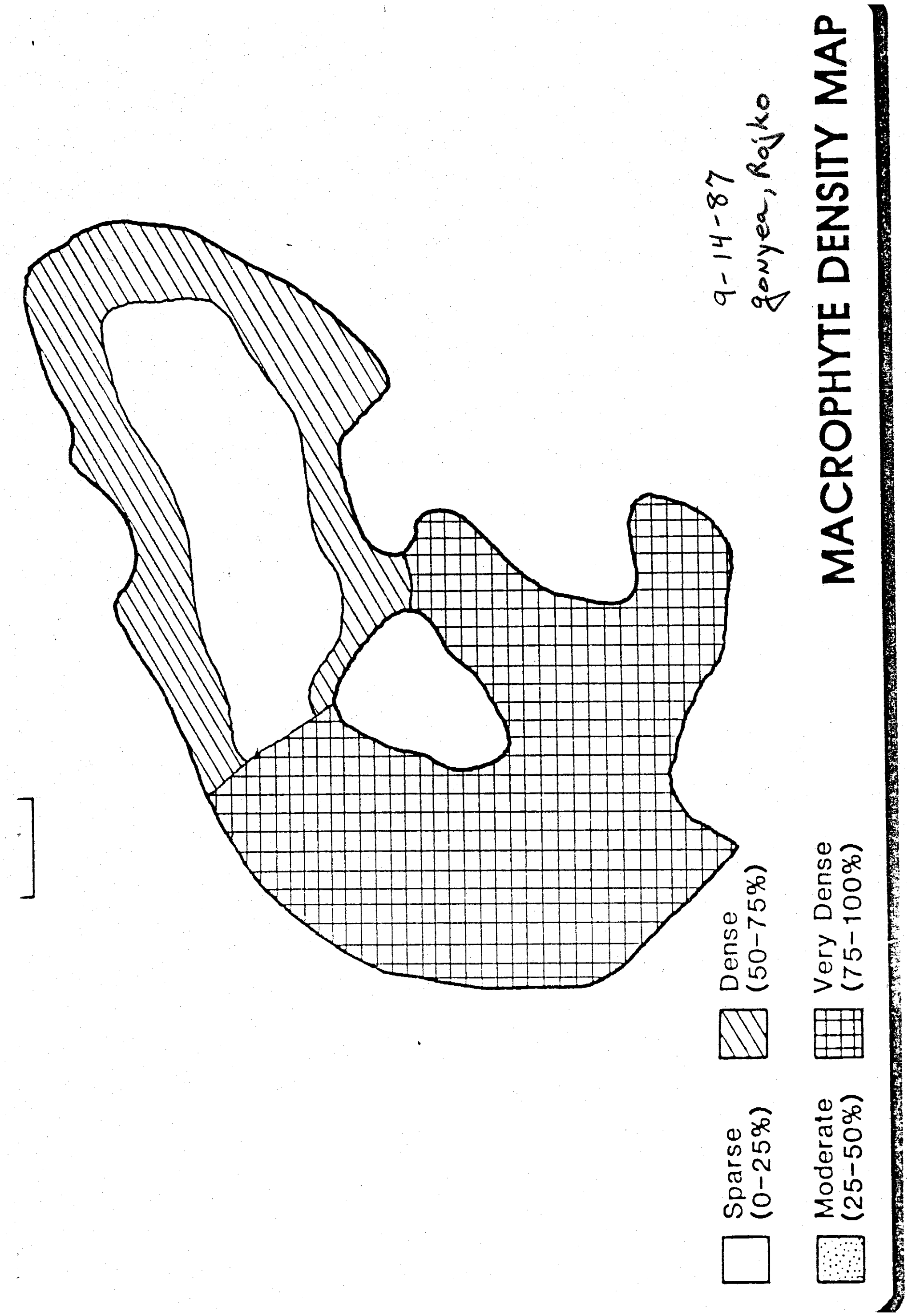


Figure 3e. Minechoag Pond Macrophyte density distribution.

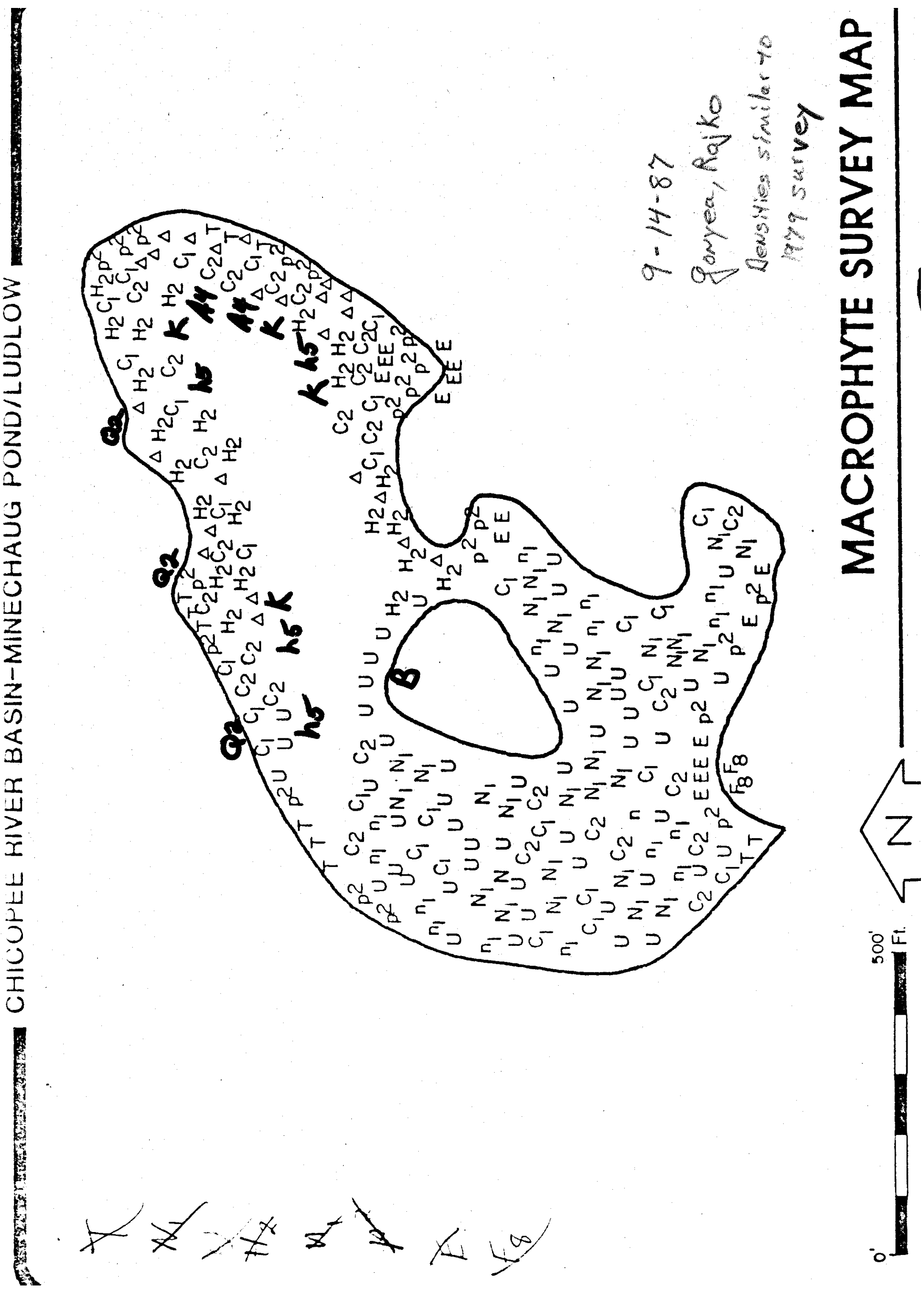


Figure 3f. Minechoag Pond Macrophyte species distribution.

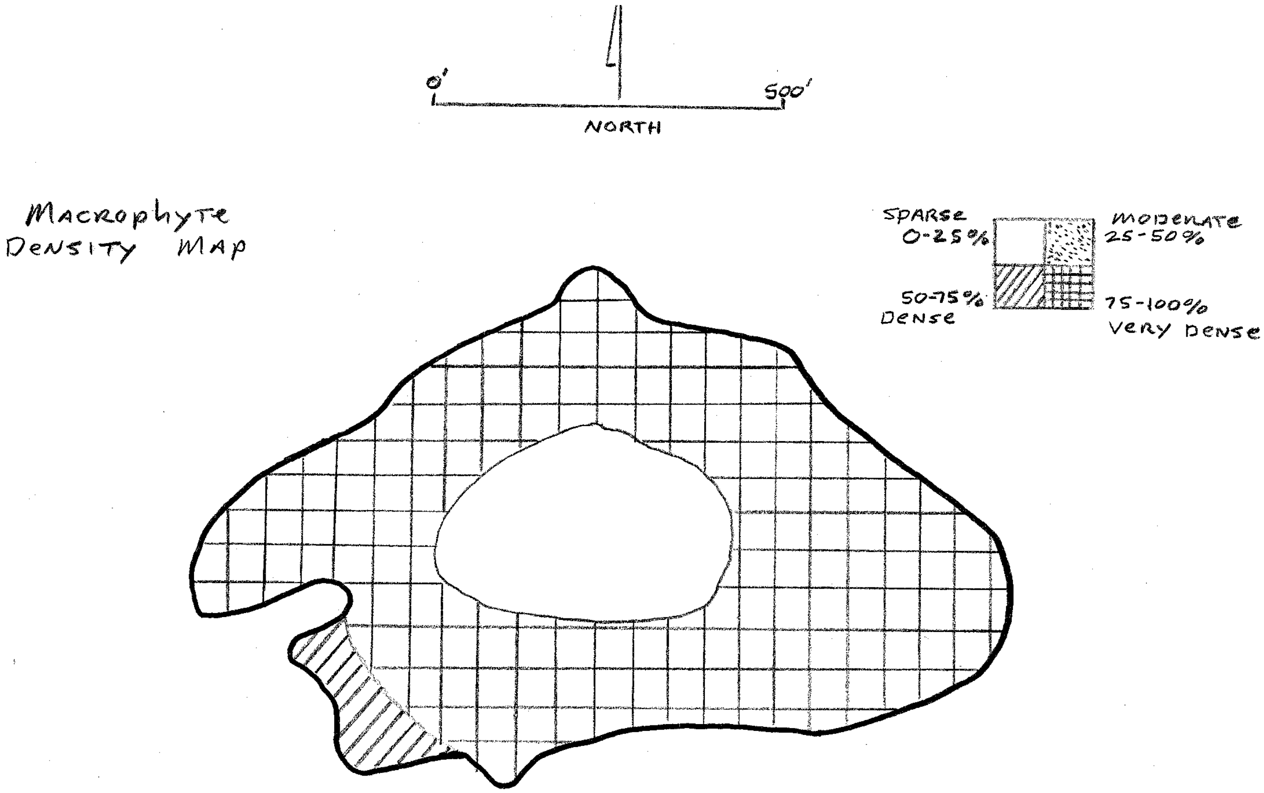


Figure 3g. Mona Lake Macrophyte density distribution.

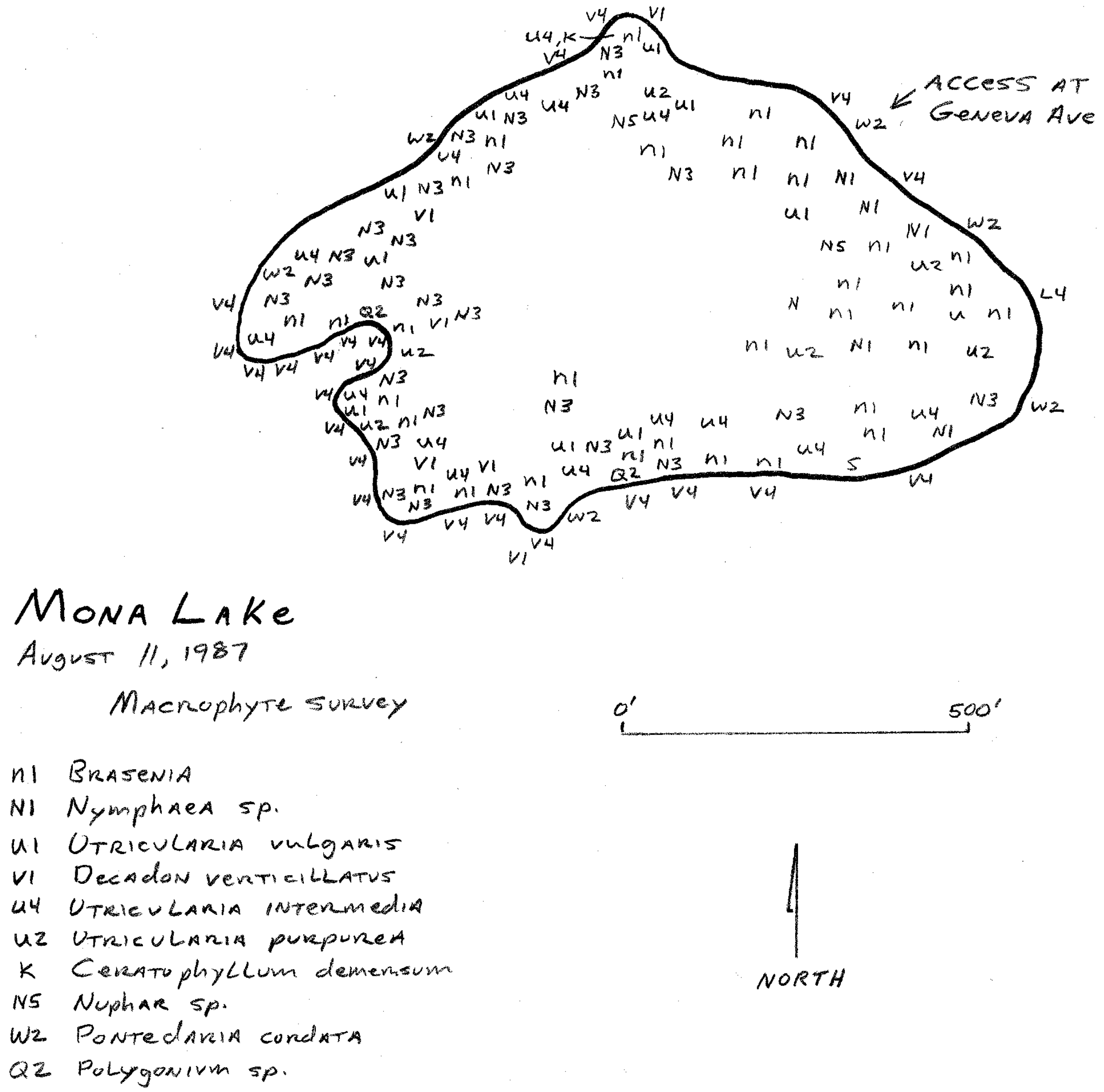


Figure 3h. Mona Lake Macrophyte species distribution.

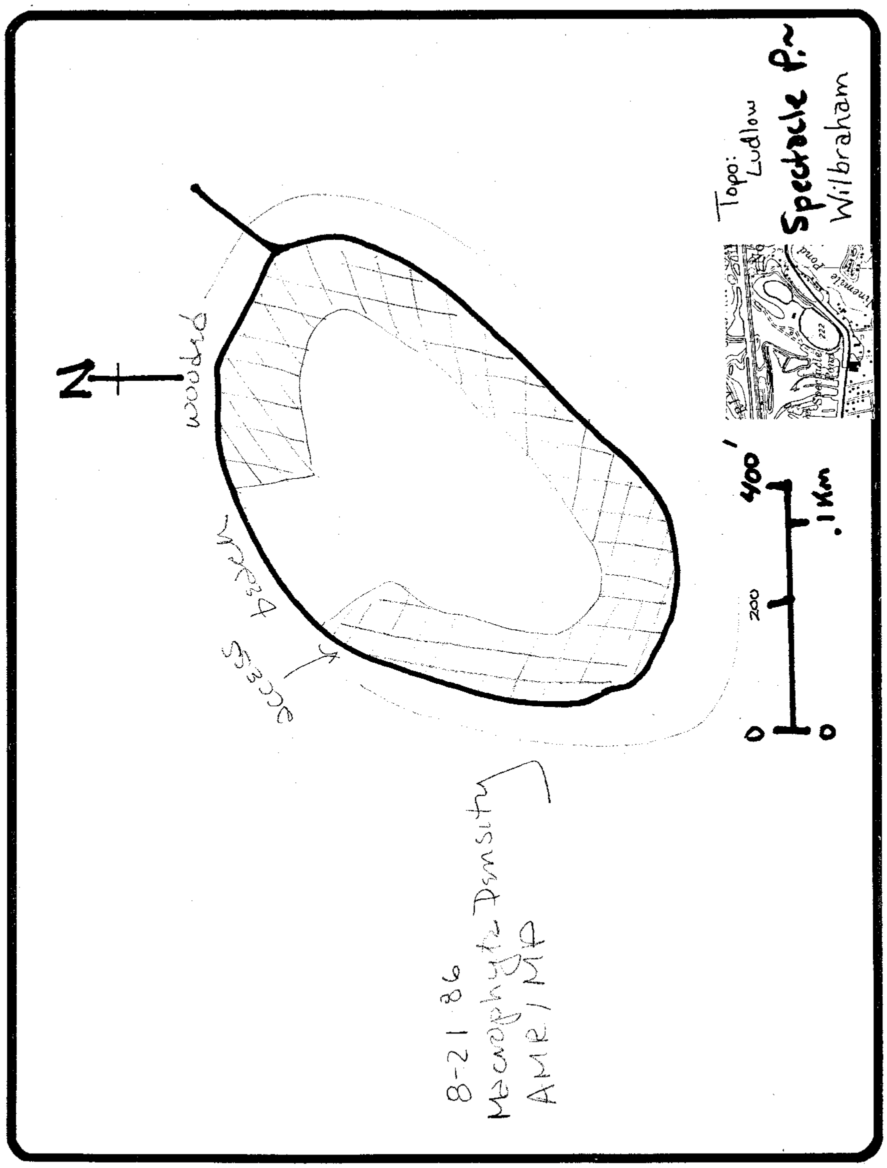


Figure 3i. Spectacle Pond Macrophyte density map.

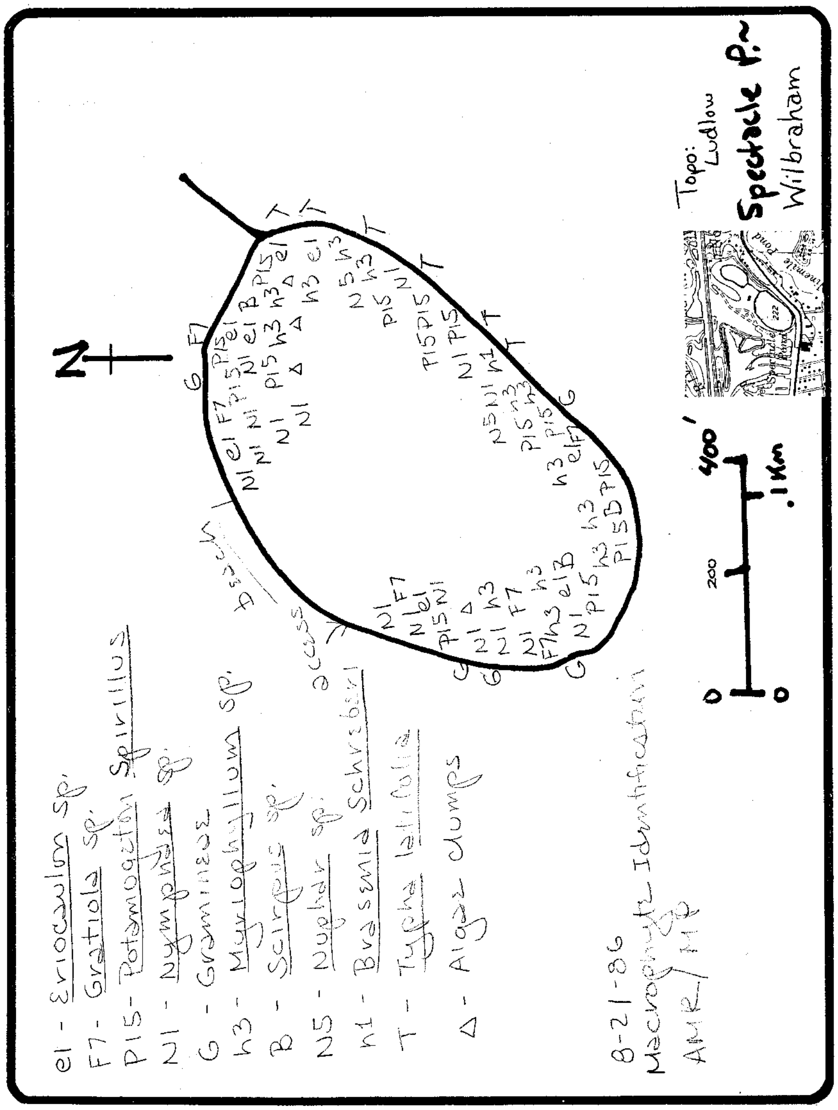


Figure 3j. Spectacle Pond Macrophyte species distribution map.

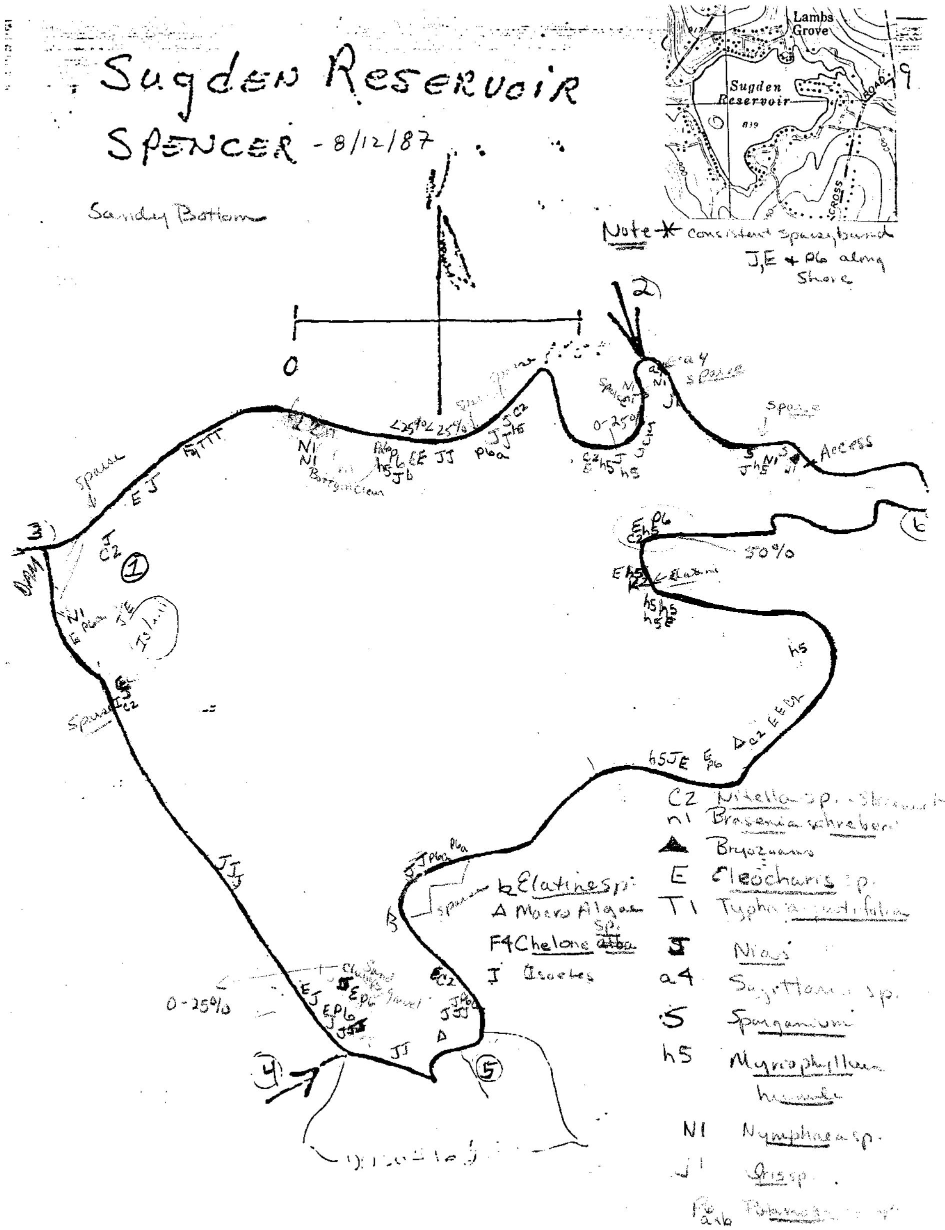


Figure 3k. Sugden Reservoir Macrophyte species distribution.

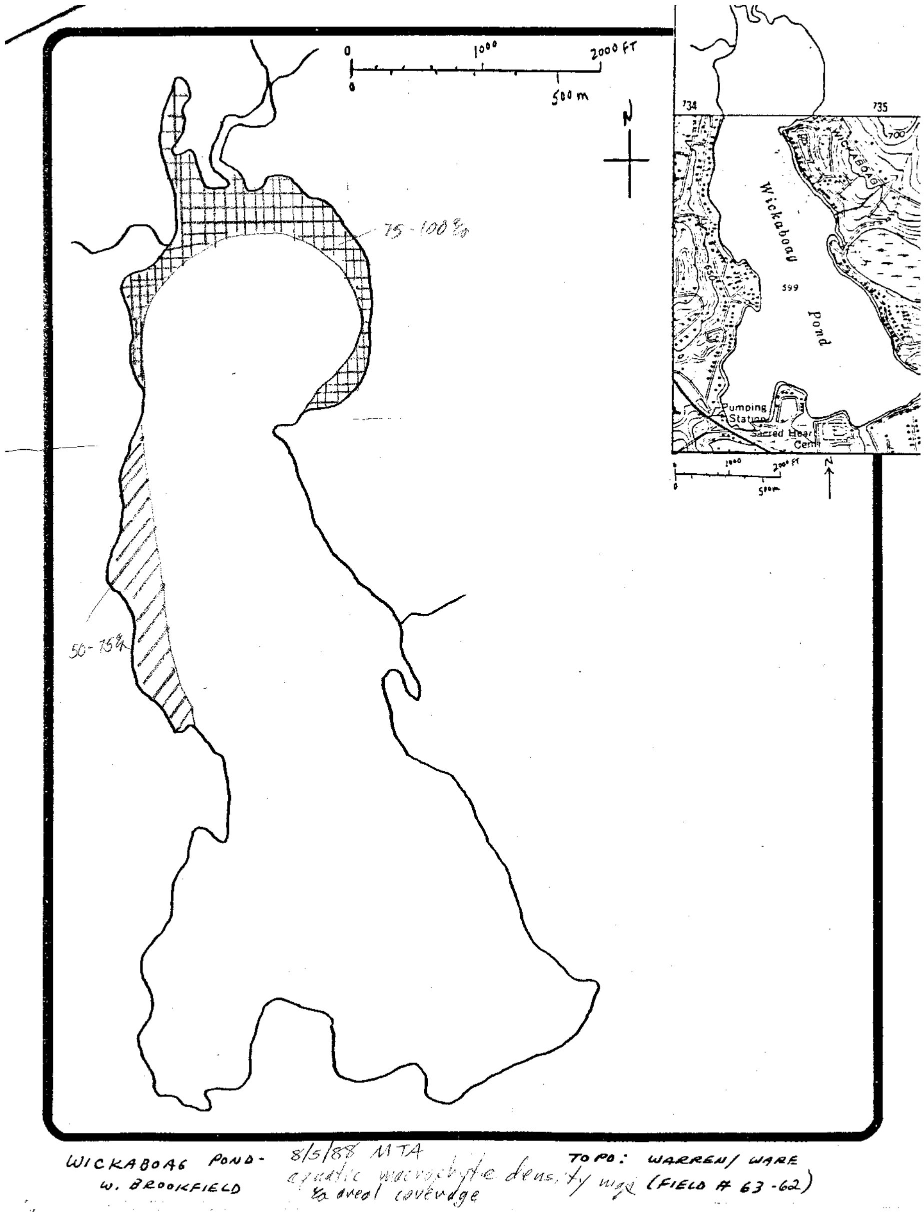


Figure 3l. Wickaboag Pond Macrophyte density map.

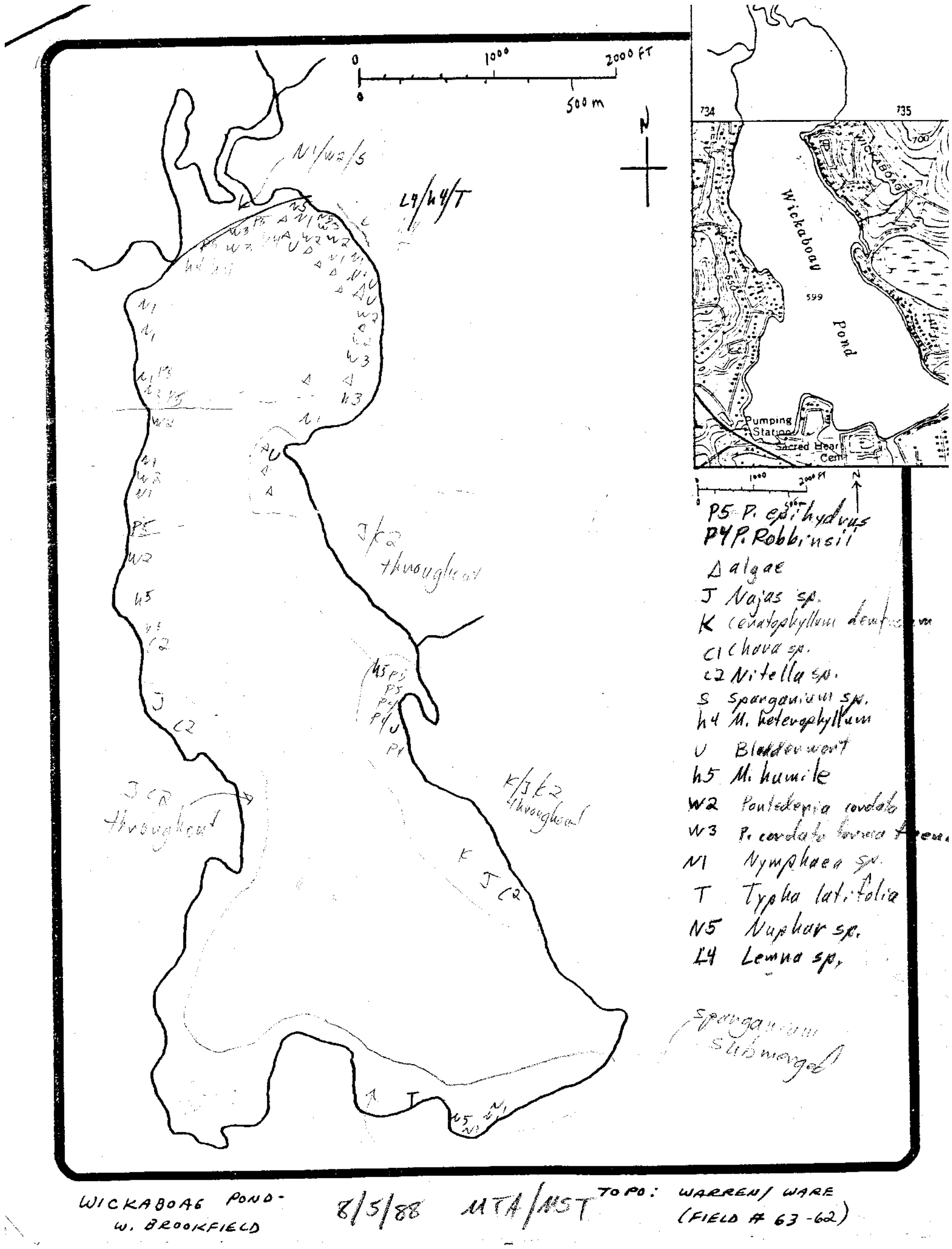


Figure 3m. Wickaboag Pond Macrophyte species distributions.

Pollutant Sources and Background

No detailed study of the nutrient sources within the 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. A review by Mattson and Isaac (1999) of other models including the use of mean values from Reckhow et al., (1980) or the MassGIS dataviewer tool appeared to overestimate loads to lakes. The phosphorus loading estimates from the NPSLAKE model are used with estimates of water runoff (from runoff maps of Krug et al., 1990) and these are used as inputs into a water quality model of Reckhow (1979) which is included as part of the NPSLAKE model output. A brief description of the NPSLAKE model and data inputs is given here. MassGIS digital maps of land use 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 much 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. No point sources are present in watersheds of the lakes addressed in this report. 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 (see discussion and references in Mattson and Isaac, 1999). Other, non-landuse sources of phosphorus such as inputs from waterfowl were not included, 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.

Internal sources (recycling) of phosphorus are not included because they are not considered as part of the 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 Table 2a-g.

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 sources 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 solid (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.

Table 2. NPSLAKE model results.

Table 2a. Browning Pond MA36025
Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	1184.7 Ha (4.6 mi2)
Average Annual Water Load =	7221888.4 m3/yr (8.2 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	39.4 Ha. (97.2ac)
Areal water loading to lake: q=	18.4 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:	930.2 (78.5)	120.9 (60.5)	2325.5	22324.8
Rural category				
Agriculture:	110.0 (9.3)	33.0 (16.5)	1019.9	33981.4
Open land:	28.4 (2.4)	8.5 (4.3)	147.9	1458.5
Residential Low:	45.6 (3.8)	13.7 (6.8)	250.7	17687.3
Urban category				
Residential High:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Comm - Ind:	0.9 (0.1)	13.1 (6.6)	8.7	594.2
Other Landuses				
Water:	51.3 (4.3)	0.0 (0.0)	0.0	0.0
Wetlands:	18.4 (1.6)	0.0 (0.0)	0.0	973.8
Subtotal	1184.7	189.2	3752.8	77020.0
Other P inputs:	NA	0.0 (0.0)		
21.0 Septics:	NA	10.5 (5.3)		
Total	1184.7 (100.0)	199.7(100)	3752.8	77020.0

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 = 15.1 ppb.
Predicted transparency = 3.2 meters.
If all land were forested, P export would be 145.0 kg/yr
And the forested condition lake TP would be 11.0 ppb.

Table 2b. Long Pond MA36083

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	215.4 Ha (0.8 mi2)
Average Annual Water Load =	1313181.7 m3/yr (1.5 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	5.6 Ha. (13.7ac)
Areal water loading to lake: q=	23.6 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:	30.5 (14.1)	4.0 (2.4)	76.2	731.1
Rural category				
Agriculture:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Open land:	19.5 (9.1)	5.9 (3.6)	101.5	5113.0
Residential Low:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Urban category				
Residential High:	103.5 (48.0)	132.6 (81.5)	956.1	63301.9
Comm - Ind:	15.8 (7.4)	20.3 (12.5)	158.0	9018.2
Other Landuses				
Water:	39.6 (18.4)	0.0 (0.0)	0.0	0.0
Wetlands:	6.5 (3.0)	0.0 (0.0)	0.0	343.8
Subtotal	215.4	162.7	1291.7	78508.0
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Total	215.4 (100.0)	162.7(100)	1291.7	78508.0

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 2.9 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 73.3 ppb.
Predicted transparency = 0.7 meters.

If all land were forested, P export would be 22.0 kg/yr
And the forested condition lake TP would be 9.9 ppb.

Table 2c. Minechoag Pond MA36093

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	101.1 Ha (0.4 mi2)
Average Annual Water Load =	616180.4 m3/yr (0.7 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	8.8 Ha. (21.6ac)
Areal water loading to lake: q=	7.0 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:	17.9 (17.7)	2.3 (2.1)	44.6	428.4
Rural category				
Agriculture:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Open land:	18.6 (18.4)	5.6 (5.1)	96.6	4005.0
Residential Low:	4.6 (4.6)	1.4 (1.3)	25.4	1790.9
Urban category				
Residential High:	50.2 (49.7)	98.2 (89.7)	306.3	24574.3
Comm - Ind:	1.0 (1.0)	2.0 (1.8)	10.2	995.7
Other Landuses				
Water:	8.8 (8.7)	0.0 (0.0)	0.0	0.0
Wetlands:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Subtotal	101.1	109.5	483.2	31794.4
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Total	101.1 (100.0)	109.5(100)	483.2	31794.4

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 = 62.4 ppb.
Predicted transparency = 0.8 meters.

If all land were forested, P export would be 12.0 kg/yr
And the forested condition lake TP would be 6.8 ppb.

Table 2d. Mona Lake MA36094

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	20.9 Ha (0.1 mi2)
Average Annual Water Load =	127711.1 m3/yr (0.1 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	4.0 Ha. (9.8ac)
Areal water loading to lake: q=	3.2 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:	6.2 (29.5)	0.8 (1.7)	15.4	148.2
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:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Urban category				
Residential High:	10.8 (51.7)	46.1 (98.3)	95.8	6344.3
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	4.0 (18.9)	0.0 (0.0)	0.0	0.0
Wetlands:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Subtotal	20.9	46.9	111.3	6492.5
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Total	20.9 (100.0)	46.9(100)	111.3	6492.5

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 = 76.6 ppb.
Predicted transparency = 0.6 meters.

If all land were forested, P export would be 2.2 kg/yr
And the forested condition lake TP would be 3.6 ppb.

Table 2e. Spectacle Pond (West) MA36142.

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	10.1 Ha (0.0 mi2)
Average Annual Water Load =	61612.3 m3/yr (0.1 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	3.4 Ha. (8.5ac)
Areal water loading to lake: q=	1.8 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:	3.3 (32.6)	0.4 (2.5)	8.2	79.0
Rural category				
Agriculture:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Open land:	1.0 (10.2)	0.3 (1.8)	5.3	15.4
Residential Low:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Urban category				
Residential High:	0.4 (4.2)	5.2 (30.6)	2.3	196.9
Comm - Ind:	0.9 (8.9)	10.9 (65.0)	8.9	608.3
Other Landuses				
Water:	4.5 (44.2)	0.0 (0.0)	0.0	0.0
Wetlands:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Subtotal	10.1	16.8	24.8	899.6
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Total	10.1 (100.0)	16.8(100)	24.8	899.6

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 = 35.6 ppb.
Predicted transparency = 1.3 meters.

If all land were forested, P export would be 0.7 kg/yr
And the forested condition lake TP would be 1.6 ppb.

Table 2f. Sugden Reservoir MA36150

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	1550.0 Ha (6.0 mi2)
Average Annual Water Load =	9448890.3 m3/yr (10.7 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	33.5 Ha. (82.8ac)
Areal water loading to lake: q=	28.2 m/yr.
Homes with septic systems within 100m of lake.=	118.0
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:	1095.6 (70.7)	142.4 (38.3)	2738.9	26293.3
Rural category				
Agriculture:	221.1 (14.3)	66.3 (17.8)	2104.5	70857.9
Open land:	19.6 (1.3)	5.9 (1.6)	101.7	293.4
Residential Low:	63.8 (4.1)	19.1 (5.1)	350.8	24750.7
Urban category				
Residential High:	23.7 (1.5)	58.8 (15.8)	152.0	11828.8
Comm - Ind:	8.2 (0.5)	20.3 (5.5)	81.8	4564.3
Other Landuses				
Water:	79.6 (5.1)	0.0 (0.0)	0.0	0.0
Wetlands:	38.5 (2.5)	0.0 (0.0)	0.0	2037.9
Subtotal	1550.0	312.9	5529.7	140626.4
Other P inputs:	NA	0.0 (0.0)		
118.0 Septics:	NA	59.0 (15.9)		
Total	1550.0 (100.0)	371.9(100)	5529.7	140626.4

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 1.1 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 24.4 ppb.
Predicted transparency = 2.0 meters.

If all land were forested, P export would be 186.2 kg/yr
And the forested condition lake TP would be 12.2 ppb.

Table 2g. Wickaboag Pond MA36166

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	4591.9 Ha (17.7 mi2)
Average Annual Water Load =	27992522.4 m3/yr (31.7 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	129.6 Ha. (320.0ac)
Areal water loading to lake: q=	21.6 m/yr.
Homes with septic systems within 100m of lake.=	246.0
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:	2870.3 (62.5)	373.1 (35.6)	7175.9	68888.3
Rural category				
Agriculture:	1055.0 (23.0)	316.5 (30.2)	9801.2	332311.0
Open land:	146.9 (3.2)	44.1 (4.2)	764.0	11341.6
Residential Low:	115.0 (2.5)	34.5 (3.3)	632.7	44635.3
Urban category				
Residential High:	109.3 (2.4)	136.0 (13.0)	873.2	60911.0
Comm - Ind:	17.4 (0.4)	21.6 (2.1)	173.0	5351.5
Other Landuses				
Water:	144.9 (3.2)	0.0 (0.0)	0.0	0.0
Wetlands:	133.0 (2.9)	0.0 (0.0)	0.0	7049.4
Subtotal	4591.9	925.8	19800.0	535540.0
Other P inputs:	NA	0.0 (0.0)		
246.0 Septics:	NA	123.0 (11.7)		
Total	4591.9 (100.0)	1048.8(100)	19800.0	535540.0

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 = 21.6 ppb.
Predicted transparency = 2.2 meters.

If all land were forested, P export would be 560.8 kg/yr
And the forested condition lake TP would be 11.5 ppb.

Water Quality Standards Violations

In consideration that all seven lakes are listed as 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 all lakes except Sugden Reservoir which was listed for nutrients, as the cause for violation of the Water Quality Standards related to impairment of primary and secondary contact recreation and aesthetics. In addition, Browning Pond and Sugden Reservoir are also listed for organic enrichment/Low dissolved oxygen, and Wickaboag Pond is also listed for turbidity. These 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….

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 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 no more than 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. In the case of Browning Pond the target is the same as the current predicted total phosphorus concentration and thus no reduction in loading is required.

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. 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: Early (pre-1990) survey TP concentrations have a detection limit of approximately 50 ppb, and values reported less than this are suspect.

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)
MA36025	Browning Pond	15-19	10-14	15	20	15
MA36083	Long Pond	25-50	>50	73	210	30
MA36093	Minechoag Pond	25-50	>50	62	40	30
MA36094	Mona Lake	25-50	>50	77	130	30
MA36142	Spectacle Pond	25-50	>50	35	20	20
MA36150	Sugden Reservoir	15-19	10-14	24	60	15
MA36166	Wickaboag Pond	15-19	10-14	22	50	15

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. 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 larger than those predicted by the NPSLAKE model (see Long Pond, Mona Lake, Sugden Reservoir and Wickaboag Pond in Table 3). 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. Spectacle Pond is a seepage lake with a very small watershed and thus the NPSLAKE model prediction for loading if probably too high as indicated by the over prediction of lake phosphorus concentrations. As a further effort to protect this trout pond the target TP concentration was set lower (to 20 ppb) than that indicated by the ecoregion maps (25-50 ppb).

Phosphorus loading allocations for each landuse category are shown (in most cases rounded to the nearest kg/yr) in Table 4. No reduction in forest loading is targeted, because other than logging operations, which are relatively rare and are required by the DEM to use BMPs as part of their logging operations, this source is unlikely to be significantly reduced by additional BMPs. The remaining load reductions are allocated as a proportional phosphorus loading reduction.

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

Table 4. TMDL Load Allocations.
Table 4a. Browning Pond MA36025 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	121	121
Agriculture	33	33
Open Land	9	9
Residential (Low den.)	14	14
Residential (High den.)	0	0
Comm. Indust.	13	13
Septic System	10	10
Other	0.0	0.0
Total Inputs	200	200

Table 4b. Long Pond MA36083 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Forest	4	4
Agriculture	0	0
Open Land	6	2
Residential (Low den.)	0	0
Residential (High den.)	133	53
Comm. Indust.	20	8
Septic System	0	0
Other	0	0
Total Inputs	163	68

Table 4c. Minechoag Pond MA36093 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Forest	2	2
Agriculture	0	0
Open Land	6	3
Residential (Low den.)	1	1
Residential (High den.)	98	46
Comm. Indust.	2	1
Septic System	0	0
Other	0	0
Total Inputs	110	53

Table 4d. Mona Lake MA36094 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Forest	1	1
Agriculture	0	0
Open Land	0	0
Residential (Low den.)	0	0
Residential (High den.)	46	18
Comm. Indust.	0	0
Septic System	0	0
Other	0	0
Total Inputs	47	19

Table 4e. Spectacle Pond MA36142 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Forest	0.4	0.4
Agriculture	0	0
Open Land	0.3	0.3
Residential (Low den.)	0	0
Residential (High den.)	5.2	3
Comm. Indust.	10.9	5
Septic System	0	0
Other	0	0
Total Inputs	16.8	8.7

Table 4f. Sugden Reservoir MA36150 TMDL Load Allocation.

Source	Current TP Loading (kg/yr)	Target TP Load Allocation (kg/yr)
Forest	142	142
Agriculture	66	25
Open Land	6	2
Residential (Low den.)	19	7
Residential (High den.)	59	22
Comm. Indust.	20	8
Septic System	59	23
Other	0	0
Total Inputs	372	230

Table 4g. Wickaboag Pond MA36166 TMDL Load Allocation.

Source	Current TP Loading (kg/yr)	Target TP Load Allocation (kg/yr)
Forest	373	373
Agriculture	317	167
Open Land	44	23
Residential (Low den.)	35	18
Residential (High den.)	136	72
Comm. Indust.	22	11
Septic System	123	65
Other	0	0
Total Inputs	1049	729

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 these phosphorus TMDLs were 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 annual phosphorus load to the ponds 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).

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 cannot 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 Watershed Basin 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 Basin 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 2000 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 Extension	Conduct soil P tests; apply no more fertilizer than required. Install BMPs to prevent runoff to surface waters.
Manure leaching	Landowner and NRCS and UMass Extension	Conduct soil P tests. Apply no more manure than required by soil P test. Install manure BMPs.
Erosion and Animal related 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, Conservation Commission	Various techniques including seeding, diversion dikes, sediment fences, detention ponds etc.
Resource Extraction		
Timber Harvesting	Landowner, logger, Regional DEM forester Conservation Commission	Check that an approved forest cutting plan is in place and BMPs for erosion are being followed
Gravel Pits	Pit owner, Regional DEP, Conservation Commission	Check permits for compliance, recycle wash water, and install sedimentation ponds and berms. Install rinsing ponds.
Residential, urban areas		
Septic Systems	Homeowner, Lake associations, 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 in septic systems.
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, Town or city Dept. Public Works	Reduce impervious surfaces, institute street sweeping program, catch basin cleaning, install detention basins etc.
Highway Runoff	MassHighway, Mass Turnpike	Regulate 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	Landowner, Conservation	Determine cause of problem; install riprap, plant

lakeside erosion	Commission	vegetation.

Table 7. Suggested Implementation by Lake

Lake Name WBID=> Implementation Suggested	Browning Pond MA36025	Long Pond MA36083	Minechoag Pond MA36093	Mona Lake MA36094	Spectacle Pond MA36142	Sugden Reservoir MA36150	Wickaboag Pond MA36166
Public Education	X	X	X	X	X	X	X
NPS Survey	X	X	X	X	X	X	X
Lake Management Plan	X	X	X	X	X	X	X
Forestry BMPs	X					X	X
Agriculture BMPs						X	X
Residential BMPs						X	X
Septic System Maintenance	X					X	X
Urban BMPs		X	X	X	X	X	
Highway BMPs			X		X		X
In-Lake Management	X	X	X	X	X	X	X
Other (Gravel pits, golf courses, see text)							

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 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 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 staff 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 effectiveness in 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

Public meetings were announced in the Environmental Monitor and in letters mailed to local officials, watershed organizations and interested local residents. Two public meeting were held on October 30, 2001. The first meeting was held at 5:00-6:30pm the Town Hall in West Brookfield near Lake Wickaboag, and the second meeting was held at 7:30-9:00pm at the Kennedy Middle School in Indian Orchard near Long Pond. Attendees at both meetings are listed in Appendix III.

Public Comment and Reply

Comment: What monitoring resources are available to check if Best Management Practices are working to improve water quality in Lake Wickaboag?
Response: One possible source of assistance is the Chicopee Watershed Team led by Paul Lyons (in attendance). As part of the Massachusetts Watershed Initiative annual team workplan, specific watershed projects, including water quality monitoring projects, can be submitted and prioritized. Another source of volunteer monitoring assistance is the University of Massachusetts Water Watch Partnership. In order for DEP to consider water quality data from volunteer organizations, a Quality Assurance Project Plan (QAAP) must be approved by DEP and EPA. The Massachusetts Water Watch Partnership can provide technical assistance and support to develop a QAPP. A guidebook titled "The Massachusetts Volunteer Monitors Guidebook to Quality Assurance Plans" published on 10/1/01 has been forwarded to Al Collins.

Comment: Do you need "full public access" to a beach in order to be eligible for DEM's Lake & Pond grants? Lake Wickaboag's swimming area is restricted to only W. Brookfield residents.
Response: It must have at least one formal means of access open to all residents of Massachusetts in order to be eligible for DEM grant awards.

Comment: The Board of Health noted approximately 45 septic systems on lake Wickaboag have been upgraded in the last 5 years, of which approximately 5 systems have been tight tanks).
Response: Additional Title V financial assistance is available through DEP's Community Septic Management Program. This program provides low interest loans to communities and homeowners for septic system planning, upgrades and a management plan. During 1996-1998, every municipality in Massachusetts was given an opportunity to participate. The Town of W. Brookfield opted not to participate at that time. However, currently, any interested communities can participate and are eligible to receive a total of $10,000 in Pre-Loan assistance as part of the program. Mike DiBara will follow-up with Joanne Kasper Dunne, DEP's Regional Title V Loan Coordinator

Comment: What is the potential environmental impact from the Chapman Valve (an old industrial site), which used foundry sand from their operations (possibly containing metals and oils) as fill material for the Kennedy Middle School playground, which abuts Long Pond?

Response: Katie Galluzo, Planning Director for the City of Springfield, noted that the City of Springfield has commissioned a study to look at the potential impacts from the old Chapman site.

Comment: What can be done to remove weeds in Long Pond? During the last 7-8 years residents have seen a dramatic in weed growth throughout the pond.

Response: Nutrient reductions will help slow further eutrophication of the lake. However, to control aquatic plants in the short term requires direct management such as harvesting, drawdowns, or herbicides. Dredging is effective in control of aquatic plants, but this is very expensive. Further information on plant management is available in the Draft Generic Environmental Impact Report on Eutrophication in Massachusetts lakes (Mattson, et al., 1998).

Comment: The Boy Scouts Troup 356 has been monitoring Spectacle Pond for years (data attached to letter). Perhaps you will come to the same conclusions we did, namely: 1) Exotic aquatic vegetation does not appear to be a problem. 2) Spec Pond is one of the clearest ponds in Massachusetts (Secchi readings over 4 meters). 3) Phosphorus levels are normal –i.e. lower not higher, 4) pH and temperature are normal, 5) The overall health of the pond is excellent.
Response: The Department agrees with your assessment. Spectacle Pond is a very clear water pond and should be protected. In such ponds, even small increases in phosphorus can lead to noticeable decreases in transparency and this is why a protective TMDL is established here.

References

Carlson, R.E. 1977. A Trophic State Index for Lakes. Limnol. Oceanogr. 22(2):361-369.

Cooke, G.D., E.B. Welsh, S.A. Peterson, P.R. Newroth. 1993. Restoration and Management of Lakes and Reservoirs. 2nd Ed. Lewis Publishers. Boca Raton.

BEC and Purcell Asso. 1980. Springfield Lakes and Ponds Inventory and Restoration Plan. City of Springfield Park Comm. Baystate Environmental Consultants Inc. East Longmeadow, MA and Purcell Associates, Glastonbury CT.

Boutiette, L.N.Jr., and C.L. Duerring. 1994. Massachusetts Nonpoint Source Management Manual. "The MegaManual" A Guidance Document for Municipal Officials. Mass. Dept. Environmental Protection., Boston, MA.

DEP, 1997. Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas. A Guide for Planners, Designers and Municipal Officials. Massachusetts Dept. Environmental Protection., EOEA, State Commission for Conservation of Soil, Water and Related Resources, Natural Resources Conservation Service USDA.

DEP, 1998. Massachusetts Section 303(d) List of Waters- 1998. Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

DEP, DWM. 1998. Commonwealth of Massachusetts, Summary of Water Quality, 1998. Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

DEP, 2001. Massachusetts Volunteers Guide for Surveying a Lake Watershed and Preparing an Action Plan. Department of Environmental Protection, Boston MA.

Dillon, P.J. and F.H. Rigler. 1974. A test of a simple nutrient budget model predicting the phosphorus concentration in lake water. J. Fish. Res. Bd. Can. 31:1771-1778.

EPA. 1983. Results of the Nationwide Urban Runoff Program. Volume 1, Final Report. Water Planning Division U.S.E.P.A. Washington DC. NTIS #PB84-185552.

Griffith, G.E., J.M. Omernik, S.M. Pierson, and C.W. Kiilsgaard. 1994. Massachusetts Ecological Regions Project. USEPA Corvallis. Massachusetts DEP, DWM Publication No. 17587-74-70-6/94-D.E.P.

Horne, A.J. and C.R. Goldman. 1994. Limnology. 2nd Ed. McGraw-Hill Inc. New York.

Kittredge, D.B., Jr. and Parker, M. 1995. Massachusetts Forestry Best Management Practices Manual. Mass. Dept. Environmental Protection. Office of Watershed Management and U.S.E.P.A. 56pp.

Likens, G.E. 1972. Nutrients and Eutrophication.: The Limiting-Nutrient Controversy. Limnology and Oceanography, Special Symposia Volume I. 328pp.

Mattson, M.D., P.J. Godfrey, R.A. Barletta and A. Aiello. 1998. Draft Generic Environmental Impact Report. Eutrophication and Aquatic Plant Management in Massachusetts. Massachusetts Department of Environmental Protection and Massachusetts Department of Environmental Management. 435 pp.

Mattson, M.D. and R.A. Isaac. 1999. Calibration of Phosphorus Export coefficients for Total Maximum Daily Loads of Massachusetts Lakes. Lake and Reservoir Man. 15(3):209-219.

Reckhow, K.H. 1979. Uncertainty Analysis Applied to Vollenweider's Phosphorus Loading Criteria. J. Water Poll. Control Fed. 51(8):2123-2128.

Reckhow, K.H., M.N. Beaulac, J.T. Simpson. 1980. Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients. U.S.E.P.A. Washington DC. EPA 440/5-80-011.

Rohm, C.M., J.M. Omernik, and C.W. Kiilsgaard. 1995. Regional Patterns of Total Phosphorus in Lakes of the Northeastern United States. Lake and Reservoir Man. 11(1): 1-14.

Schindler, D.W. and E.J. Fee. 1974. Experimental Lakes Area: Whole-Lake Experiments in Eutrophication. J. Fish. Res. Bd. Can. 31:937-953.

Vallentyne, J.R. 1974. The Algal Bowl – Lakes and Man. Ottawa, Misc. Spec. Publ. 22. Dept. of the Environ.. 185pp.

Vollenweider, R.A. 1975. Input-Output Models with Special Reference to the Phosphorus Loading Concept in Limnology. Sch. Zeit. Hydrologic 37:53-84.

Vollenweider, R.A. 1976. Advances in Defining Critical Loading Leveles for Phosphorus in Lake Eutrophication. Mem. Ist. Ital. Idrobiol., 33:53-83.

Wetzel, R.G. 1983. Limnology. 2nd Ed. Saunders College Publishing. New York.

Appendix I. 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 II. Common Scientific Terms.

Algae - Microscopic plants, generally not visible to naked eye except for large colonies.
BMPs – Best Management Practices, management that maintains uses while reducing pollution.
Ecoregion – a region that is similar in topography, soils, vegetation and nutrient levels
Eutrophic - Nutrient rich with abundant plant growth
Eutrophication – the tendency over time to add nutrients and become more eutrophic
Macrophyte - Large Aquatic plant, visible to naked eye.
Mesotrophic- moderate nutrient concentrations and plant growth
Oligotrophic- nutrient poor with little plant growth
Phytoplankton – Algae that are free floating in the water.
TMDL – Total Maximum Daily Load

Appendix III. Meeting Attendees List for the Two Meetings.

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

ARGEO PAUL CELLUCCI
Governor

JANE SWIFT
Lieutenant Governor

BOB DURAND
Secretary

LAUREN A. LISS
Commissioner

MEETING ATTENDEES LIST

Meeting: Chicopee LAkes (W. Brookfield)
Date: 10/30/2001 Place: W. Brookfield Town Hall

Name	Affiliation	phone	email
JOHN TIVNAN	Select man		
1 TONY LONG	SELECTMAN		
2 PAUL LYONS	EOEA/MWI	413.323.8998	Paul.Lyons@state.ma.us
3 BRIAN DUVAL	MA DEP CERO	508-849-4027	brian.duval@state.ma.us
4 Bruce Rosinoff	US EPA	617-918-1678	Rosinoff.Bruce@EPA.GOV
5 Ginny Scarlet	Browning Pond	508-885-2555	rscarlet@world.std.com
6 Richard Scarlet	Browning Pond	"	rscarlet@world.std.com
7 Joseph ZAlieckAS	Sugden Reservoir	508-885-5550	N/A
8 JOHANNA BARRY	W.B. EXECUTIVE SECRETARY	508-867-1421	
9 MARY BETH CZAJA	Lake Wickaboag P.A.	508-248-9862	marybeth@northamericantoll.com
10 Al Collings	Lake Wickaboag Preservation Assoc	508 867 7165	acollings@discover-fe.com
11 Nathan DeWolf	W Brookfield C.C.	508-867-3437	romulus@megamind.net
12 John Frizzell	W. Brookfield B of H.	508 867-7800	
13 LARRY HARRIS	LAKE WICKABOAG PRESERVATION ASSOC	508-867-3516	LARRY.HARRIS@COMPAQ.COM
14 Senator Stephen Brewer	Room 109	State House Boston, MA 02133	
15			
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Attendees for Chicopee Lakes TMDL Public Meeting Oct. 30, 2001 at Kennedy School.

Attendees at Meeting at Kennedy School included mostly residents from Mona and Long Ponds:

Henry & Velma Marotte
Maurice R. Roberge
Fabiola A. Gamache
Michael Waldo
Erik Wenstrom
Linda Porey
Stephen Roberge
Helene Stewart
Laurie Dean
Paul Lyons (EOEA)
Russell Isaac (DEP)
Mike DiBara (DEP)
Tracey Miller (DEP)
Deirdre Cabral (DEP)