Total Maximum Daily Loads of Phosphorus for Selected Connecticut Basin Lakes

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DEP, DWM TMDL Report MA34002-2001-4   December 17, 2001

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Front Cover

Photograph of Leverett Pond in Leverett.

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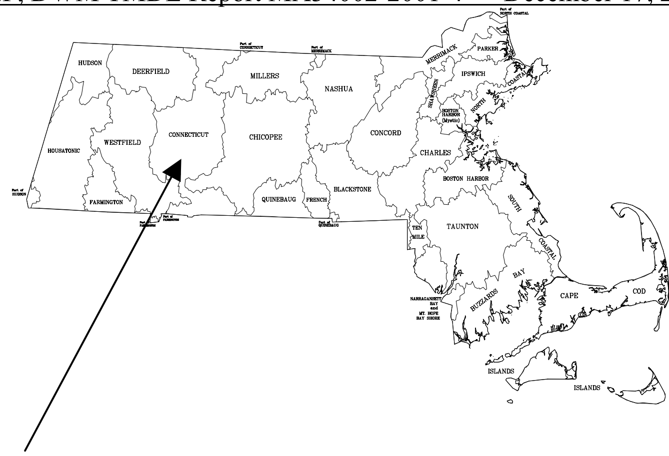

Location of Connecticut Basin in Massachusetts.

Key Feature: Total Phosphorus TMDLs for six lakes in the Connecticut Watershed.

Locations: Aldrich Lake East, Granby (MA34002); Aldrich Lake West, Granby (MA34106); Leverett Pond, Leverett (MA34042); Loon Pond, Springfield (MA34045); Lake Warner, Hadley (MA34098); Lake Wyola, Shutesbury, (MA34103).

Land Type: New England Upland

303d Listings: Six Lakes accounting for 13 stressors on 303d list including: Noxious Plants; Organic enrichment/low DO; Nutrients; and Turbidity

Data Sources: Synoptic Lake surveys, Land use information.

Modeling: NPSLAKE phosphorus loading model, Reckhow water quality model, Best Professional Judgment

Monitoring Plan: Massachusetts Watershed Initiative Five-Year Cycle and volunteer monitors

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 Connecticut Basin 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)
MA34002	Aldrich Lake East	39.3	1761.1	30	1342
MA34106	Aldrich Lake West	39.1	1786.1	30	1393
MA34042	Leverett Pond	19.8	106.5	15	80
MA34045	Loon Pond	34.9	47.1	30	41
MA34098	Lake Warner	120	7150.4	30	1790
MA34103	Lake Wyola	20.9	393.9	15	282

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	Aldrich Lake East MA34002	Aldrich Lake West MA34106	Leverett Pond MA34042	Loon Pond MA34045	Lake Warner MA34098	Lake Wyola MA34103
Public Education	X	X	X	X	X	X
NPS Survey	X	X	X	X	X	X
Lake Management Plan	X	X	X	X	X	X
Forest BMPs	X	X			X	
Agriculture BMPs			X		X	
Residential BMPs			X		X	X
Septic System Maintenance			X		X	X
Urban BMPs				X		
Highway BMPs				X	X	
In-Lake Management	X	X	X	X	X	X
Other (Goose management, see text)			X	X		X

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 is a required submittal 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 Connecticut River 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 by weight or 16 by atomic ratio (Vallentyne, 1974). Examination of relatively high N/P ratios in water suggests P is most often limiting and careful reviews of numerous experimental studies have concluded that phosphorus is a limiting nutrient in most freshwater lakes (Likens, 1972; Schindler and Fee, 1974). Most diagnostic/feasibility studies of Massachusetts lakes also indicate phosphorus as the limiting nutrient. Even in cases where nitrogen may be limiting, previous experience has shown that it is easier, more cost-effective and more ecologically sound to control phosphorus than nitrogen. The reasons include the fact that phosphorus is related to terrestrial sources and does not have a significant atmospheric source as does nitrogen (e.g., nitrates in precipitation). Thus, non-point sources of phosphorus can be managed more effectively by best management practices (BMPs). In addition, phosphorus is relatively easy to control in point source discharges. Finally, phosphorus does not have a gaseous phase, while the atmosphere is a nearly limitless source of nitrogen gas which can be fixed by some types of phytoplankton (the blue-greens, or cyanobacteria) even in the absence of other sources of nitrogen. For all of the reasons noted above, phosphorus is chosen as the critical element to control freshwater eutrophication, particularly for algal dominated lakes or in lakes threatened with excessive nutrient loading.

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

Nutrient budgets: Nutrient budgets and loading rates in lakes are determined on a yearly basis because lakes tend to accumulate nutrients as well as algal and macrophyte biomass over long time periods compared to rivers, which constantly flush components downstream. 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, yet the modeling is done on a yearly basis.

There are three basic approaches to estimating current nutrient loading rates: the measured mass balance approach 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.

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 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 can not 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. 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 for each town, derived from aerial photography taken in 1985, except for Hadley which was taken in 1997. 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	Area	303d list pollutant/stressor
MA34002	Aldrich Lake East	Granby	18.5	Noxious plants
MA34106	Aldrich Lake West	Granby	10.7	Noxious plants
MA34042	Leverett Pond	Leverett	65	Noxious plants;Turbidity
MA34045	Loon Pond	Springfield	25.4	Nutrients;Noxious plants
MA34098	Lake Warner	Hadley	68	Nutrients; Low DO;Noxious plants;Turbidity
MA34103	Lake Wyola	Shutesbury	129	Nutrients; Low DO;Noxious plants

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

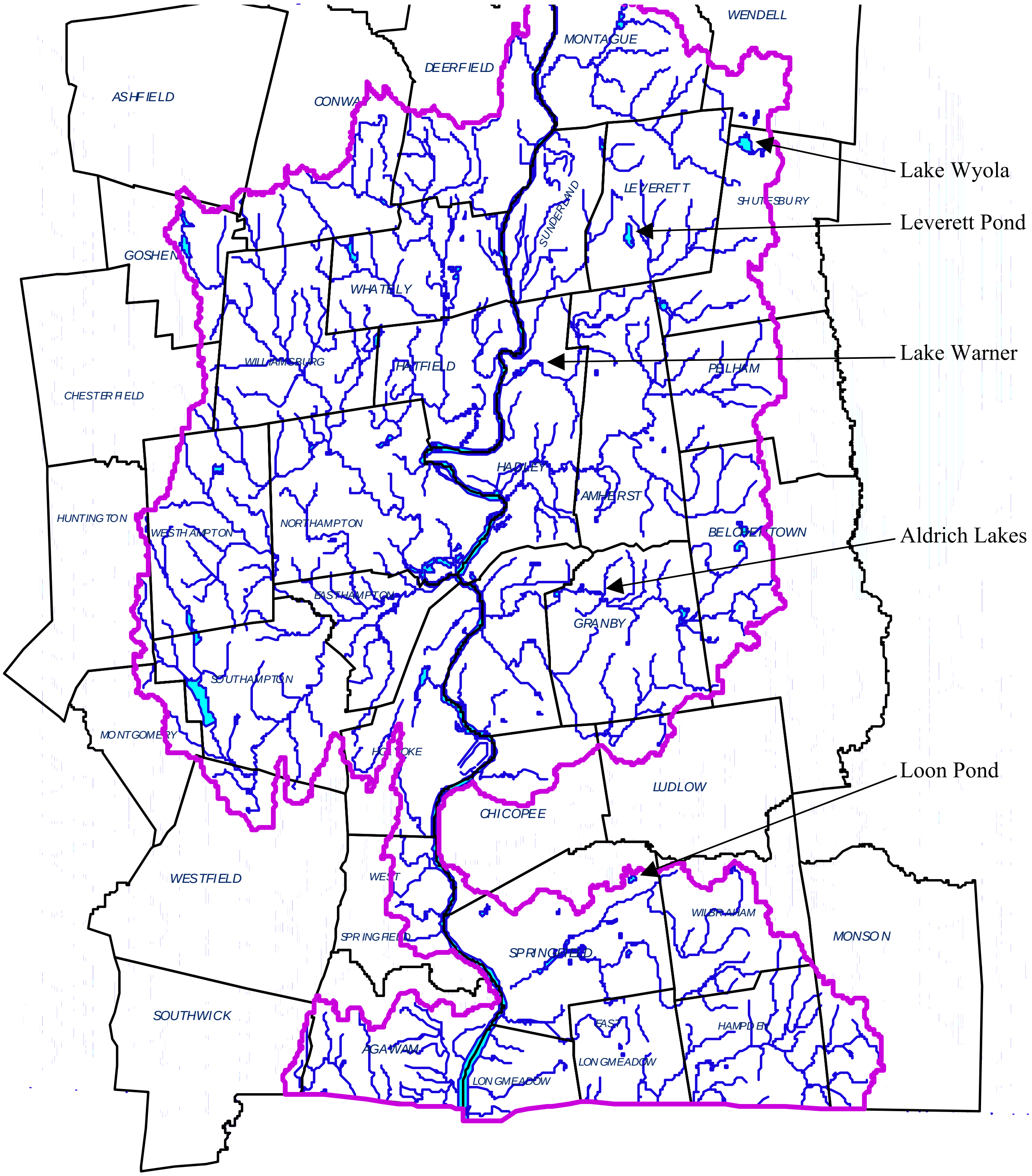


Figure 1. Locations of Connecticut Basin Lakes.

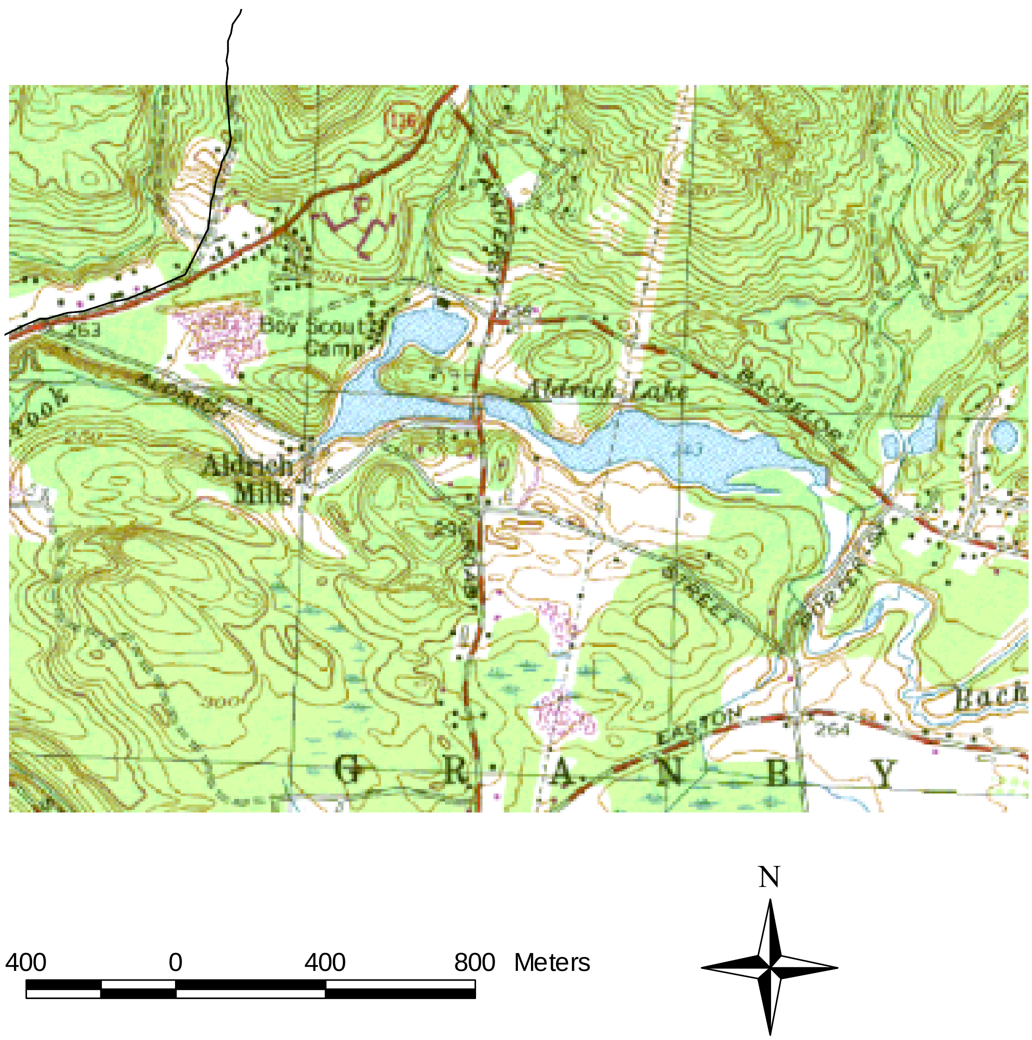


Figure 2a. Aldrich Lake (East and West) Environs.

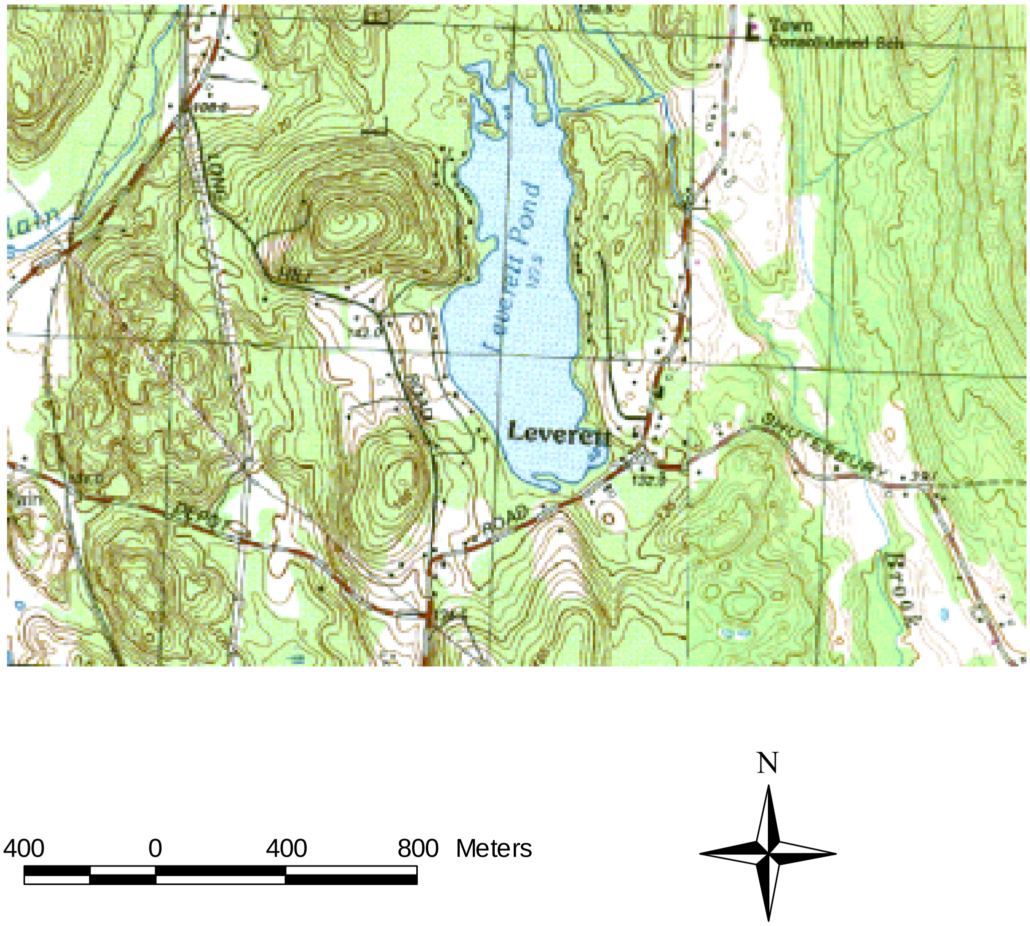


Figure 2b. Leverett Pond Environs.

Figure 2c. Loon Pond Environs.

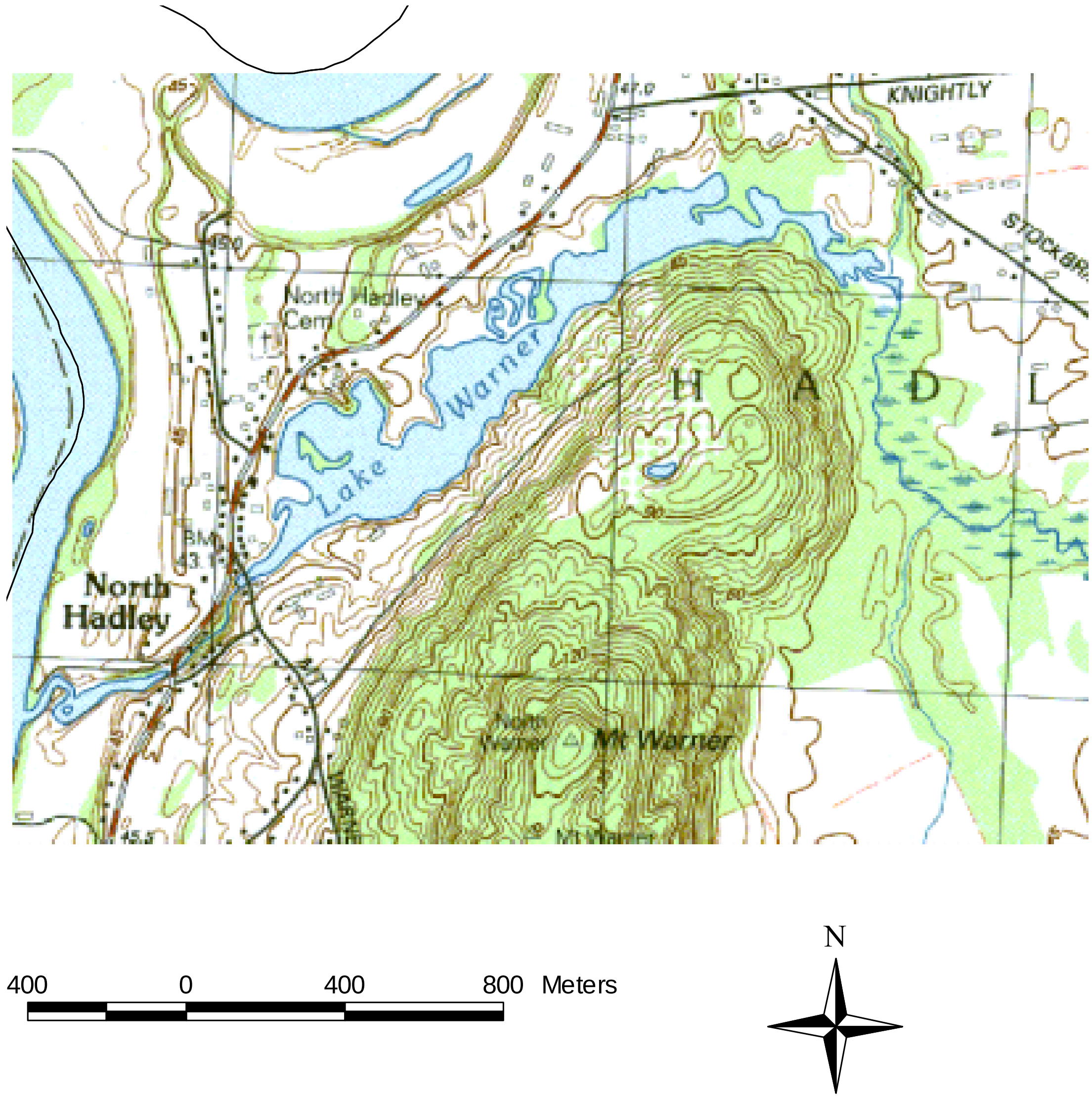


Figure 2d. Lake Warner Environs.

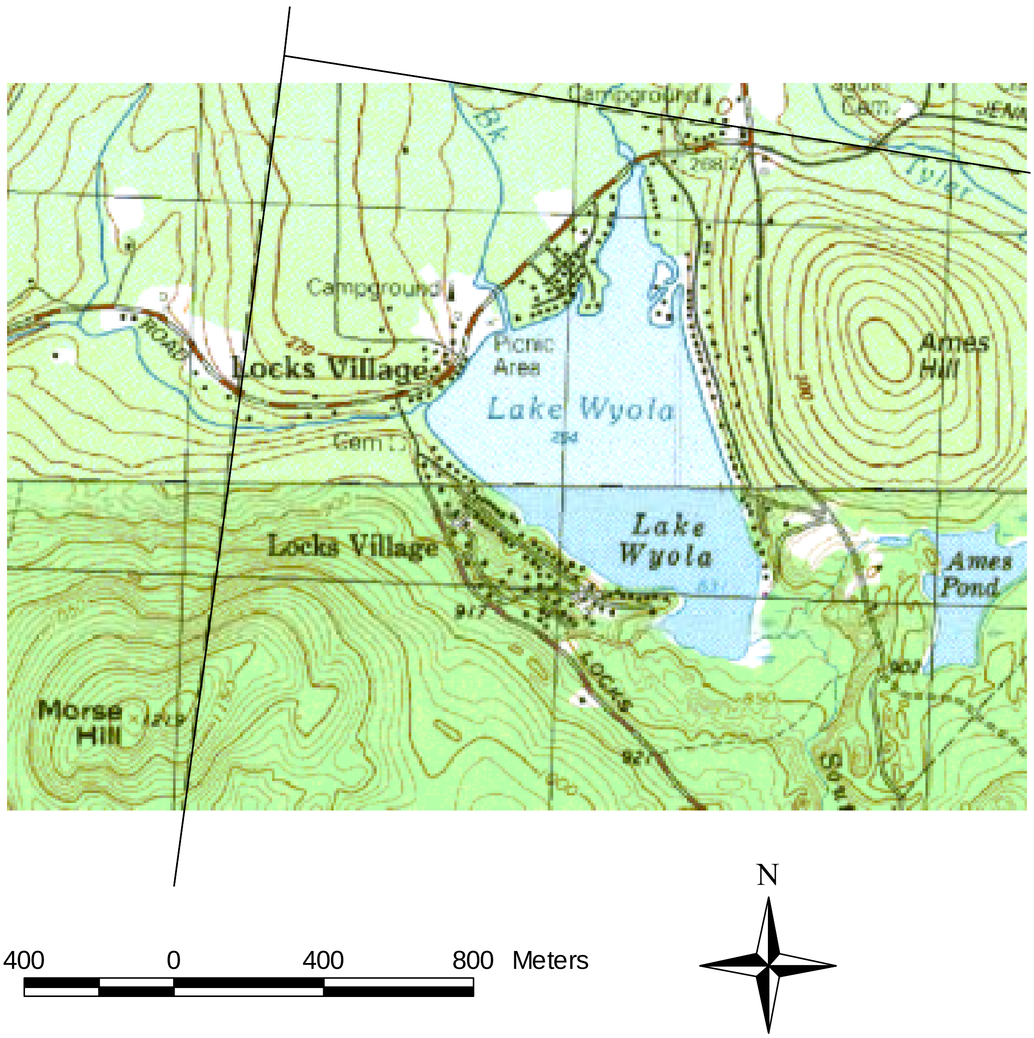


Figure 2e. Lake Wyola Environs.

Lake Descriptions:

Aldrich Lake in Granby is a reservoir which is separated by Amherst Road into two basins. The east basin is approximately18.5 acres and the west basin is approximately 10.7 acres. The major landuse within the watershed is forests, which account for 71 percent of the watershed. Another 21 percent of the area is used for agriculture, open land and low density residential housing with the remaining portion consisting of high density residential and commercial-industrial land use and water or wetlands. Populations in Granby ranged between 5,380 and 5,565 from 1980 to the 1990 census. Miser predictions on growth are 6,359 for the year 2000 and 6,693 for the year 2010 with an estimated 20 year growth rate of about 20 percent. The Belchertown Waste Water Treatment Plant (WWTP) is located upstream. Aldrich Lake was assessed by DEP in the summer of 1994 and the assessment comments reported: " very dense growths of aquatic macrophytes (primarily *Elodea* sp. and *Ceratophyllum demersum*) and macroscopic filamentous algae cover the entire pond."

Leverett Pond in Leverett is a large pond of approximately 65 acres. The watershed is 60 percent forested, 23 percent water and wetlands, 15 percent rural and the remaining 2 percent consists of high density residential land use. Populations in Leverett ranged between 1,471 and 1,785 from 1980 to the 1990 census. Miser predictions on growth are 2,083 for the year 2000 and 2,289 for the year 2010 with an estimated 20 year growth rate of about 28 percent. Secchi depth was recorded at 3.8 m in 1978, however, Leverett Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: " Very dense growths of aquatic macrophytes cover the entire littoral zone. The non-native macrophyte *Myriophyllum spicatum* has been detected, via citizen monitoring and confirmed by DWPC limnologists, in the northwest portion of the lake and along the eastern shore. Populations have been expanding and threaten the entire lake. Citizen monitoring data during summer 1993 indicated three months of Secchi disk transparency values below the safety criteria (<1.2 m). "

Loon Pond in Springfield is a small pond of approximately 25 acres. The watershed is 42 percent water and wetlands, 39 percent urban with areas of high density residential and commercial-industrial land use, 10 percent forested and the remaining 9 percent consists of open land. 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. MassHighways Route 20 is within the watershed of the pond. Secchi disk transparency was recorded at 3.0 m in 1978. Loon Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "High phosphorus levels and potential nuisance macrophyte species threaten future conditions. "

Lake Warner in Hadley is a large reservoir of approximately 68 acres. The watershed is 58 percent forested and the remainder consists of 20 percent agricultural, 14 percent rural and 8 percent urban land use with areas of high density residential and commercial-industrial land use. Populations in Hadley ranged between 4,125 and 4,231 from 1980 to the 1990 census. Miser predictions on growth are 4,591 for the year 2000 and 4,707 for the year 2010 with an estimated 20 year growth rate of about 11 percent. Masshighways Route 47 is within the watershed of the reservoir. Secchi disk transparency was recorded at 1.0 m in 1978. Lake Warner was assessed by DEP in the summer of 1994 and the assessment comments reported: "High phosphorus levels and potential nuisance macrophyte species threaten future conditions. " A report by Snow and DiGiano (1976) indicated that the sediments are likely the source of high total phosphorus in the lake and that an alum treatment of approximately 12 gm/m^2 would reduce TP to 45 ppb.

Lake Wyola in Shutesbury is a large lake of approximately 129 acres. The area of the original natural lake was approximately doubled as a result of a dam created a century ago. The watershed is 86 percent forested, 6 percent water and wetlands, 6 percent rural and the remainder consists of urban (high density residential) land use. Populations in Shutesbury ranged between 1,049 and 1,561 from 1980 to the 1990 census. Miser predictions on growth are 2,179 for the year 2000 and 2,937 for the year 2010 with an estimated 20 year growth rate of about 88 percent. With such a high population growth rate, and presumably changes in landuse, the current loading of phosphorus are probably higher than reported here, however, the target and the TMDL to protect water quality will remain the same. Secchi disk transparency was recorded at 4.2 m in a DEP baseline survey in 1988. Lake Wyola was assessed by DEP in the summer of 1994 and the assessment comments reported: "Moderate total phosphorus levels, oxygen depletion from 6 to 10 meters (< 1 mg./l below 8 meters), and very dense growths of aquatic macrophytes (primarily *Utricularia* sp.) occur on the north and south ends of the lake." However, recent citizen volunteer data indicate total phosphorus levels are very low, averaging less than 10 ppb with Secchi disk transparency ranging between 4 and 5 meters during July and August with one anomalous reading of 1 m in June (see Appendix 1 in NEE, 1997). A management plan was developed to address four issues 1) occasional lake drawdown for maintenance of dam and lakeshore areas 2) aquatic vegetation control 3) sediment removal and control and 4) bank stabilization (NEE, 1997).

Weed maps were available for Leverett Pond, Loon Pond, Lake Warner and Lake Wyola as shown in Figure 3a-g below. Species codes for the macrophyte maps are provided in Appendix II.

LEVERETT
AQUATIC VEGETATION MAP
13 JULY 1978

~~LEVERETT POND~~

~~LEVERETT~~

~~HB~~

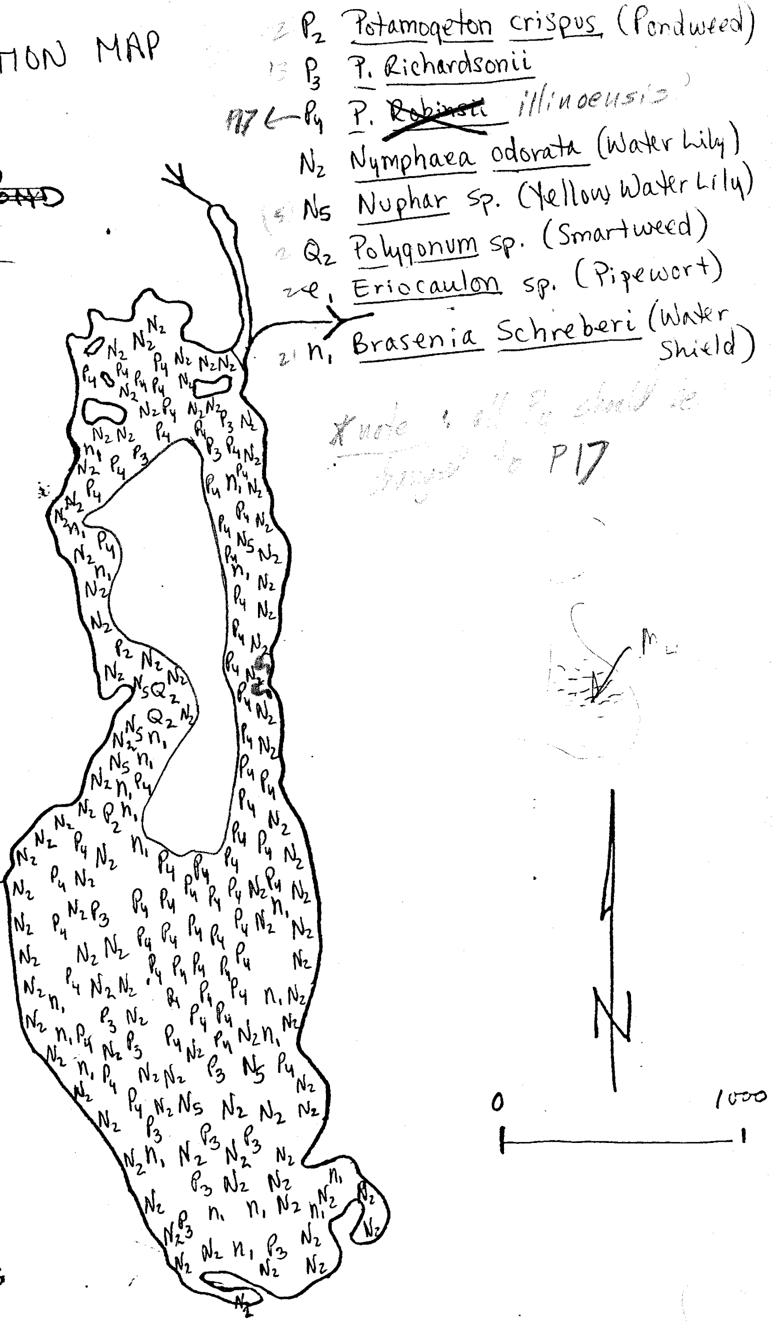
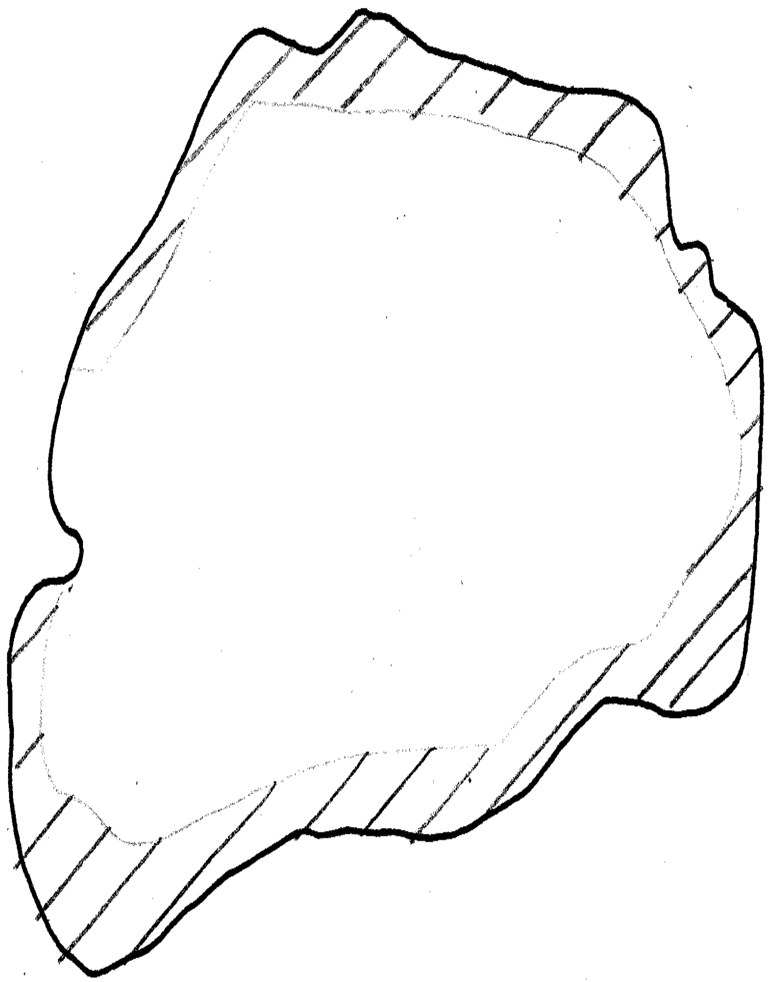


Figure 3b. Leverett Pond Macrophyte density and Species distributions (1978).



MACROPHYTE DENSITY MAP

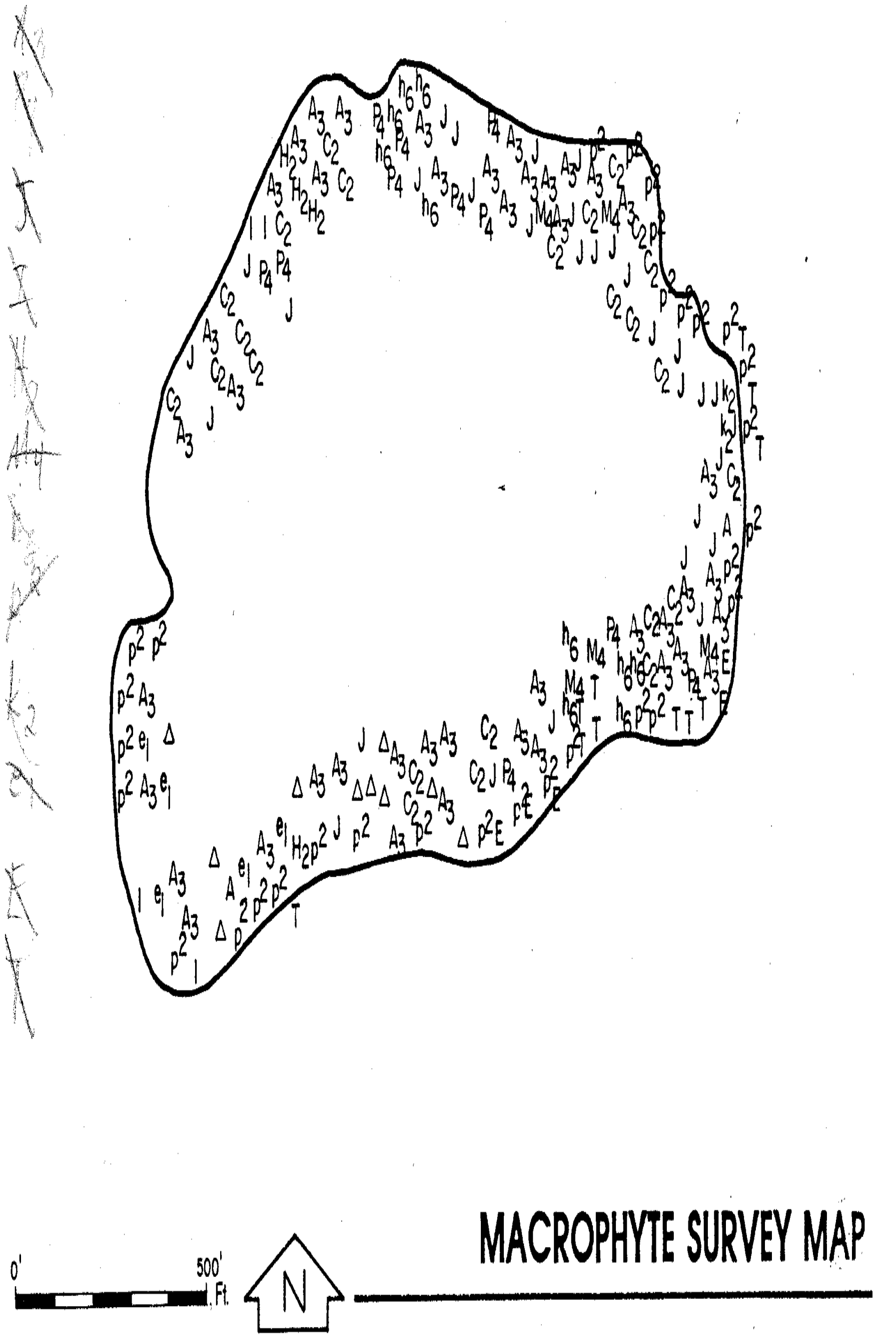
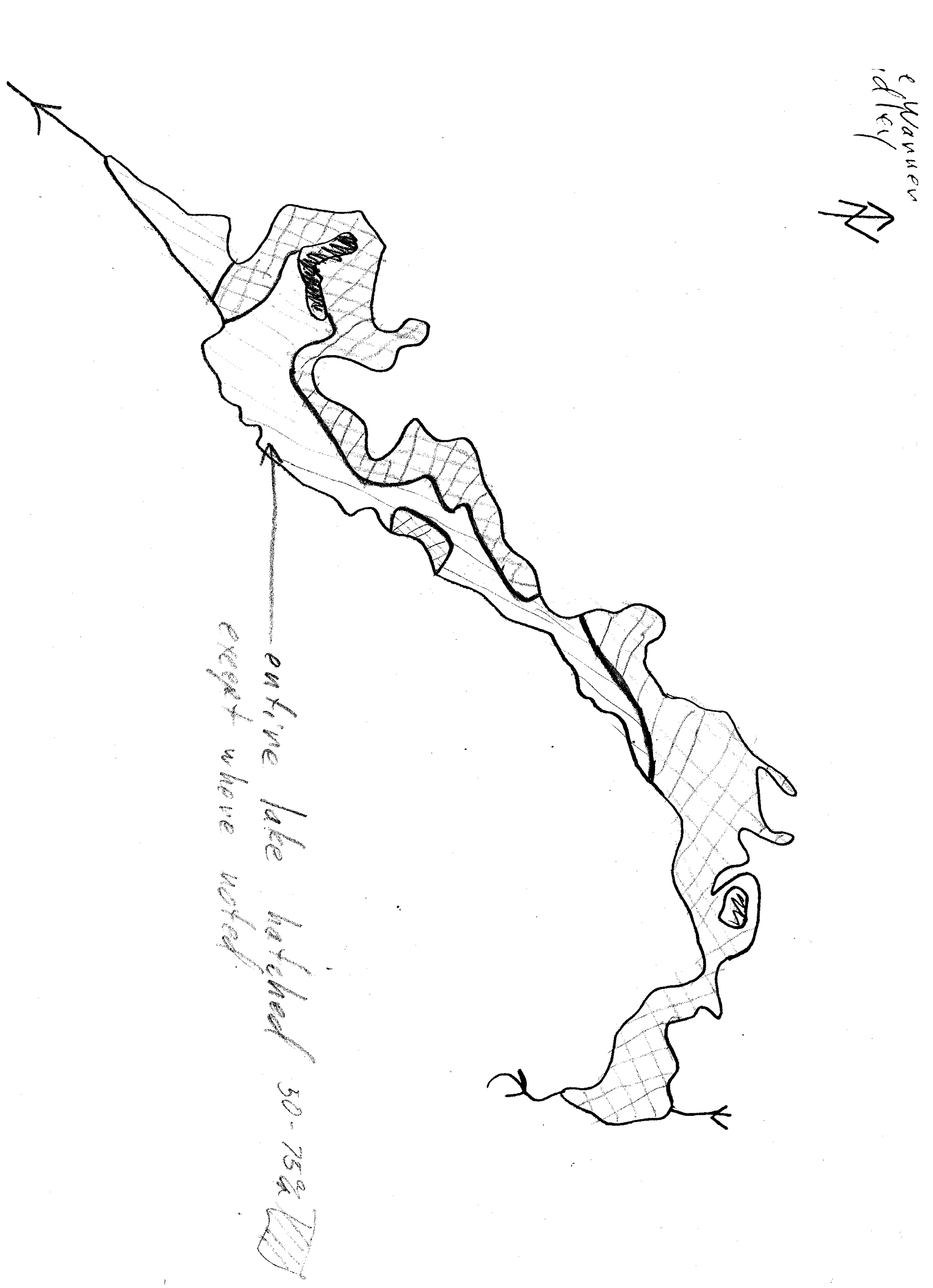


Figure 3d. Loon Pond Macrophyte density and distribution (1978).


N
entire lake hatched 30-75%
except where noted.

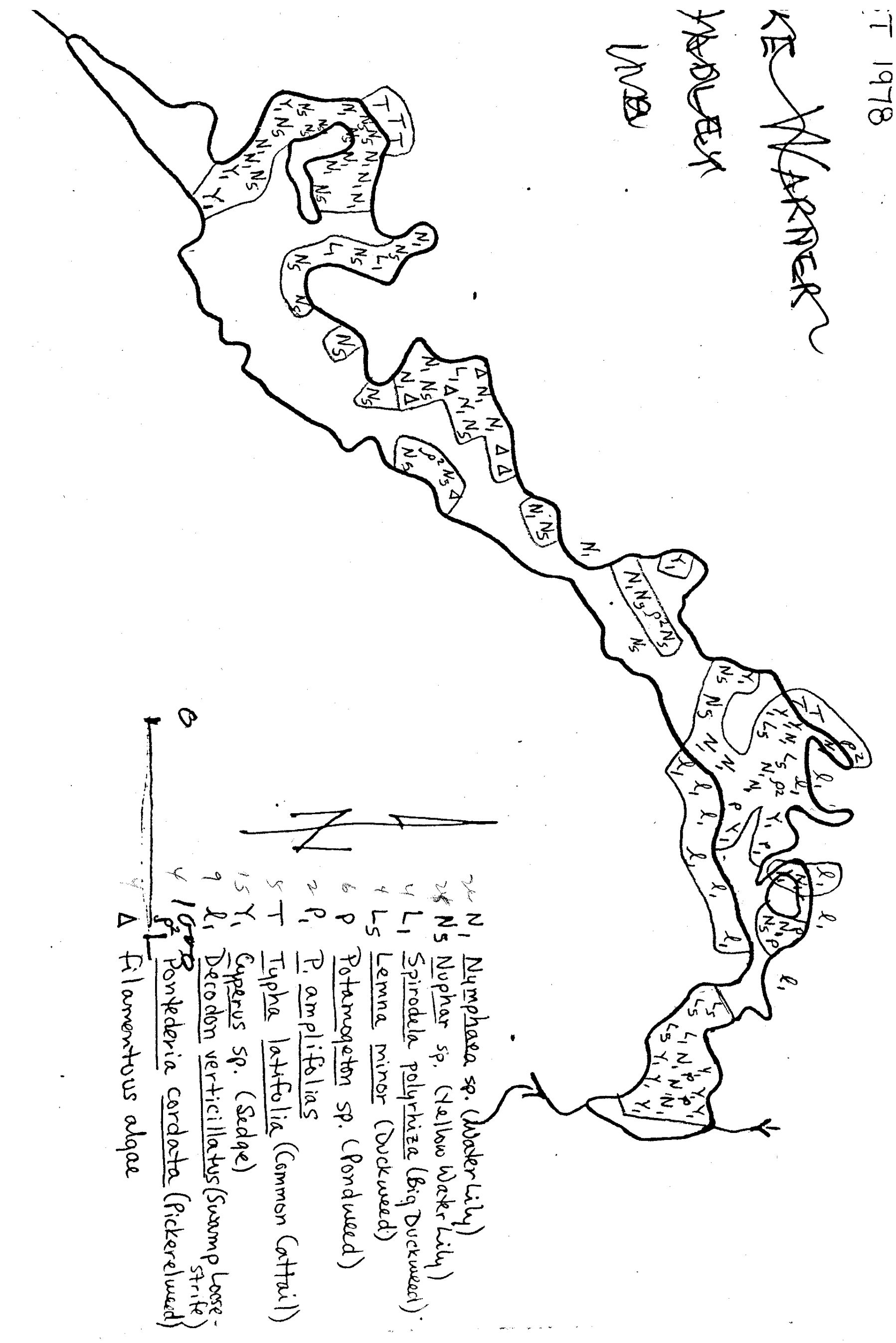


Figure 3f. Lake Warner Macrophyte density and distribution (1978).

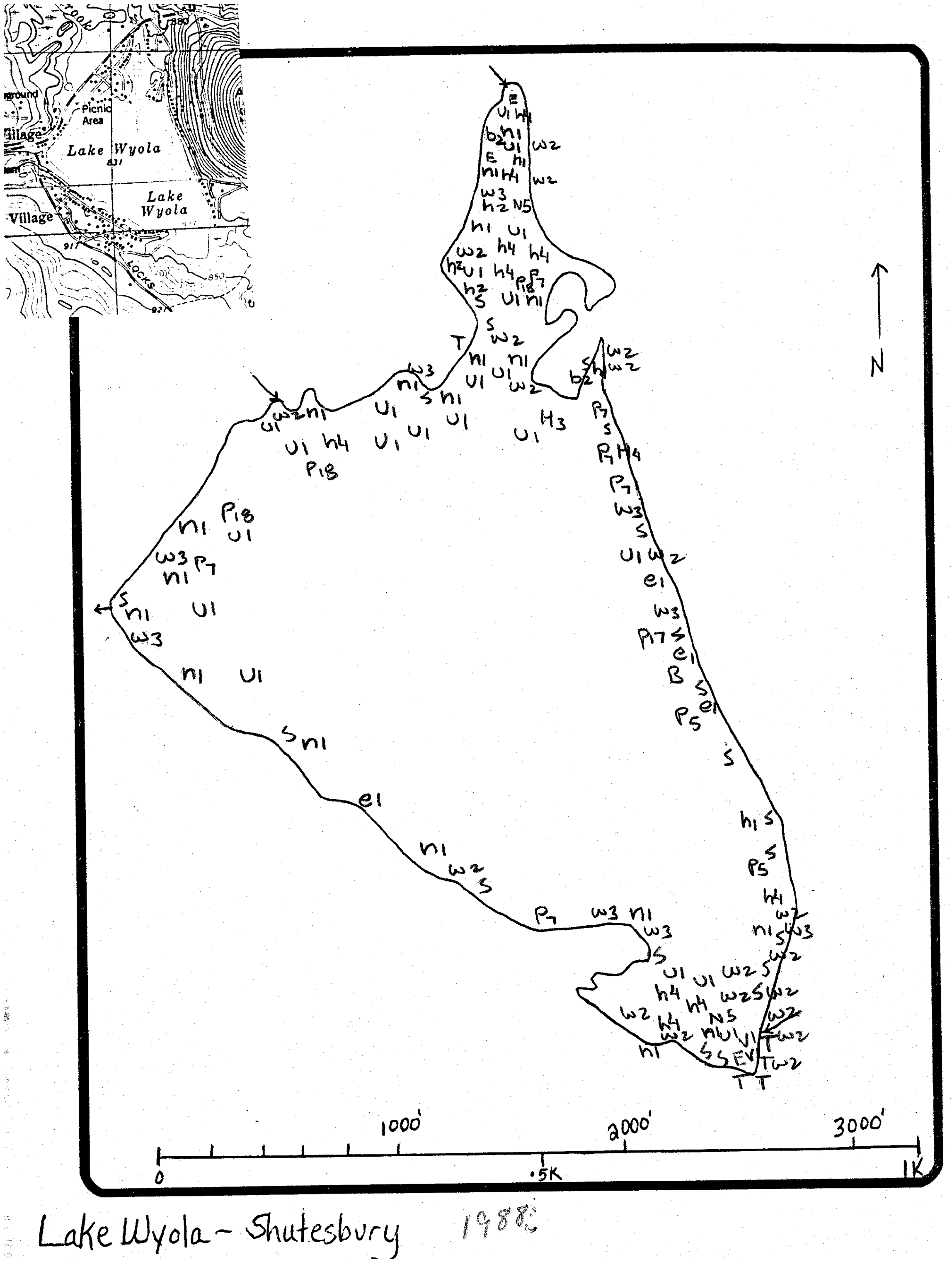


Figure 3g. Lake Wyola Macrophyte species distribution (1988).

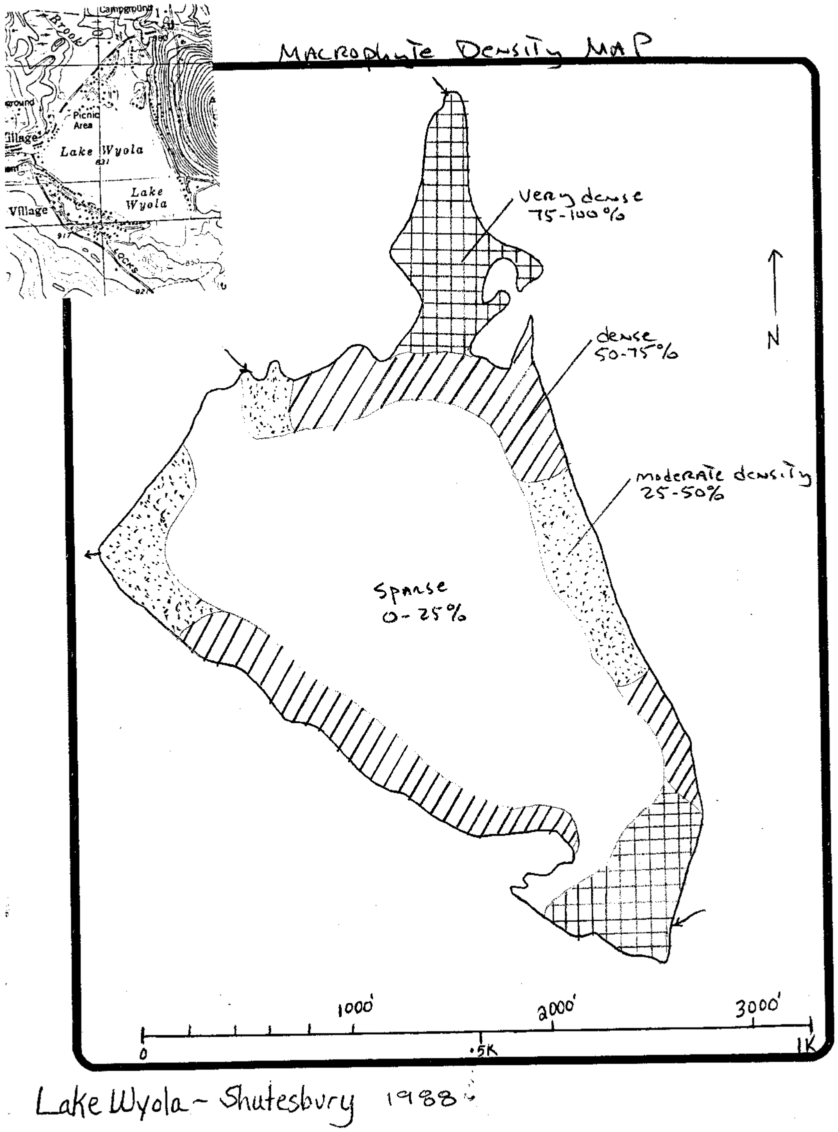


Figure 3h. Lake Wyola Macrophyte density map (1988).

Pollutant Sources and Background:

Unfortunately, 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. The phosphorus loading estimates from the model are used with estimates of water runoff and these are used as inputs into a water quality model of Reckhow (1979). A brief description of the NPSLAKE model and data inputs is given here. MassGIS digital maps of land use 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. Other sources such as atmospheric deposition to lakes was determined to be small and not significant in the NPSLAKE model, perhaps because lakes tend to be sinks rather than sources of phosphorus (Mattson and Isaac, 1999). For similar reasons wetlands were also not considered to be significant sources of phosphorus following (see discussion and references in Mattson and Isaac, 1999). Other, non-landuse sources of phosphorus such as inputs from waterfowl were 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 is not included because it is not considered as a net external load to the lake, but rather a seasonal recycling of phosphorus already present in the lake. In cases where this internal source is large it may result in surface concentrations higher than predicted from landuse loading models and may contribute to water quality violations during the critical summer period. As additional monitoring data become available, these lakes will be assessed for internal contributions and possibly control of these sources by alum or other means. The major sources according to the land use analysis are shown for each lake in Table 2.

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 not 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.

In the case of Leverett Pond, the NPSLAKE model predictions of in-lake total phosphorus based on landuse do not agree well with in-lake total phosphorus concentrations observed in 1993 (although they do agree with conditions in 1978, see above). As noted above, volunteer measurements of Secchi disk depths were less than 1.2 meters in 1993 (see above) and total phosphorus concentrations were 20 ppb, but the model predicts transparency to be 3.7 meters based on predicted total phosphorus concentrations of 12.9 ppb. Thus, there is probably an additional source of phosphorus to the pond and the most likely source is internal phosphorus from the sediments. This source was estimated by difference so that the new model predictions shown in Table 2c agree with the observed concentration. Further study on phosphorus sources to this pond is suggested.

Table 2. NPSLAKE model results.

Table 2a. Aldrich Lake East MA34002

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	5980.6 Ha (23.1 mi2)
Average Annual Water Load =	36457867.4 m3/yr (41.3 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	8.8 Ha. (21.7ac)
Areal water loading to lake: q=	414.6 m/yr.
Homes with septic systems within 100m of lake.=	1.0
Other P inputs =	606.0 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:	4263.3 (71.3)	554.2 (31.5)	10658.3	102319.2
Rural category				
Agriculture:	523.6 (8.8)	157.1 (8.9)	5940.4	213553.7
Open land:	337.2 (5.6)	101.2 (5.7)	1753.4	51463.2
Residential Low:	371.3 (6.2)	111.4 (6.3)	2041.9	144046.3
Urban category				
Residential High:	241.6 (4.0)	205.3 (11.7)	1459.8	118392.8
Comm - Ind:	30.0 (0.5)	25.5 (1.4)	298.7	15583.2
Other Landuses				
Water:	70.6 (1.2)	0.0 (0.0)	0.0	0.0
Wetlands:	143.1 (2.4)	0.0 (0.0)	0.0	7585.6
Subtotal	5980.6	1154.6	22198.3	653554.8
Other P inputs:	NA	606.0 (34.4)		
1.0 Septics:	NA	0.5 (0.0)		
Total	5980.6 (100.0)	1761.1(100)	22198.3	653554.8

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 20.0 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 39.3 ppb.
Predicted transparency = 1.2 meters.

If all land were forested, P export would be 749.7 kg/yr,
and the forested condition lake TP would be 16.7 ppb.

Table 2b. Aldrich Lake West MA34106

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	6171.3 Ha (23.8 mi2)
Average Annual Water Load =	37620514.8 m3/yr (42.6 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	4.9 Ha. (12.1ac)
Areal water loading to lake: q=	770.4 m/yr.
Homes with septic systems within 100m of lake.=	20.0
Other P inputs =	588.0 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:	4401.5 (71.3)	572.2 (32.0)	11003.7	105635.2
Rural category				
Agriculture:	525.7 (8.5)	157.7 (8.8)	5957.9	214117.5
Open land:	352.9 (5.7)	105.9 (5.9)	1835.2	52338.9
Residential Low:	390.8 (6.3)	117.2 (6.6)	2149.6	151642.0
Urban category				
Residential High:	243.0 (3.9)	202.6 (11.3)	1475.1	119513.7
Comm - Ind:	38.9 (0.6)	32.4 (1.8)	388.0	16163.9
Other Landuses				
Water:	75.4 (1.2)	0.0 (0.0)	0.0	0.0
Wetlands:	143.1 (2.3)	0.0 (0.0)	0.0	7585.6
Subtotal	6171.3	1188.1	22855.4	667607.6
Other P inputs:	NA	588.0 (32.9)		
20.0 Septics:	NA	10.0 (0.6)		
Total	6171.3 (100.0)	1786.1(100)	22855.4	667607.6

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 36.6 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 39.1 ppb.
Predicted transparency = 1.2 meters.

If all land were forested, P export would be 773.9 kg/yr,
and the forested condition lake TP would be 16.9 ppb.

Table 2c. Leverett Pond MA34042

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	166.8 Ha (0.6 mi2)
Average Annual Water Load =	1016846.3 m3/yr (1.2 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	35.8 Ha. (88.4ac)
Areal water loading to lake: q=	2.8 m/yr.
Homes with septic systems within 100m of lake.=	40.0
Other P inputs =	37.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	100.1 (60.0)	13.0 (12.2)	250.2	2402.3
Rural category				
Agriculture:	5.5 (3.3)	1.7 (1.6)	43.2	1327.8
Open land:	3.0 (1.8)	0.9 (0.8)	15.6	228.5
Residential Low:	16.1 (9.6)	4.8 (4.5)	88.5	6241.3
Urban category				
Residential High:	4.3 (2.6)	29.2 (27.4)	23.9	2021.1
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	35.8 (21.4)	0.0 (0.0)	0.0	0.0
Wetlands:	2.0 (1.2)	0.0 (0.0)	0.0	105.4
Subtotal	166.8	49.5	421.3	12326.3
Internal P inputs*:	NA	37.0 (34.7)		
40.0 Septics:	NA	20.0 (18.8)		
Total	166.8 (100.0)	106.5(100)	421.3	12326.3

Summary of Lake Total Phosphorus Modeling Results

*Predicted by difference to agree with observed TP concentrations.
Areal P loading L= 0.3 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 19.8 ppb.
Predicted transparency = 2.4 meters.

If all land were primeval forest P export would be 16.8 kg/yr
And the forested condition lake TP would be 3.1 ppb.

Table 2d. Loon Pond MA34045

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	27.6 Ha (0.1 mi2)
Average Annual Water Load =	168432.8 m3/yr (0.2 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	9.9 Ha. (24.4ac)
Areal water loading to lake: q=	1.7 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:	2.8 (10.0)	0.4 (0.8)	6.9	66.6
Rural category				
Agriculture:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Open land:	2.6 (9.4)	0.8 (1.7)	13.5	775.8
Residential Low:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Urban category				
Residential High:	3.8 (13.6)	16.0 (34.0)	20.7	1750.4
Comm - Ind:	7.0 (25.5)	30.0 (63.6)	70.2	4737.7
Other Landuses				
Water:	9.9 (35.8)	0.0 (0.0)	0.0	0.0
Wetlands:	1.6 (5.7)	0.0 (0.0)	0.0	83.3
Subtotal	27.6	47.1	111.3	7413.8
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Total	27.6 (100.0)	47.1(100)	111.3	7413.8

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 = 34.9 ppb.
Predicted transparency = 1.4 meters.

If all land were forested, P export would be 2.1 kg/yr,
and the forested condition lake TP would be 1.6 ppb.

Table 2e. Lake Warner MA34098

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	7733.6 Ha (29.9 mi2)
Average Annual Water Load =	47143848.3 m3/yr (53.4 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	26.0 Ha. (64.2ac)
Areal water loading to lake: q=	181.3 m/yr.
Homes with septic systems within 100m of lake.=	24.0
Other P inputs =	5448.0 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:	4464.7 (57.7)	580.4 (8.1)	11161.8	107152.9
Rural category				
Agriculture:	1515.2 (19.6)	454.6 (6.4)	16084.2	566814.5
Open land:	632.0 (8.2)	189.6 (2.7)	3286.4	121039.7
Residential Low:	411.2 (5.3)	123.3 (1.7)	2261.4	159531.5
Urban category				
Residential High:	437.8 (5.7)	250.5 (3.5)	2898.8	231671.5
Comm - Ind:	160.6 (2.1)	91.9 (1.3)	1600.8	89958.7
Other Landuses				
Water:	66.8 (0.9)	0.0 (0.0)	0.0	0.0
Wetlands:	45.3 (0.6)	0.0 (0.0)	0.0	2401.6
Subtotal	7733.6	1690.4	37491.8	1281208.6
Internal P inputs*:	NA	5448.0 (76.2)		
24.0 Septics:	NA	12.0 (0.2)		
Total	7733.6 (100.0)	7150.4(100)	37491.8	1281208.6

Summary of Lake Total Phosphorus Modeling Results

*Predicted by difference to agree with observed TP concentrations.
Areal P loading L= 27.5 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 120.0 ppb.
Predicted transparency = 0.4 meters.

If all land were primeval forest P export would be 990.8 kg/yr
And the forested condition lake TP would be 16.6 ppb.

Table 2f. Lake Wyola MA34103

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	1770.9 Ha (6.8 mi2)
Average Annual Water Load =	10795301.9 m3/yr (12.2 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	50.4 Ha. (124.6ac)
Areal water loading to lake: q=	21.4 m/yr.
Homes with septic systems within 100m of lake.=	165.0
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:	1528.4 (86.3)	198.7 (50.4)	3821.1	36682.7
Rural category				
Agriculture:	28.8 (1.6)	8.6 (2.2)	199.1	5696.8
Open land:	16.4 (0.9)	4.9 (1.2)	85.1	2384.5
Residential Low:	63.4 (3.6)	19.0 (4.8)	348.6	24588.9
Urban category				
Residential High:	32.8 (1.9)	80.2 (20.4)	275.6	18694.5
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	76.4 (4.3)	0.0 (0.0)	0.0	0.0
Wetlands:	24.7 (1.4)	0.0 (0.0)	0.0	1306.9
Subtotal	1770.9	311.4	4729.6	89354.1
Other P inputs:	NA	0.0 (0.0)		
165.0 Septics:	NA	82.5 (20.9)		
Total	1770.9 (100.0)	393.9(100)	4729.6	89354.1

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.8 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 20.9 ppb.
Predicted transparency = 2.3 meters.

If all land were forested, P export would be 217.1 kg/yr,
and the forested condition lake TP would be 11.5 ppb.

Water Quality Standards Violations:

All of the six lakes are designated Class B waters under the Massachusetts Surface Water Quality Standards, the data listed above were judged sufficiently well documented to place the lake on the Massachusetts 303d list for 1998 (DEP, 1998). Noxious Aquatic Plants is the most common pollutant/stressor listed for the lakes, other stressors include turbidity, nutrients and organic enrichment/low DO (see Table 1). These pollutant stressors are the listed causes of the violations of the Water Quality Standards related to impairment of primary and secondary contact recreation and aesthetics.

For the Class B waters, the 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 some lakes may have surface TP concentrations that are much larger than that predicted by the NPSLAKE model. In such cases, 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.

According to the Carlson Trophic State analysis (Carlson,1977) a lake should have total phosphorus concentrations of about 40 ppb to meet the 4-foot transparency requirement for swimming beaches in Massachusetts. The target should be set lower than this to allow for a margin of safety. The lower phosphorus concentrations will lessen the chance of nuisance algal blooms, which may occur as macrophyte biomass is reduced by direct controls.

Shallow ponds 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)
MA34002	Aldrich Lake	25-50	> 50	39	NA	30
MA34106	Aldrich Lake	25-50	>50	39	NA	30
MA34042	Leverett Pond	5-9	15-19	20	20	15
MA34045	Loon Pond	25-50	> 50	35	30	30
MA34098	Lake Warner	25-50	> 50	120	120	30
MA34103	Lake Wyola	5-9	15-19	21	30*	15

* Recent citizen volunteer data indicate TP is less than 10 ppb.

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:

With the exception of Aldrich Lakes East and West, point source wasteload allocation is zero. 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.
The annual point source load of total phosphorus from the Belchertown Waste Water Treatment Plant (WWTP) delivered to Aldrich Lakes East and West was calculated based on the average annual discharge and concentrations at the plant, with reductions calculated for uptake along the stream channel and permanent storage in the intervening ponds such as Forge Pond. Details on these calculations are given in Appendix I.

Phosphorus loading allocations for each landuse category are shown (rounded to the nearest kg/yr or nearest 10 kg/yr) in Table 4. In most cases, no reduction in forest loading is targeted, because logging operations are typically small scale and already have BMPs in place, thus this source is unlikely to be reduced by additional BMPs. In some lakes such as the Aldrich Lakes and Lake Warner which have large areas of forests and which may have significant logging operations, forestry BMPs are recommended. These could include training of local conservation commissions on review procedures for projected logging operations, and should include unpaved road BMPs as part of timber harvesting. The load reductions for other landuses are allocated as a proportional phosphorus loading reduction except for Aldrich Lakes East and West which have point sources.

In the case of Aldrich Lake East and West, the target allocation for the point source was set at a reduction of 66 percent which is expected to be easily achieved under the new NPDES permit (MA0102148) for the Belchertown WWTP. Upgrades to the WWTP are currently in construction and the interim EPA limits for average phosphorus discharge of 5 mg/l will be dropped October 15, 2000 when the new limits of 0.25mg/l are in effect. These new limits represent a more than ten fold reduction in total phosphorus discharge over a yearly basis (from current 2.8 mg/l to 0.25 mg/l), and thus are expected to easily meet the 66 percent reduction required under the TMDL for Aldrich Lake East and West. However, the TMDL in preparation for Forge Pond (MA34024) which is immediately downstream of the WWTP may impose more restrictive limits than this TMDL. Recent data from the first seven months of operation in 2001 following the upgrade have shown TP in the discharge to average 0.17 mg/l, which is well under permit levels and it is expected to result in improved conditions in waters below the discharge point. Although significant reductions in other NPS sources of phosphorus are not required to meet the TMDLs for Aldrich Lakes East and West, NPS reductions will be encouraged to further improve water quality conditions and to allow for future development growth in the watershed.

In the case of Leverett Pond, because the target total phosphorus concentration (based on ecoregion expectations) is larger than the NPSLAKE model predictions based on landuse alone. As noted above, field data suggest the lake has additional sources of phosphorus which are not estimated by the landuse model. Due to the large discrepancy in predicted vs. observed values we estimated internal loading from the difference in loading in order to make the predictions fit the observed concentrations in the lake.

Lake Warner is another case where the NPSLAKE landuse model makes a lower prediction than the target TP concentration. However, in this case the model estimate is likely to be low because the lake previously received high loadings from a now discontinued point source. The lake is likely to have high internal loading remaining from the historic discharge. Due to the large discrepancy in predicted vs. observed values we estimated internal loading from the difference in loading in order to make the predictions fit the observed concentrations in the lake.

In this case, the predicted internal load is so high that it is targeted at a 90 percent reduction (possibly with an alum treatment) and the remaining non-forested areas are targeted for a 41 percent 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 4a. Aldrich Lake East MA34002 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Forest	554	554
Agriculture	157	153
Open Land	101	99
Residential (Low den.)	111	109
Residential (High den.)	205	200
Comm. Indust.	25	24
Septic System	1	0
Point Sources	606	202
Total Inputs	1760	1342

Table 4b. Aldrich Lake West MA34106 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Forest	572	572
Agriculture	158	158
Open Land	106	106
Residential (Low den.)	117	117
Residential (High den.)	203	203
Comm. Indust.	32	32
Septic System	10	10
Point Sources	588	196
Total Inputs	1786	1393

Table 4c. Leverett Pond MA34042 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Forest	13	13
Agriculture	2	1
Open Land	1	1
Residential (Low den.)	5	4
Residential (High den.)	29	21
Comm. Indust.	0	0
Septic System	20	14
Internal P sources	37	26
Total Inputs	107	80

Table 4d. Loon Pond MA34045 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	0	0
Agriculture	0	0
Open Land	1	1
Residential (Low den.)	0	0
Residential (High den.)	16	14
Comm. Indust.	30	26
Septic System	0	0
Other	0	0
Total Inputs	47	41

Table 4e. Lake Warner MA34098 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	580	580
Agriculture	460	270
Open Land	190	110
Residential (Low den.)	120	70
Residential (High den.)	250	150
Comm. Indust.	90	50
Septic System	10	10
Other	5450	550
Total Inputs	7150	1790

Table 4f. Lake Wyola MA34103 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	199	199
Agriculture	9	4
Open Land	5	2
Residential (Low den.)	19	8
Residential (High den.)	80	34
Comm. Indust.	0	0
Septic System	83	35
Other	0	0
Total Inputs	395	282

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. 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 can not be reduced or eliminated until the sources of phosphorus are identified. Because many of the nutrient sources are not under regulatory control of the state, engagement and cooperation with local citizens groups, landowners, local officials and government organizations will be needed to implement this TMDL. The Massachusetts Department of Environmental Protection will use the 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 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 funding sources for these efforts is provided in the Program Background section, above.

The major implementation effort would take place during the year 2005 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 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 stormwater management plans for Phase II NPDES. Initiate additional BMPs in critical areas.	Towns, MassPike and MassHighway.
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	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	Check that an approved forest cutting plan is in place and BMPs for erosion are being followed. Provide training to local ConComms on harvesting BMPs.
Gravel Pits	Pit owner, Regional DEP, Conservation commission	Check permits for compliance, recycle wash water, 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, batch 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 lakeside erosion	Landowner, Conservation Commission	Determine cause of problem; install riprap, plant vegetation.

Additional implementation recommendations for each lake include the following:

Aldrich lakes are probably best treated by targeting the Belchertown Waste Water Treatment Plant as previously noted in the TMDL load allocations in Table 4a and 4b. After the lower TP limits are in place and the lake is allowed to flush for a year, further consideration can be given to additional watershed controls and a possible alum treatment of the lake.

It is recommended that Leverett Pond use a comprehensive approach to target septic pumping, inspections and upgrades while using targeted harvesting and/or herbicides to create and maintain boating channels around the lake and connecting boat launch areas to open water.

Loon Pond was found to have relatively clear water but water quality is threatened and bacteria may be a problem at the beach unless geese are controlled. Feeding of geese should be prohibited and geese should be encouraged to move to other locations away from the lake. Runoff from the nearby shopping plaza and streets should be targeted for stormwater controls.

Although the wastewater discharge noted in Snow and DiGiano (1976) to Lake Warner has ceased, the lake continues to suffer from eutrophication, particularly blooms of duckweed, *Wolfia* which cover the surface. It is likely that sediments are the major source of phosphorus supporting these blooms. While dredging may be too expensive, a small scale alum treatment, perhaps supported by the University of Massachusetts with student labor, might be an effective treatment for the lake. Addition stormwater controls and agricultural BMPs could be implemented within the watershed.

Lake Wyola appears to have much better water quality than expected from the NPSLAKE model. In fact, recent citizen data on TP indicate TP concentrations as low as 3-4 ppb (NEE, 1997). Further recommendations from the NEE (1997) report focus on water level control and erosion control, but do not address nutrient control specifically. Although it does not appear that the septic systems are having a significant impact on phosphorus levels in the lake at this time, it is possible that as systems age they will fail in the future. Thus, it would be prudent to push for additional improvements in septic system pumping, inspection and upgrades to ensure problems do not develop in the future. The many ducks and geese noted at the lake should be discouraged from using the lake by prohibiting the feeding of waterfowl.

Table 7. Suggested Implementation by Lake

Lake Name WBID=> Implementation Suggested	Aldrich Lake East MA34002	Aldrich Lake West MA34106	Leverett Pond MA34042	Loon Pond MA34045	Lake Warner MA34098	Lake Wyola MA34103
Public Education	X	X	X	X	X	X
NPS Survey	X	X	X	X	X	X

Lake Management Plan	X	X	X	X	X	X
Forest BMPs	X	X				X
Agriculture BMPs			X		X	
Residential BMPs			X		X	X
Septic System Maintenance			X		X	X
Urban BMPs				X		
Highway BMPs				X	X	
In-Lake Management	X	X	X	X	X	X
Other (Goose management; see text)			X	X		X

* MA34002 Aldrich Lake East, Granby; MA34106 Aldrich Lake West, Granby; MA34042 Leverett Pond, Leverett; MA34045 Loon Pond , Springfield; MA34098 Lake Warner, Hadley; MA34103 Lake Wyola, Shutesbury.

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 will be encouraged.

Public Participation

A public meeting was announced by mailing to town officials and by posting in the Environmental Monitor. The meeting was held on October 9, 2001 from 6:30-9:00PM in the U.S.Fish and Wildlife Office in Hadley Massachusetts. Eleven people attended along with the 2 DEP presenters (see Appendix).

Public Comment and Reply

No written comments were received by the end of the 30-day comment period. The following comments were received during the public meeting or at subsequent meetings, and are separated below by lake.

Leverett Pond

Comment: Canada Geese are a problem at the lake and residents want to know how to manage non-migratory geese. Last year up to 700 were on the pond at one time whereas 10 years ago there were typically only 20 to 30 geese on the pond.

Response: Canada geese can be a problem if present in large numbers. They excrete large amounts of nutrients and fecal coliform bacteria (the indicator of the microbial quality of the water). The problem is statewide as large numbers of geese have become resident and the long-tern solution must address the statewide population of geese. The problems are compounded when the public feeds the geese or creates favorable turf grass feeding areas adjacent to lakes. Thus, public education is a key element of local control efforts. The Massachusetts Division of Fisheries and Wildlife can be contacted for advice and they offer the following information. There are four basic options for goose control: hunting, harassment, fencing and habitat/food alteration. Recreational hunting is effective and can be combined with harassment described below. Information on recreational hunting, licenses, seasons and limits can be obtained at Massachusetts Division of Fisheries Wildlife and Environmental Law Enforcement (508) 792-7270 or at local district offices. Special depredation permits are needed to kill geese out of season and to kill eggs in nests. Contact USDA at 413 253-2403 for further information on special permits. Harassment of geese is generally allowed in Massachusetts with no permit provided no physical contact is made. Harassment may include chasing the geese, noisemaking shotgun shells that make a bang over the flock, other noisemakers, the use of dogs etc. Fencing can be effective and in some cases even a simple fence made from a bright yellow rope or string with reflective aluminum may work. A more permanent solution is to change the habitat and food sources, which may include propagation of tall grass or brush along shorelines, and prohibition of feeding of geese. An example ordinance is available from DEP or from the Massachusetts Division of Fisheries and Wildlife. Finally, spraying commercially available bitter goose repellent chemicals (e.g. “Goose Chase”) on grass may work temporarily. The best approach is to use combinations of the above techniques (e.g. harassment during the recreational hunting season).

Comment: Internal phosphorus loadings from the sediments may be a problem and is difficult and costly to deal with.
Response: Sediment sources of phosphorus are expensive to remediate (see response to Lake Warner below). Alum treatment is a possibility, but watershed BMPs and erosion controls should be implemented prior to any treatment of sediment phosphorus.

Lake Wyola

Comment: Volunteer monitoring indicates TP in single digit ppb range. This lake should not be on TMDL list; it is a good quality temperate lake.

Response: The Department agrees that the lake has very low TP and should not be listed for nutrients. Earlier total phosphorus measurements by the Department were biased high due to a high detection limit at the laboratory. The lake also has a balanced plant community that is not causing nuisance conditions. In addition, the low dissolved oxygen in the hypolimnion is typical of temperate lakes in the region and should not be viewed as an impairment on the 303d list. We will recommend that it be removed from the next 303d list. Even if removed from the 303d list, this TMDL for phosphorus will continue to be in effect as a protective TMDL to ensure maintenance of good water quality in the lake.

Comment: Suggested DEM be more vigilant in waterfowl management at the swimming beach area.
Response (with DEM input): In the last two years, DEM Lakes and Ponds staff have embarked on a multi-faceted approach to reducing their numbers and making our properties less welcoming to them. We have a permit from the federal government to treat eggs and otherwise try to reduce geese populations. Unfortunately, there has not been real success yet in our efforts. Park Staff at many of our locations also regularly clean up after geese, and we have put up a variety of fences and other barriers to keep them away. In a few cases, we have employed dogs to remain on site to scare them off. We will continue to make every effort to keep the geese away, but as long as habitat remains favorable and food is available (many people still feed them), they'll stick around. See comment and response discussion of geese control on Leverett Pond, above, in regards to local ordinances again feeding of geese. An example ordinance is available from DEP or from the Massachusetts Division of Fisheries and Wildlife.

Lake Warner

Comment: What can be done about the sediment? (i.e., the recycling of P from the sediment).
Response: The large amount of phosphorus in the lake sediments is difficult and expensive to remove or control. It is important to note that in most cases controls of external sources of nutrients and sediments should be conducted prior to treatment of lake sediments. Dredging the lake provides a long-term solution, but this is very expensive. Aluminum can be added as alum and/or sodium aluminate to create a floc that binds with phosphorus and effectively prevents phosphorus release from the sediments. Based on past case studies, costs for a commercial treatment of Lake Warner would probably be close to $50,000. The town could explore the option of a treatment being conducted with the help of faculty and students from local colleges/Universities as a student project to follow up on the recommendations of an alum treatment by a previous UMass study (Snow and DiGiano, 1976). Some of the costs of the project might be covered as part of a grant application as previously mentioned in the TMDL report.

Another option the town might consider would be to decommission the dam to allow free flow of the river (and also reduce liability to the town). This would tend to flush algae, duckweeds and nutrients out of the basin, improving water quality and allowing fish migration back into the watershed. However, draining the lake may not be acceptable for residents and dam removal would require further study and that environmental permits. The Massachusetts Division of Fisheries and Wildlife's River Restore program may be able to provide guidance on dam decommissioning issues.

Comment: Can Amherst be required to participate in any remediation since the discharge from its wastewater treatment plant entered Lake Warner for many years? The discharge was routed to the Connecticut River about 20 years ago.
Response: While the dam forming Lake Warner is about 170 years old, it did flood what was once fertile farmland and thus dense growth of aquatic plants is expected to be higher here than if this were a natural pond. Although the point source discharge was corrected over twenty years ago, phosphorus continues to enter the pond comes from runoff of both towns. At this point in time, remediation is probably best approached as a cooperative effort between the towns of Amherst and Hadley. The state can offer competitive grants for various types of remediation. These grant programs include the DEM lakes and Ponds grant program and the 319-grant program administered by DEP.

Comment: How was the watershed for Lake Warner delineated? Does it include the entire Mill River watershed upstream? If not, the loading rates may not be accurate.
Response: The delineation was done on computer with Arcinfo and the MassGIS images of USGS topographic maps along with elevation models and centerline stream coverages. As shown at the top of Table 2e, the watershed covers 29.9 square miles and does include the upstream portion of the Mill River up to the headwaters in Shutesbury and Leverett. Further details on the modeling are presented in Mattson and Isaac, (1999).

Comment: Based on recommendations in the text, it appears that forestry BMPs in the chart on Table 7 should not be checked. To be consistent with the narrative, residential BMPs and highway BMPs should be recommended/checked.

Response: The Table 7 has been replaced with a new table.

General Questions/Comments

Comment: Concern was expressed about the loading model and the lack of monitoring data. This leads to questioning how the target levels were developed since there seems to be a lack of strong science.
Response: The land use loading approach used in the NPSLAKE model is a generally accepted approach to estimating annual loads to lakes. The TMDL report emphasizes that additional steps need to be taken to further identify the sources of nutrients to the lakes and the Department is offering a pilot program to conduct nonpoint source watershed surveys with the aid of the recently developed guidebook (DEP, 2001). The targets for each lake were developed based on two ecoregion studies of typical lake nutrient concentrations in the region and are considered protective of designated uses and in support of state water quality standards.

Comment: The status of the GEIR for lake restoration was questioned. It is long overdue.
Response: ENSR has a contract to do the final edit as well as produce a lake management handbook. These should be finished by the spring of 2002.

Comment: There is a need to support continuing local efforts if the water quality objectives are to be met.
Response: The Department has recently hired four regional nonpoint source coordinators to assist towns, lake and watershed associations and other groups in development of competitive grant and loan applications to improve water quality. Tracey Miller is the contact for the DEP Regional Office in Springfield.

Comment: The fact that DEM Lakes and Pond grants require actual dollar match by the towns makes it difficult to qualify for the grants.
Response (with DEM input): It has been Department of Environmental Management policy that all lake and pond grants involve a 50/50 cash match as a way to demonstrate the community's long-term commitment to protecting and managing the water body and its watershed. While DEM realizes that for some communities, raising the cash match may be more difficult than for other communities, the only remedy for now is to request a smaller grant amount. The grant program now offers grants up to $25,000.

Comment: How do local citizens began to assess the current status (condition) of our ponds?
Response: Secchi disk measurements and collecting water chemistry data are relatively inexpensive assessment tools to identify water quality problems. Local lake associations should tap into the volunteer monitoring assistance that the Massachusetts Water Watch Partnership (413 545-2842) offers at the University of Massachusetts, Amherst. There is also funding available to volunteer monitoring groups via the Executive Office of Environmental Affairs Volunteer Monitoring Grants. Contact the EOEA Basin Team Leader (John O'Leary for the Connecticut River Basin at 413 587-9329) or the Congress of Lakes and Ponds (COLAP, 800/845-2769 or 508 429-5085) for more information on volunteer monitoring.

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. 1989. Diagnostic/Feasibility Study for the Management of Forge Pond, Granby, Massachusetts. Baystate Environmental Consultants, Inc. East Longmeadow, MA.

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.

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.

NEE. 1997. Management Plan for Lake Wyola, Shutesbury, MA. New England Environmental, Inc. Amherst, MA.

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.

Snow, P.D., and F.A. DiGiano. 1976. Mathematical Modeling of Phosphorus Exchange Between Sediments and Overlying Water in Shallow Eutrophic Lakes. Sept. 1976 Report No. Env. E. 54-76-3, Envir. Eng. Dept. Civil Eng. Umass, Amherst, MA.

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. Calculations and Assumptions for Point Source Loading from the Belchertown WWTP.

A method was developed to estimate the mass of total phosphorus from upstream point sources which reaches a TMDL lake after riparian uptake and permanent storage in upstream lakes. A similar analysis was conducted as part of the Forge Pond D/F study of BEC (1989). However, BEC (1989) calculations included background stream concentrations at the source and simply estimated percent concentration reduction downstream. This method does not separate the effects of dilution from uptake. In the approach presented here, the point source is distinguished from the background concentrations which are assumed, and the difference, the excess phosphorus, is calculated. At two stations downstream, a predicted excess total phosphorus is calculated based on a simple conservation of mass balance equation which assumes runoff volume is proportional to contributing watershed areas at points downstream. These measured stream total phosphorus at those points is used to calculate an observed excess total phosphorus concentration and the difference between the expected and observed excess is assumed to be due to uptake and storage.

Using data summarized in BEC (1989), we used data from 3 downstream sites (Hannum Road, Boardman Road and the Forge Pond inlet) measured on two dates (June and July 1980). Over a distance of 2.7 km between the Hannum Road and Forge Pond sites the TP concentrations fell from 1.6 to 0.74 mg/l and 2.1 to 0.29 mg/l for the two sample dates, respectively. Subwatershed areas at these points were delineated by the watershed tool in the MassGIS Arcview viewer. Runoff was assumed to be constant at .61 meters per year. This assumption does not alter the dilution or excess calculations because unit area runoff is assumed equal in all subwatersheds. The background concentration in streamwater was assumed to range between 0.01 and 0.2 mg/l with a most likely value of 0.1 mg/l. The results indicated that most of the apparent reduction in excess total phosphorus concentration was due to dilution which accounted for about a 54 percent reduction in excess total phosphorus. The remaining loss of excess total phosphorus ranged between 3.9 percent and 7.5 percent loss per kilometer of stream for the 0.01 and 0.2 mg/l background concentrations, respectively. The best estimate, based on 0.1 mg/l background, was 5.5 percent loss per km.

To predict what fraction of the point source phosphorus reached Forge Pond we used the equation:

$$f = (1-X)^K$$

Where f = fraction of point source reaching site.
X= fractional uptake rate per km
K = distance in km to site from upstream point source.

Given that Forge Pond is approximately 3.7km downstream f is calculated to be .81. Assuming the point source discharges 1352 kg/yr based on the 2.8 mg/l TP concentration and the average system flow rate of 0.35 mgd (BEC, 1989), and assuming 81 percent of the point source phosphorus is expected to reach Forge Pond, we estimate the loading to Forge Pond is 1097 kg/yr. This is slightly higher than the total stream loading of 834.6 kg/yr for the Weston Brook inlet calculated by BEC (1989), however, the result appears reasonable given the conservative assumptions above.

The fraction of this phosphorus retained in Forge Pond is estimated by the retention coefficient Rp of .221 based on the Kirchner and Dillon equation cited in BEC (1989):

$$Rp = 13.2/(13.2+q)$$

Where Rp = fraction of P retained in lake
q = water loading rate to lake = 46.41 m/yr.

Thus, the amount of the point source phosphorus leaving the lake is estimated to be:

$$1097 \text{ kg/yr} * (1\text{-Rp}) = 855 \text{ kg/yr.}$$

Calculating the loss of point source phosphorus in the 6.1 km stream between Forge Pond outlet and Aldrich Lake East inlet from above:

$$855 * (1\text{-}.055)^{6.1} = 605 \text{ kg/yr.}$$

Thus, the point source contribution to Aldrich Lake East is 605 kg/yr. Under the worst case conditions, with no uptake in either the stream or Forge Pond, the entire annual load of 1352 kg/yr would reach Aldrich Lake East. If all phosphorus were taken up the point source contribution would be zero.

Again, we can use equation 2 above to estimate the fraction of phosphorus retention in Aldrich Lake East as 0.03, assuming a q of 414 m/yr (see Table 3). Because there is no stream between Aldrich Lake East and West, the only loss is due to retention and the final estimated point source loading to Aldrich Lake West is 588kg/yr. Again, the worst case estimate, assuming no uptake or storage would be 1352 kg/yr. If all phosphorus were taken up the point source contribution would be zero.

Appendix II. Macrophyte Species Codes.

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

P. spirillus “Snailseed Pondweed” P15
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

E. palustris “Common Spike Rush” E3

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

Brasenia schreberi "Water Shield"	n1
Nelumbo lutea "American Lotus"	n2
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

Lycopus sp. "Water Horehound"	t4
Mentha sp. "Mint"	t5
Solanum dulcamara "Nightshade"	t6
Utricularia sp. "Bladderwort"	U
U. vulgaris "Common Bladderwort"	U1
U. purpurea "Purple Bladderwort"	U2
U. radiata "Floating Bladderwort"	U3
U. intermedia "Flat-leaved Bladderwort"	U4
Megalodonta beckii "Water Marigold"	Z1
Eupatorium sp. "Joe-pye Weed"	Z2
Bidens sp. "Bur Marigold", "Beggar-ticks",	Z3
Helenium sp. "Sneezeweed"	Z4
Solidago sp. "Goldenrod"	Z5
Aster sp. "Aster"	Z6
Coreopis rosea "Pink Tickseed"	Z7
Equisetum sp. "Horsetail"	i
E. fluviatile "Swamp or Water Horsetail"	i1
Drosera rotundifolia "Roundleaf Sundew"	D
Vaccinium sp. "Cranberry"	d
Phragmites sp. "Reed Grass"	q

Appendix III. Public Meeting Attendees List.

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: Connecticut Lakes TMDL

Date: Oct. 9, 2001 **Place:** USFW Hadley MA

Presentation by Russ Issac and Mark Mattson MA DEP DWM

	Name	Affiliation	phone	email
1	William G. Elliott	LAKE WYOLA	413 259-1456	welliott@external.umass.edu
2	Johns Mieczkowski	Selectman Hadley	584 6206	
3	RICHARD V WILGA	Selectmen Hadly		
4	Mason Phelps	Lake Wyola	978 544-2735	
5	JIM FIELD	FRIENDS OF LEVERETT POND	545-2682	JMFIELD@EHS.UMASS.EDU
6	Tracey Miller	MA DEP	413-755-2162	tracey.miller@state.ma.us
7	Russell A. ISAAC	"	508-767-2876	
8	Deirdre Cabral	MA DEP		
9	[illegible]	EOEA	413-587-9329	
10	JAN ROWAN	USFWS	413/548-9138	Jan_Rowan@FWS.gov
11	MITCH MULHOLLAND	FRIENDS OF LEVERETT POND	413-545-1626	MULHOLLAND@TEI.UMASS.EDU
12	MIKE DIBARA	MA DEP	(508) 767-2885	
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