Total Maximum Daily Loads of Phosphorus for Selected Northern Blackstone Lakes

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Front Cover
Photograph of Dorothy Pond in Millbury

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Massachusetts Department of Environmental Protection
Division of Watershed Management
Worcester, Massachusetts

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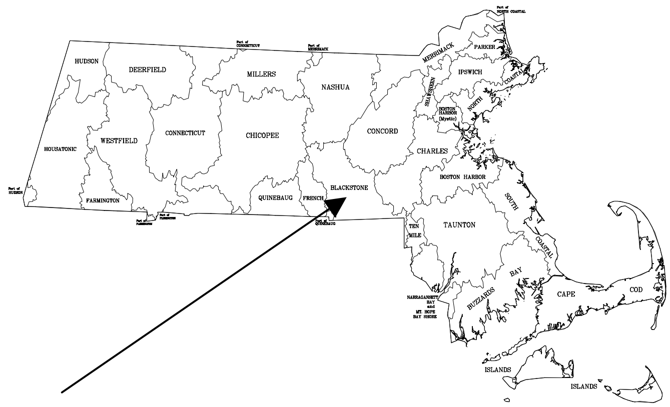

Location of Blackstone Basin in Massachusetts.

Key Feature: TMDL assessment Total Phosphorus for 16 lakes in the northern section of the Blackstone Watershed.

Locations: Auburn Pond (MA51004), Auburn; Brierly Pond (MA51010), Millbury; Curtis Pond North (MA51032), Worcester; Curtis Pond South (MA51033), Worcester; Dorothy Pond (MA51039), Millbury; Eddy Pond (MA51043), Auburn; Green Hill Pond (MA51056), Worcester; Howe Reservoir (MA51071), Millbury; Jordan Pond (MA51078), Shrewsbury; Mill Pond (MA51105), Shrewsbury; Newton Pond (MA51110), Shrewsbury; Pondville Pond (MA51120), Auburn; Smiths Pond (MA51156), Leicester; Southwick Pond (MA51157), Leicester, Stoneville Pond (MA51160), Auburn; and Shirley Street Pond (MA51196), Shrewsbury, Massachusetts.

Land Type: New England Upland

303d Listings: Sixteen lakes with 11 listings for noxious plants and 5 listings for turbidity.

Data Sources: Synoptic lake surveys, Land use informations.

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

Monitoring Plan: Massachusetts Watershed Initiative Five-Year Cycle.

Control Measures: Watershed Management, Septic system maintenance, In-lake Macrophyte Management.

Executive Summary

The Massachusetts Department of Environmental Protection (DEP) is responsible for monitoring the waters of the Commonwealth, identifying those waters that are impaired, and developing a plan to bring them back into compliance with the Massachusetts Water Quality Standards. The list of impaired waters, better known as the "303d list" identifies river, lake, and coastal waters and the reason for impairment. Once identified DEP, in accordance with the Federal Clean Water Act, is required to essentially develop a "pollution budget" designed to restore the health of the impaired body of water. The process 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 sixteen individual lakes (see table below) in the northern section of the Blackstone River Watershed. The lakes were listed on the state "303d" list for a variety of pollutant 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, the existing concentrations of phosphorus in the lake may be low enough already to achieve water quality standards however 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 Mattson and Isaac (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. The results indicate that current phosphorus loads to these lakes need to be reduced on an average of 27% and range from a low of about 2% (Eddy Pond, Auburn, MA) to a high of 68% (Southwick Pond, Leicester, MA).

WBID	Lake Name	Predicted TP (ppb)	Predicted load (kg/yr)	Target TP (ppb)	Target Load (kg/yr)
MA51004	Auburn Pond, Auburn	34	717	25	523
MA51010	Brierly Pond, Millbury	30	278	25	231
MA51032	Curtis Pond North, Worcester	26	1644	25	1584
MA51033	Curtis Pond South, Worcester	27	1609	25	1530
MA51039	Dorothy Pond, Millbury	26	366	25	350
MA51043	Eddy Pond, Auburn	15	123	15	121
MA51056	Green Hill Pond, Worcester	44.2	75	25	48
MA51071	Howe Reservoir, Millbury	50.9	104	25	51
MA51078	Jordan Pond, Shrewsbury	67.6	99	25	37
MA51105	Mill Pond Shrewsbury	46.5	275	25	148
MA51110	Newton Pond Shrewsbury	31.9	330	25	257
MA51120	Pondville Pond, Auburn	28.1	453	25	402
MA51156	Smiths Pond, Leicester	30	583	20	389
MA51157	Southwick Pond, Leicester	30.4	108	10	35
MA51160	Stoneville Pond, Auburn	26.7	970	25	907
MA51196	Shirley Street Pond, Shrewsbury,	37.7	670	25	446

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:

Recommended Action and Suggested lead Group	**Auburn Pond**	**Brierly Pond**	**N. Curtis Pond**	**S. Curtis Pond**	**Dorothy Pond**	**Eddy Pond**	**Green Hill Pond**	**Howe Reservoir**	**Jordan Pond**	**Mill Pond**	**Newton Pond**	**Pondville Pond**	**Smiths Pond**	**Southwick Pond**	**Stoneville Pond**	**Shirley Street**
Public Education Local Watershed Assoc.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Watershed Survey Watershed Team and Local Watershed Assoc.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lake Management Plan Local Watershed Assoc.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Forest BMPs Regional DEM Forester																
Agriculture BMPs NRCS																
Residential BMPs Homeowners and Towns	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Septic System Inspection and Maintenance Homeowners and Towns																
Urban BMPs Landowners and local DPW	X		X	X	X	X		X	X	X	X	X	X		X	X
Highway BMPs MassHighways, MassPike	X		X	X	X	X						X	X	X	X	
In-Lake Management Homeowners and Towns	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Other (Gravel pits, golf courses, see text)							X	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 section 319, the State Revolving Fund Program (SRF), and the Department of Environmental Management's Lakes and Pond small grants program.

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Introduction

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

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

The proposed Total Maximum Daily Loads (TMDLs) for the Northern Blackstone 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), the State Revolving Fund Program (SRF), and the Department of Environmental Management's Lakes and Pond grants 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 derived from aerial photography taken in 1985. To account for changes in landuse, population growth rates are reported for towns closest to the lake. Population (census) data and estimated growth rates are from projections provided on the internet (www.umass.edu/miser/) by the Massachusetts Institute for Social and Economic Research (MISER) at the University of Massachusetts, Amherst.

Data collected from each lake varies depending on the type of survey conducted. During the 1970s-early 1990's Baseline surveys were conducted on lakes by the Department. These Baseline surveys typically were conducted by a team of two spending one day per lake. Baseline data collected including total phosphorus concentrations, dissolved oxygen and temperature profiles, Secchi disk depth and macrophyte density and species distribution maps. Less detailed Synoptic surveys were conducted by the Department between 1993-1998 and were usually limited to visual surveys of macrophyte distributions and species types. Typically Synoptic surveys were conducted from observations at several points around the shore. Data from other sources is used as indicated.

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

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

WBID	Lake Name, Town	303d list pollutant/stressor
MA51004	Auburn Pond, Auburn	Noxious aquatic plants
MA51010	Brierly Pond, Millbury	Noxious aquatic plants
MA51032	Curtis Pond North, Worcester	Noxious aquatic plants
MA51033	Curtis Pond South, Worcester	Noxious aquatic plants
MA51039	Dorothy Pond, Millbury	Turbidity
MA51043	Eddy Pond, Auburn	Noxious aquatic plants
MA51056	Green Hill Pond, Worcester	Turbidity
MA51071	Howe Reservoir, Millbury	Noxious aquatic plants
MA51078	Jordan Pond, Shrewsbury	Turbidity
MA51105	Mill Pond Shrewsbury	Turbidity
MA51110	Newton Pond Shrewsbury	Noxious aquatic plants
MA51120	Pondville Pond, Auburn	Noxious aquatic plants
MA51156	Smiths Pond, Leicester	Turbidity
MA51157	Southwick Pond, Leicester	Noxious aquatic plants
MA51160	Stoneville Pond, Auburn	Noxious aquatic plants
MA51196	Shirley Street Pond, Shrewsbury,	Noxious aquatic plants

The locations of the sixteen lakes are shown in Figure 1. below. The local environs of the ponds are shown in Figure 2a-o below.

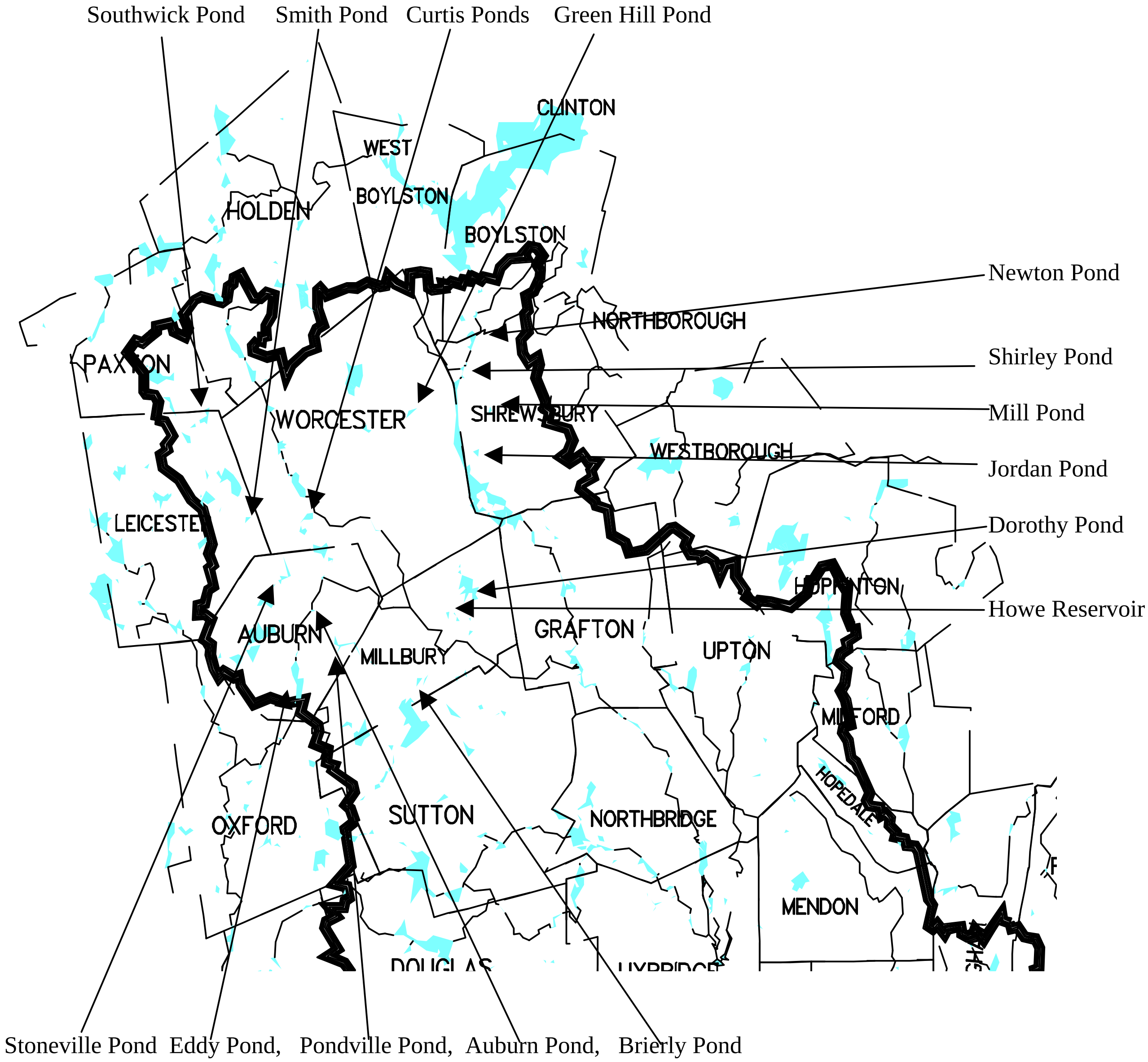

Figure 1. Locations of ponds within the Blackstone Basin.

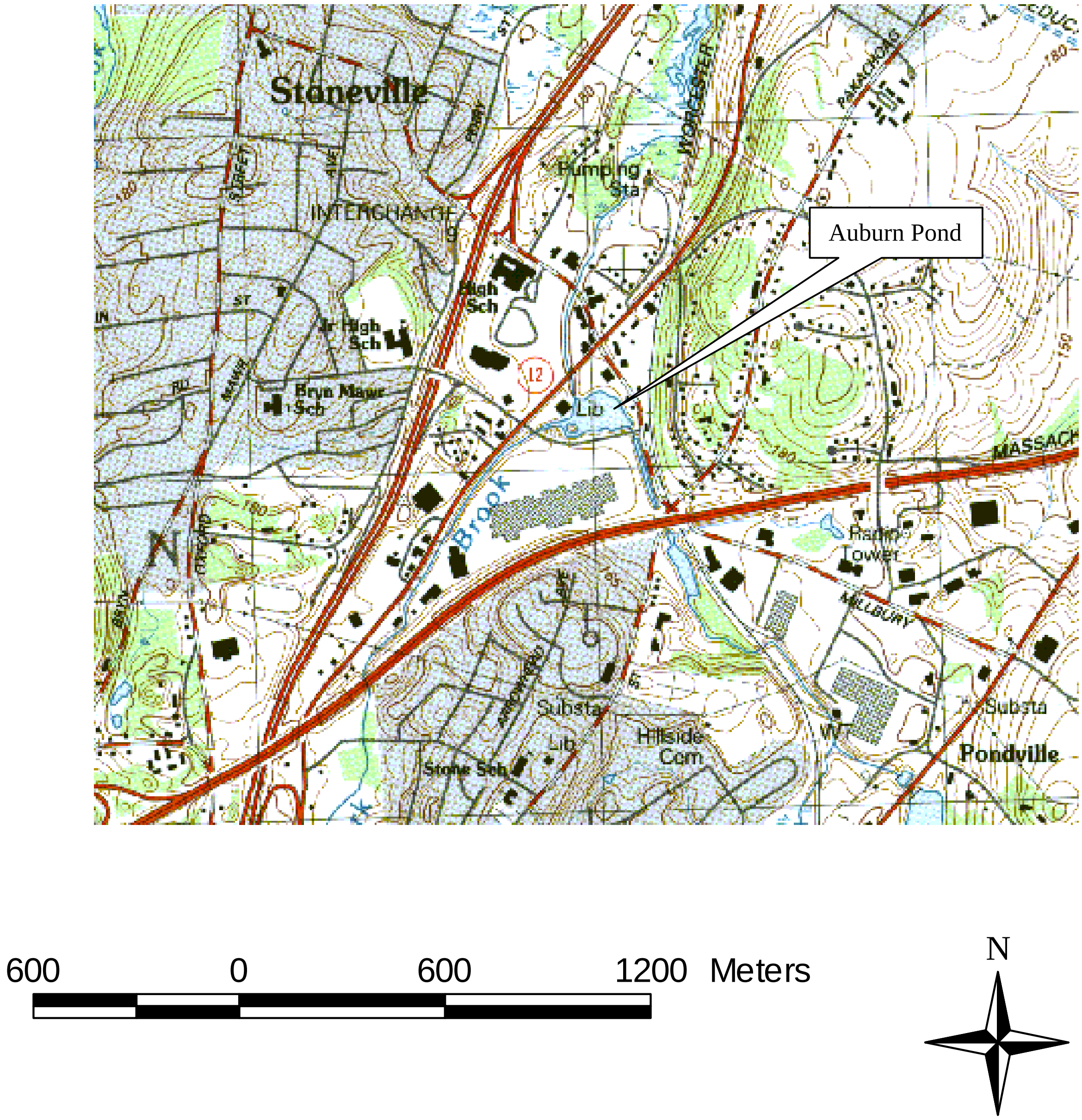

Figure 2a. Auburn Pond Environs.

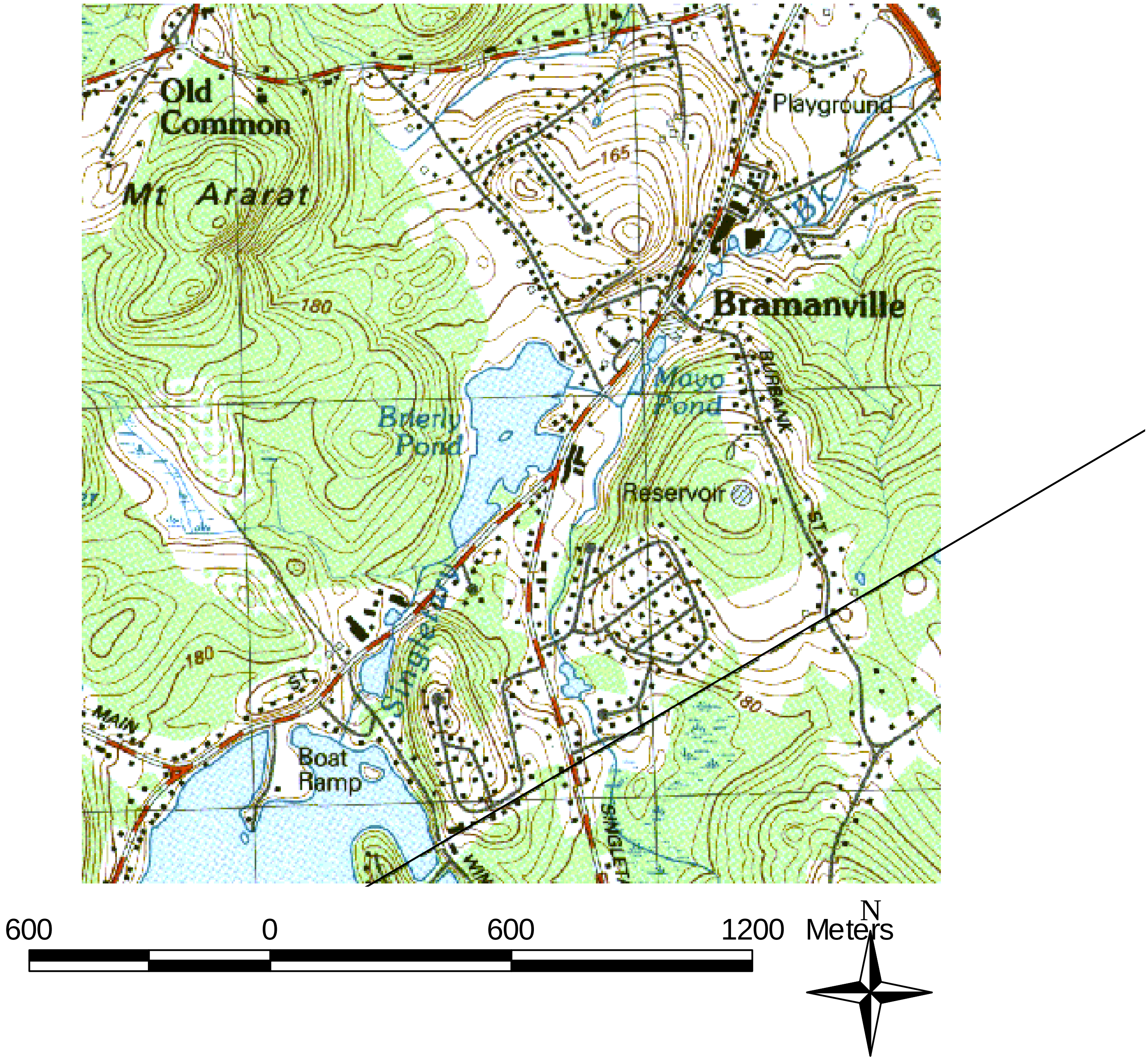

Figure 2b. Brierly Pond Environs.

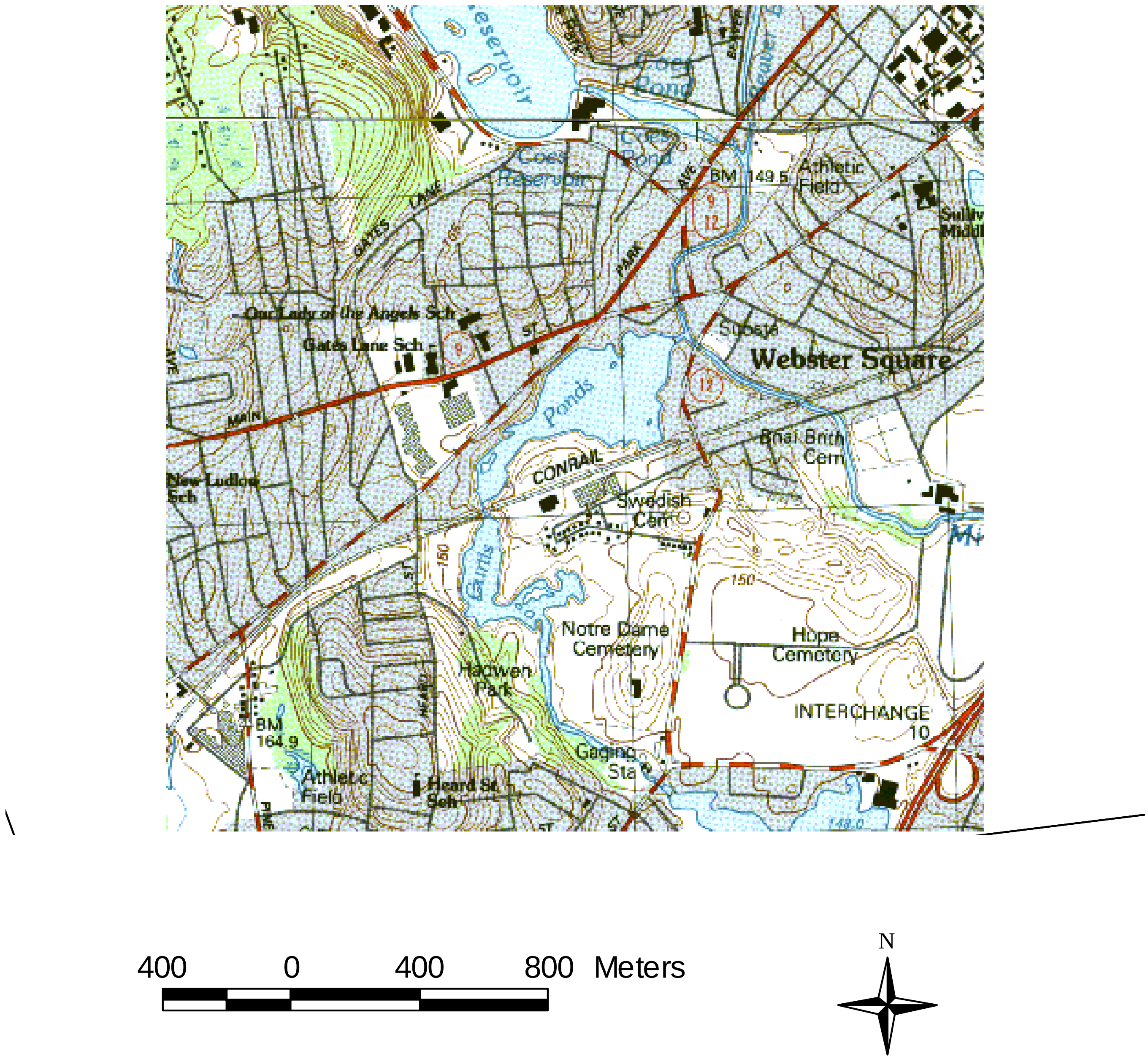

Figure 2c. Curtis Ponds (North and South) Environs.

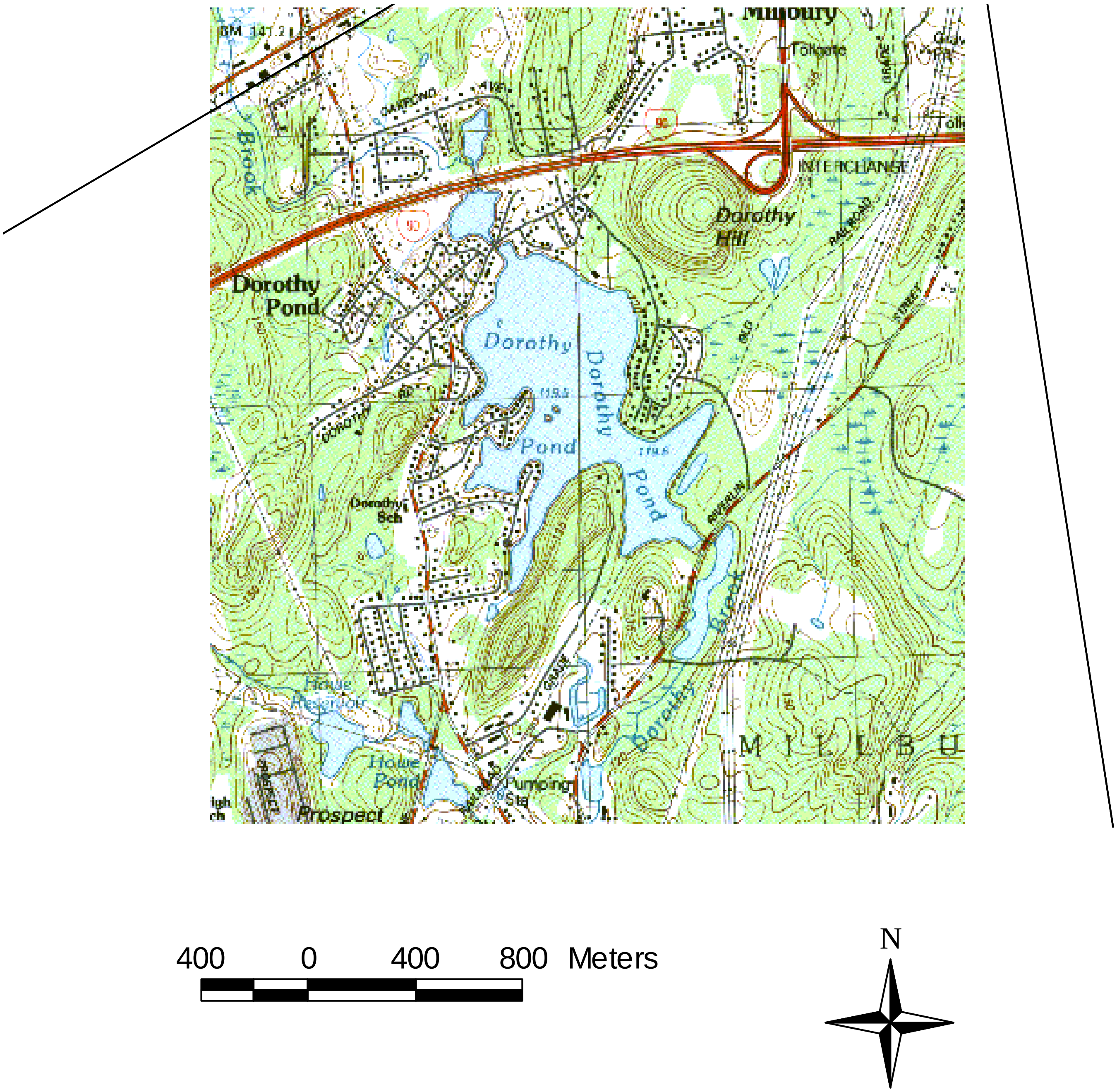

Figure 2d. Dorothy Pond Environs.

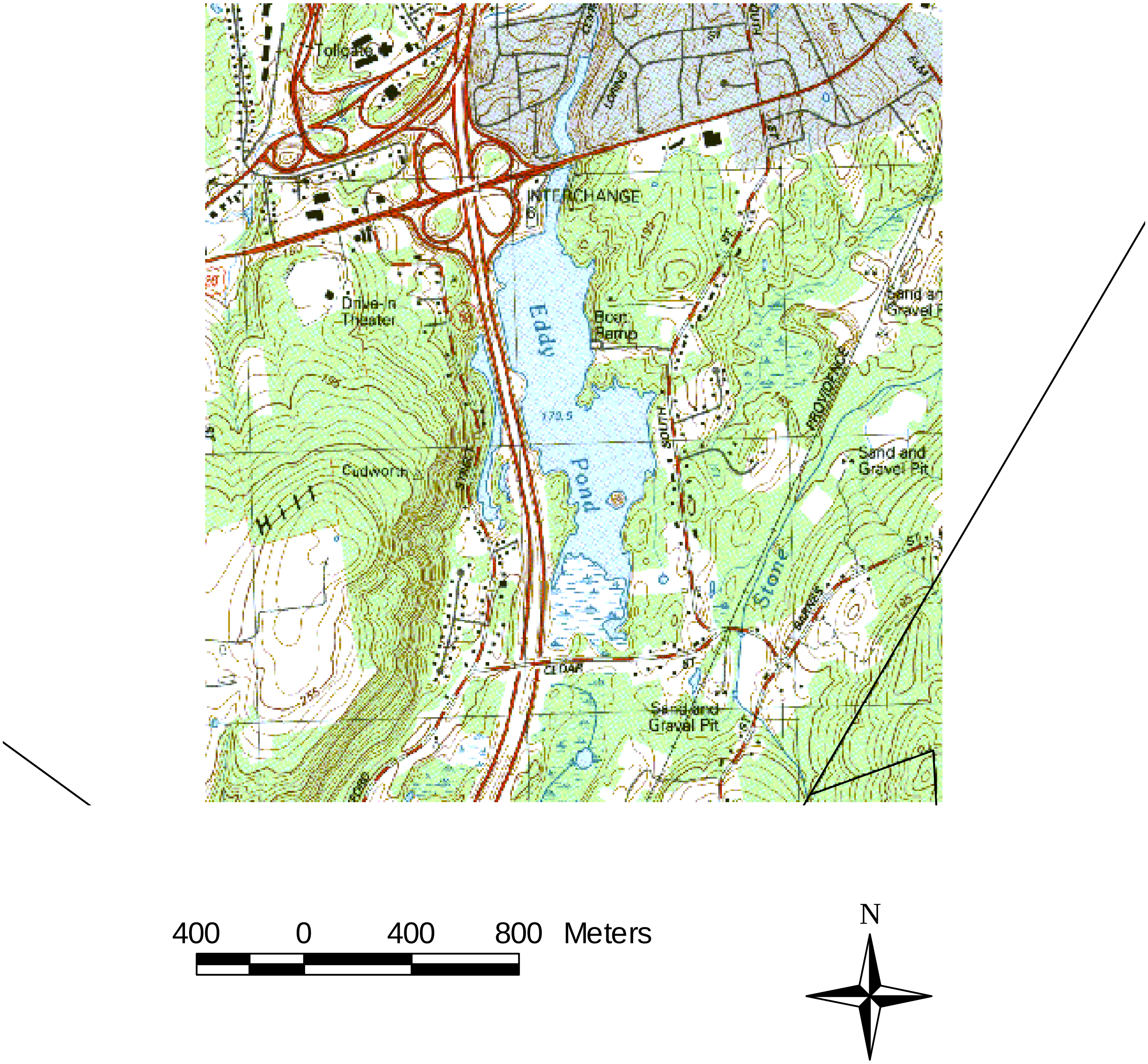

Figure 2e. Eddy Pond Environs.

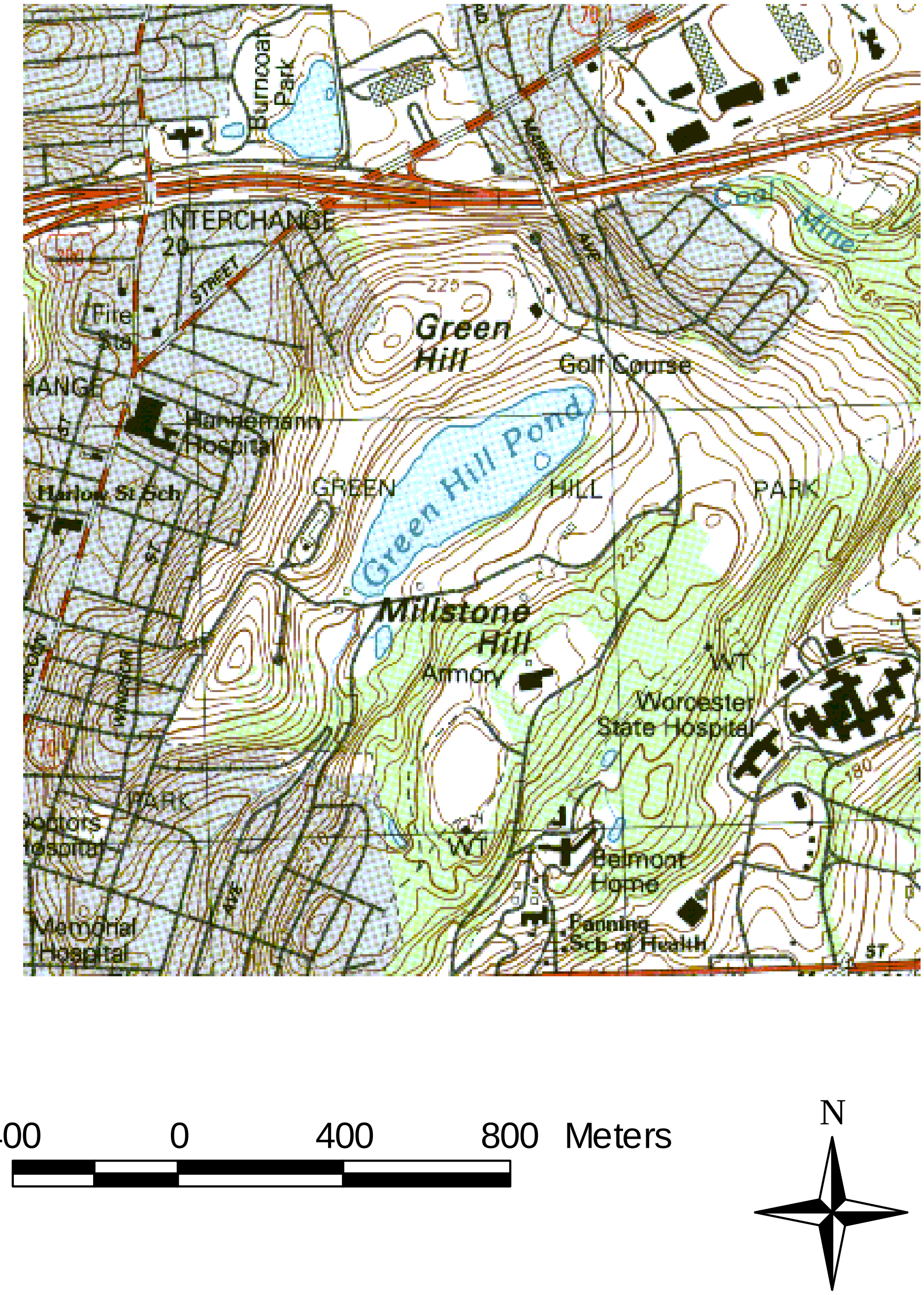

Figure 2f. Green Hill Pond Environs.

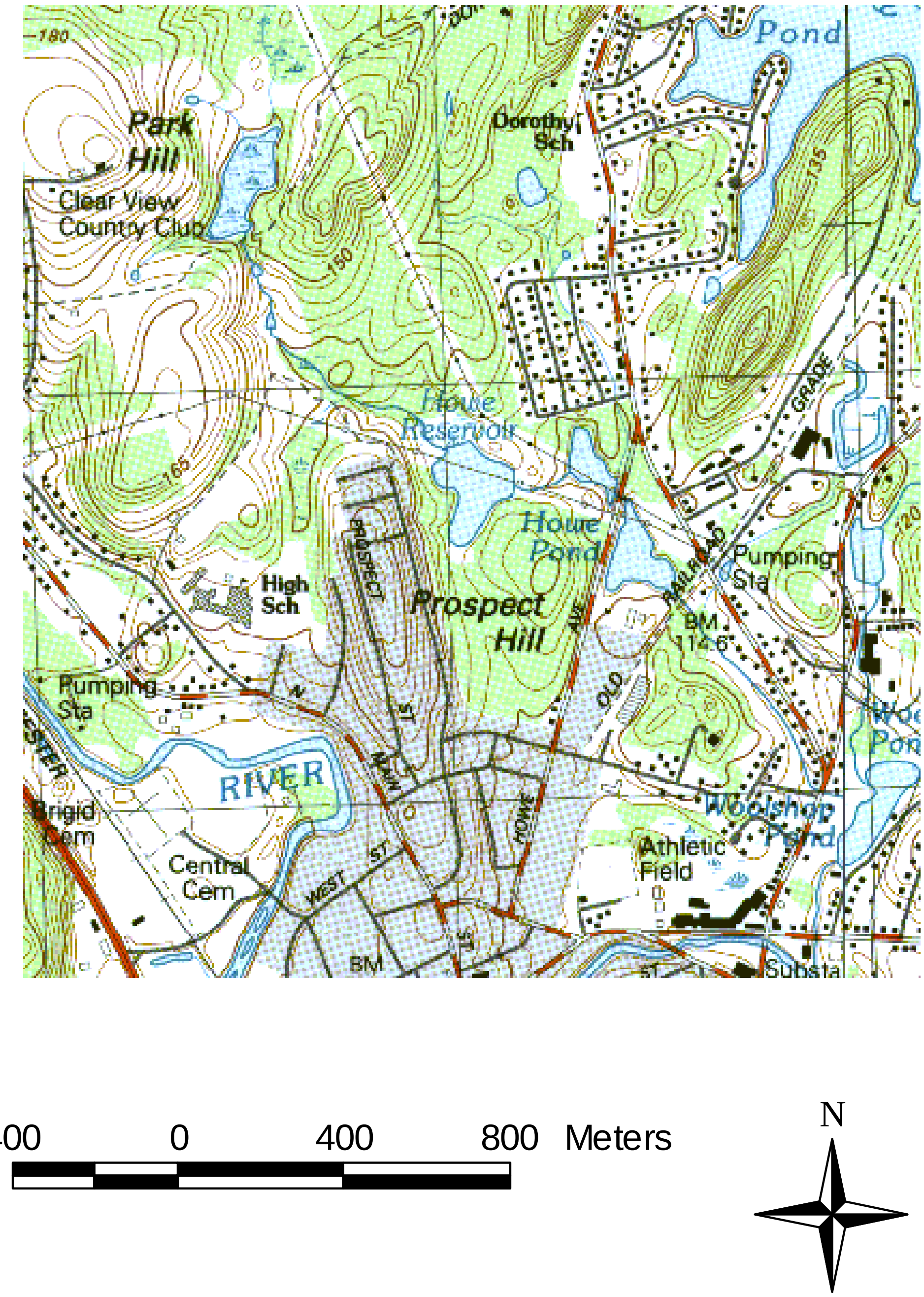

Figure 2g. Howe Reservoir Environs.

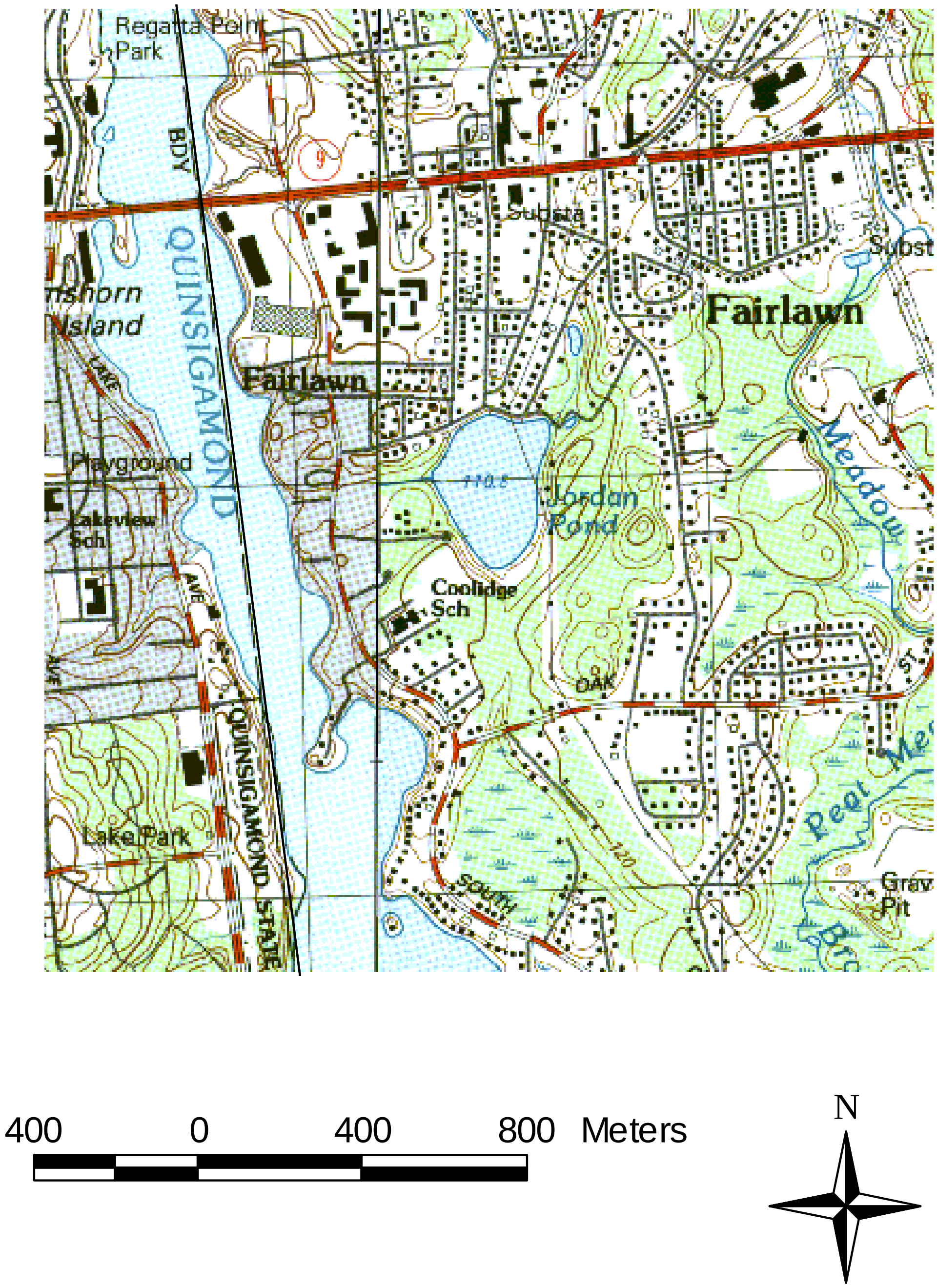

Figure 2h. Jordan Pond Environs.

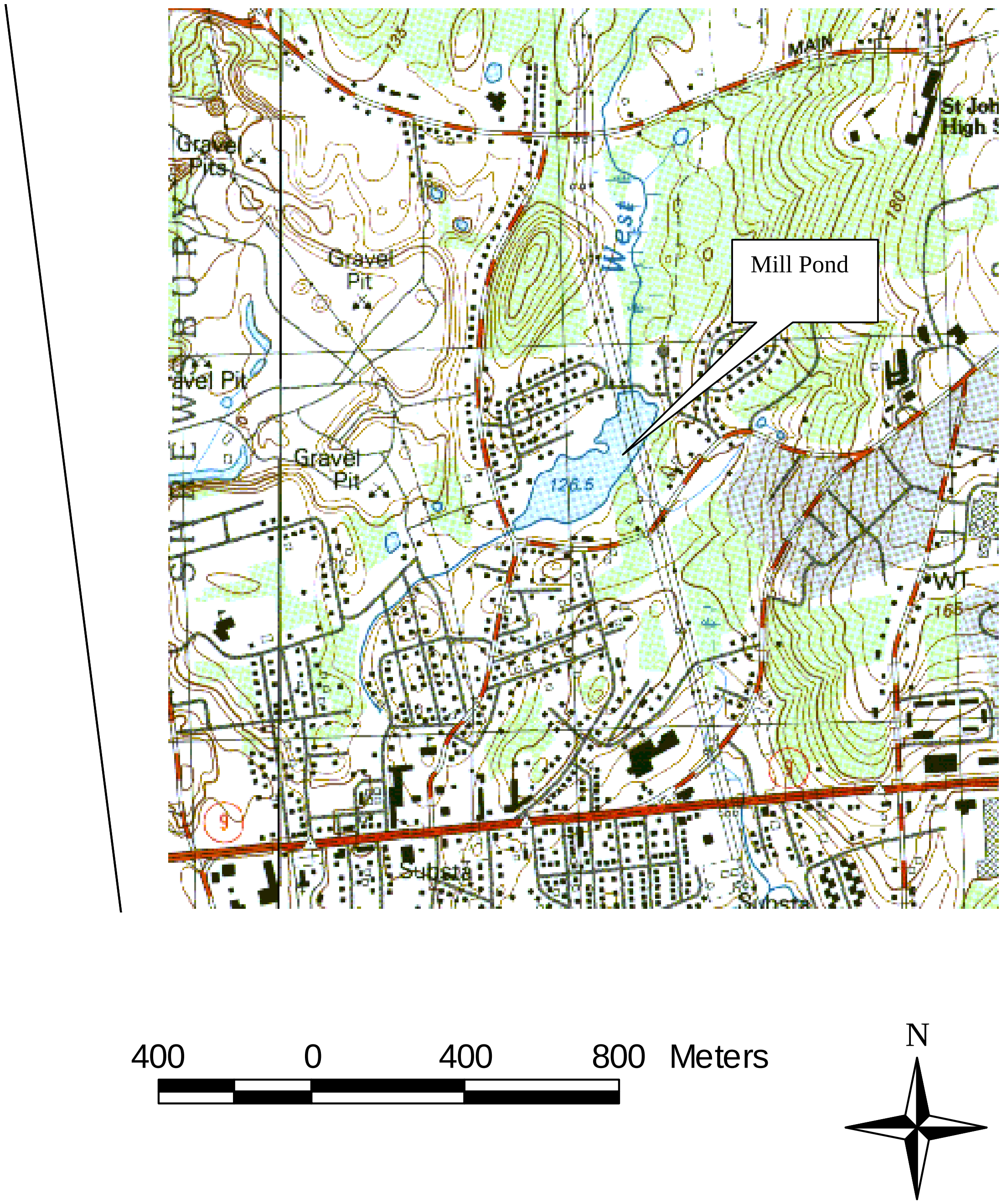

Figure 2i. Mill Pond Environs.

Figure 2j. Newton Pond Environs.

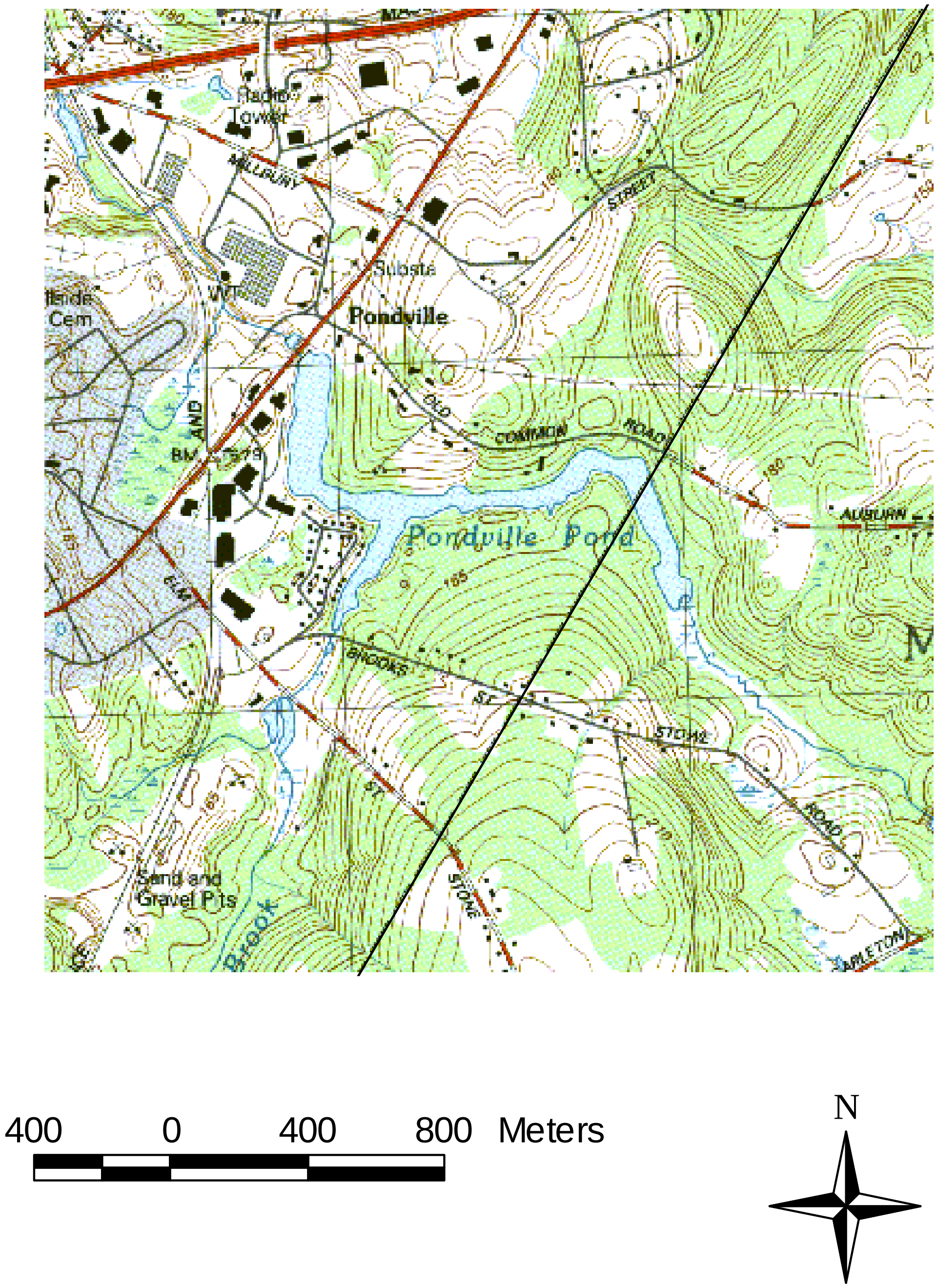

Figure 2k. Pondville Pond Environs.

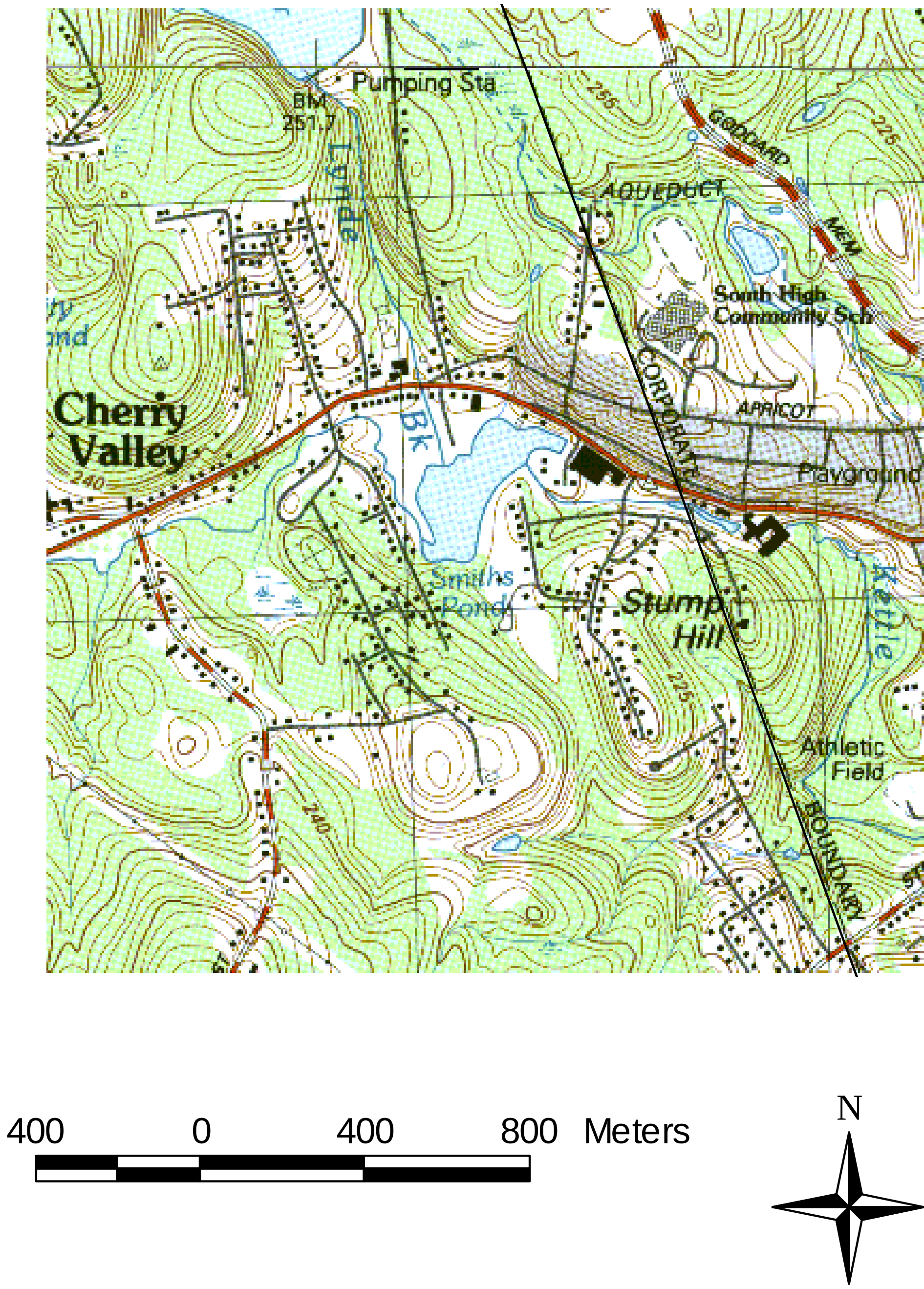

Figure 2l. Smiths Pond Environs.

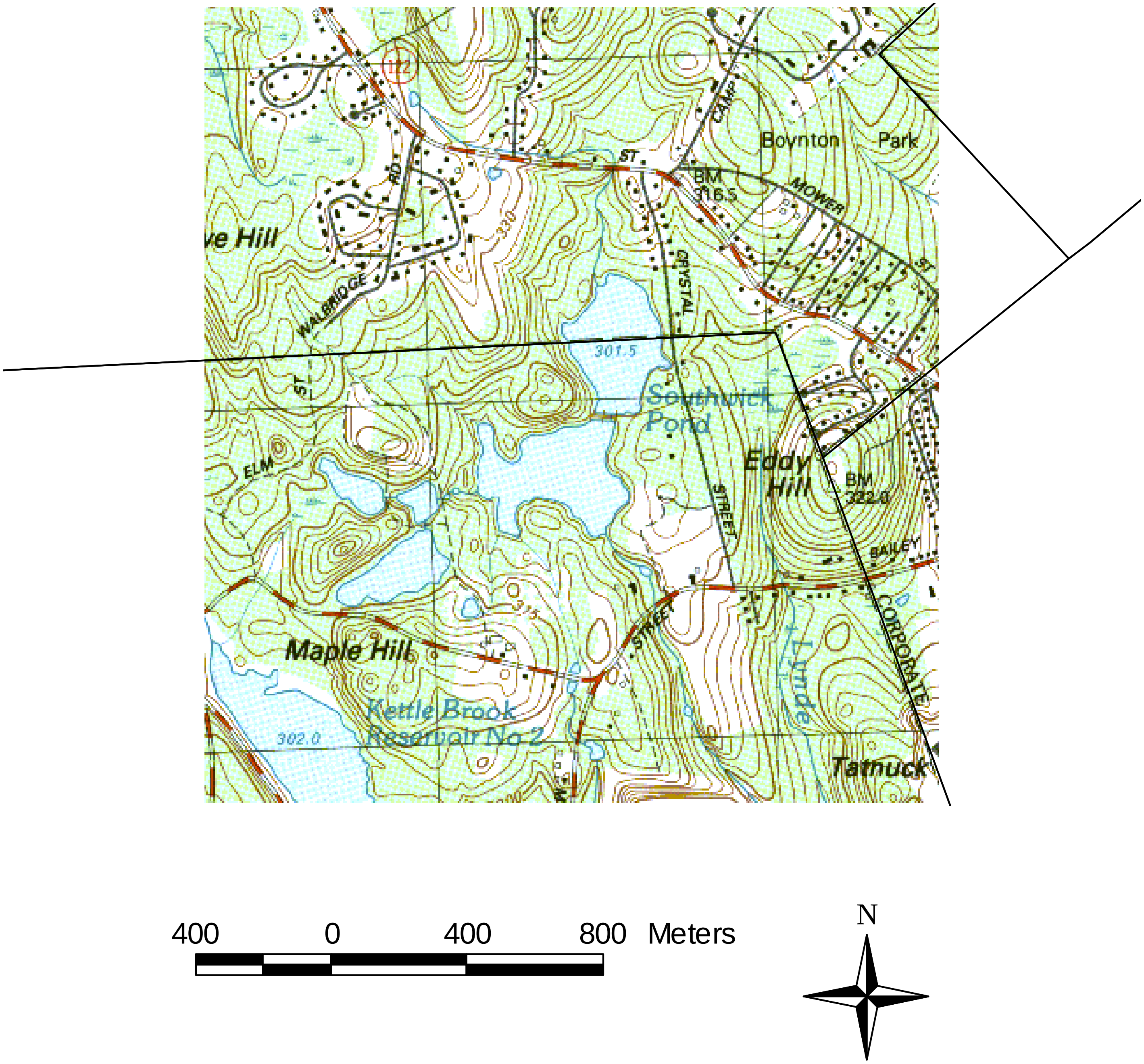

Figure 2m. Southwick Pond Environs.

Figure 2n. Stoneville Pond Environs.

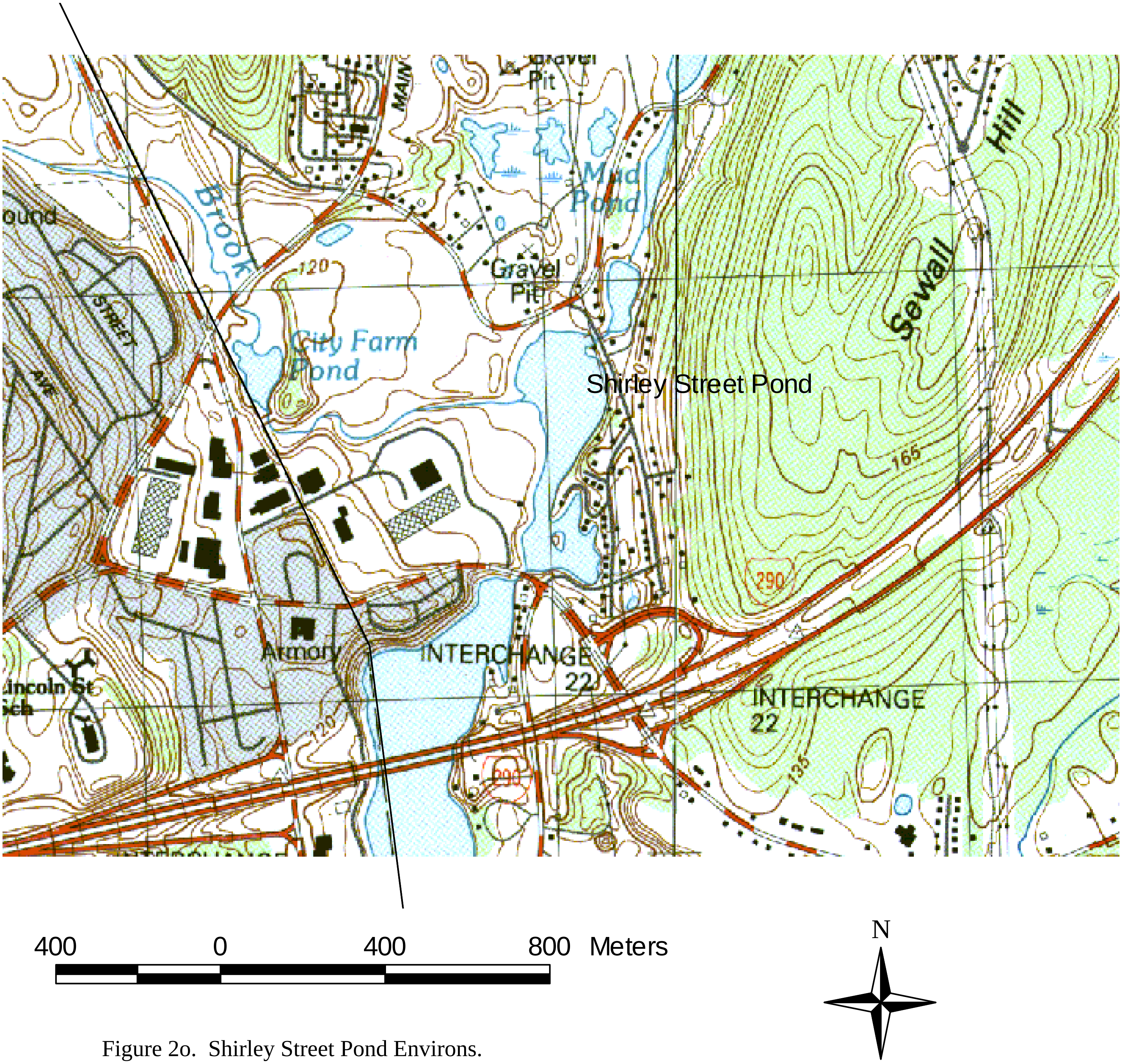

Figure 2o. Shirley Street Pond Environs.

Lake Descriptions:

Auburn Pond in Auburn is small pond of approximately 7 acres. The watershed is 51 percent forested and the remaining half consists of both rural, agricultural land use with some areas of high density residential and commercial-industrial land use. Populations in Auburn ranged between 14,845 and 15,005 from 1980 to the 1990 census. Miser predictions on growth are 15,926 for the year 2000 and 16,094 for the year 2010 with an estimated 20 year growth rate of about 7 percent. MassHighways Route 20 and the Massachusetts Turnpike (I-90) both are within the watershed of the pond. Auburn Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "A 19 July 1994 synoptic survey indicates that 75% to 100% of the pond was covered with floating, emergent, or submerged plants over three quarters of the pond. The non-native *Cabomba caroliniana* was present and likely contributed to the non-supporting aquatic life, primary contact, and secondary contact over three quarters of the pond. Turbidity was a threat to the remaining one-quarter of the pond. No other data was available to make assessments."

Brierly Pond, Millbury is approximately 18 acres in size and about 7 feet in depth. The watershed is 50 percent forested and most of the rest of the watershed is rural agriculture and water. Populations in Millbury ranged between 11,808 and 12,228 from 1980 to the 1990 census. Miser predictions on growth are 12,796 for the year 2000 and 12,962 for the year 2010 with an estimated 20 year growth rate of about 6 percent. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "A 14 July 1994 synoptic survey indicates that there is 75% to 100% coverage of all types over approximately 25% of the pond (coves near access and the upper end). Otherwise uncertain of submerged vegetation below open water. The non-native *Myriophyllum heterophyllum* was present and threatens the aquatic life in approximately 13 acres of the pond. No other data was available to make assessments." An early DEP survey in 1979 reported a Secchi disk depth of 6 feet and a total phosphorus concentration of 0.08mg/l (note this is about the detection limit of the analysis at the time).

Curtis Pond North, Worcester is approximately 31 acres in size. The watershed is 53 percent forested but urban landuse accounts for about 21 percent. Approximately 18 percent of the watershed is categorized as in rural agricultural uses, but which is actually urban cemeteries (Swedish Cemetery and Notre Dame Cemetery, both on the east and southern shores of both ponds (see Figure 2). The remaining 8 percent of the watershed consists of water and wetlands. The Conrail track divides the North from the South Pond. Highways Routes 9 and 12 are also within the watershed. Populations in Worcester ranged between 161,799 and 169,759 from 1980 to the 1990 census. Miser predictions on growth are 169,726 for the year 2000 and 176,753 for the year 2010 with an estimated 20 year growth rate of about 4 percent. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: " Historically transparency below safety criteria (4 ft. Secchi disk) and fecal coliform count > 200 /100 ml. Synoptic survey on 30 June 1994 noted high level of green turbidity that threaten to reduce transparency below safety criteria (4 ft. Secchi depth). Also noted were very dense covers of floating leaf macrophytes over about 1/4 or the pond area. The non-native species *Cabomba caroliniana* was recorded at the pond. Otherwise, no current data available to make additional assessments." An earlier DEP survey conducted in 1985 gave conflicting information on total phosphorus concentrations: The surface concentration was reported as 0.83 mg/l compared to the outlet concentration of 0.09 mg/l, just two hundred yards away. Secchi disk was reported as 1.2 meters in 1985.

Curtis Pond South, Worcester is approximately 14 acres in size. The watershed is essentially the same as for Curtis Pond North, above. Also population in the town has been described above. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "Historically fecal coliform levels > 200/100 ml. during a synoptic survey on 30 June 1994 it was noted that about one half of the pond was filled in (sand bars and cattails); the remaining pond area was covered with very dense growths of floating leaf and emergent macrophytes. Otherwise, no current data available to make additional assessments." Because of the infilling noted in the assessments, siltation was also reported on the 1998 303d list as an impairment in this pond, but this issue will be addressed in a separate TMDL. See above notes on Curtis Pond North for more information.

Dorothy Pond, Millbury is approximately 148 acres in size. The dominant landuses in the watershed are 44 percent urban, followed by 39 percent forest, with little agriculture or rural areas (about 10 percent). The remaining 7 percent of the watershed consists of water and wetlands. Much of the shoreline is lined with homes. The Massachusetts Turnpike (I-90) crosses the watershed. Population in the town has been described above. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "Historically algal "blooms" reduce transparency to below the safety criteria (4 ft. Secchi disk). Synoptic survey on 19 July 1994 noted very turbid (green/grey) conditions (< 4 ft. Secchi disk depth) likely caused by a blue-green bloom. In addition, the non-native macrophyte *Myriophyllum spicatum* was observed in the pond. Otherwise, no current data available to make additional assessments."

Eddy Pond, Auburn is approximately 134 acres in size. The watershed is 44 percent forested and about 21 percent is water and wetlands. Approximately 19 percent of the watershed is in urban land use that includes a small section of Route 20 and large area of Interstate I-395 that basically divides part of the lake. The remaining 16 percent of the watershed area is in rural and agricultural landuse. Population in the town has been described above. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "Historically high total phosphorus levels, the south and central portions of the pond are essentially a marsh, and very dense growths of aquatic macrophytes cover the remaining littoral zone. 30 June 1994 synoptic survey indicated that macrophyte cover is virtually the same (very dense submergents in Route 20 cove and upper end filled in to about the boat access). Water was very turbid (green/grey) threatening the transparency criteria. Otherwise, no current data available to make additional assessments."

Green Hill Pond, Worcester is approximately 32 acres in size. The watershed is dominated by open land of the golf course that comprises 49 percent of the watershed and essentially surrounds the pond , followed by about 31 percent in forest. The rest of the watershed consists of approximately 19 percent water and very little agricultural land (little less than 1 percent). Population in the town has been described above. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "A 22 July 1994 synoptic survey indicates that the observed aquatic plant density was sparse. Turbidity was a main cause of use impairment over the entire pond. There was a Secchi disk reading of less than 4 inches. The pond was very turbid with a silty covering on bottom and much leaf litter and trash. There was a low water level with nothing over the outlet. No other data was available to make assessments."

Howe Reservoir, Millbury is approximately 13 acres in size. The watershed is 58 percent forested with 21 percent open land and about 15 percent is in the urban landuse category. Much of the open land includes the Clear View Country Club golf course located upstream. The remaining 6 percent of the watershed is water and wetlands. Population in the town has been described above. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "A 14 July 1994 synoptic survey indicates that there were encroaching emergents over approximately one quarter of the pond. There was 75% to 100% density in patches of floating leaves over about one half of the open water. The density of the submergents was uncertain. No other data was available to make assessments."

Jordan Pond, Shrewsbury is approximately 20 acres in size. The watershed is dominated by urban land use that accounts for 59 percent of the area. Forest accounts for 27 percent of land use and approximately 10 percent is water. The rest of the watershed is open land. Populations in Shrewsbury ranged between 22,674 and 24,146 from 1980 to the 1990 census. Miser predictions on growth are 27,763 for the year 2000 and 29,898 for the year 2010 with an estimated 20 year growth rate of about 24 percent. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "Historically high total phosphorus levels and algal "blooms" reduce transparency below the safety criteria (4 ft. Secchi disk). Synoptic survey on 13 July 1994 indicated high turbidity (< 4 ft. Secchi disk depth) and plants dragged in with blackened appearance. Otherwise, no current data available to make additional assessments."

Mill Pond Shrewsbury is approximately 16 acres in size. The watershed is 58 percent forested and approximately 25 percent is in urban landuse category. About 15 percent of the watershed is in rural landuse and both water and wetlands accounting for the rest. Population in the town has been described above. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "A 22 July 1994 synoptic survey indicates that there were some patches of floating leaf plants along portions of the shore, but it was limited. A main cause of the use impairment to primary contact was the turbidity. The water was very turbid and brown and had a Secchi disk reading of less than four feet. No other data was available to make assessments."

Newton Pond Shrewsbury is approximately 48 acres in size. The watershed is 61 percent forested and about 22 percent is in rural landuse category. About 12 percent is in urban landuse and both water and wetlands accounting for the remaining 5 percent. A large gravel pit is located just to the southwest shore of the lake that may contribute sediments and nutrients to the lake. Population in the town has been described above. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "A 22 July 1994 synoptic survey indicates that floating leaf plants of 75% to 100% density were found in patches around shores and in coves (approximately 25% of the north part of the lake). There were no floating leaf plants at the end of the lake off Sewall street at the outlet and there were moderate submerged. The possible non-native *Myriophyllum* (possibly *heterophyllum*) was present and threatens the secondary contact over 43 acres of the pond. No other data was available to make assessments."

Pondville Pond, Auburn is approximately 41 acres in size. The watershed is 62 percent forested and rural land use accounting for about 27 percent. Water and wetlands comprises approximately 6 percent of the watershed while urban landuse accounts for the remaining 5 percent. MassHighways Route 20 is within the watershed. Population in the town has been described above. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "Historically high total phosphorus levels, algal "blooms" reduce transparency below safety criteria (4 ft. Secchi disk), and very dense growths of aquatic macrophytes cover the littoral zone. No current data available to make assessments. During a 30 June 1994 synoptic survey observations were noted that 2/3 of the pond has very dense growths of submergent macrophytes (primarily Cabomba caroliniana) and the remaining 1/3 was very densely covered by emergent and floating leaf plants."

Smiths Pond, Leicester is approximately 20 acres in size. The watershed is 65 percent forested and rural and urban landuses accounting for approximately 15 percent and 12 percent respectively. The rest of the watershed is water and wetlands. MassHighways Route 9 crosses the watershed. Populations in Leicester ranged between 9,446 and 10,191 from 1980 to the 1990 census. Miser predictions on growth are 11,121 for the year 2000 and 12,012 for the year 2010 with an estimated 20 year growth rate of about 18 percent. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "A 30 June 1994 synoptic survey indicates that the submergents were of moderate density. Turbidity was a cause of the partial support of primary contact the Secchi disk reading was less than 4 feet. The heavy brown turbidity was likely from the rains the night before. There was also a scum floating on the surface. No other data was available to make assessments."

Southwick Pond, Leicester is approximately 18 acres in size. It is part of the drinking water supply for the City of Worcester. The watershed is 60 percent forested with rural and agricultural land accounting for about 15 percent. Two high density housing developments within the watershed account for 14.4 percent of land use. MassHighways Route 122 crosses the watershed. The remaining 10 percent of the watershed consists of water and wetlands. Population in the town has been described above. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "A 30 June 1994 synoptic survey indicates that there was 75% to 100% coverage over almost the entire pond. No other data was available to make assessments."

Stoneville Pond, Auburn is approximately 43 acres in size. The watershed is 61 percent forested and both rural and urban landuses accounting for the rest. MassHighways Route 9 crosses the watershed. Population in the town has been described above. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "A 30 June 1994 synoptic survey indicates that the submergents were very dense in drag. The upper end of the pond was very weedy (submergents). The non-native *Cabomba caroliniana* and possible non-native *Myriophyllum* (possibly *heterophyllum*) were present and contributed to the non-supporting aquatic life, primary contact, and secondary contact criteria. No other data was available to make assessments."

Shirley Street Pond, Shrewsbury is approximately 17 acres in size. The watershed is 47 percent forested, 27 percent urban and the remaining open land and rural. A large gravel pit is located just to the northwest shore of the lake that may contribute sediments and nutrients to the lake. Population in the town has been described above. The pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "On a 22 July 1994 synoptic survey very dense growths of emergent and floating leaf aquatic macrophytes were found to cover all but the center of the pond. No other data available to make assessments."

Macrophyte maps were generally not available for these ponds with the exception of Curtis Ponds and Brierly Pond as shown below.

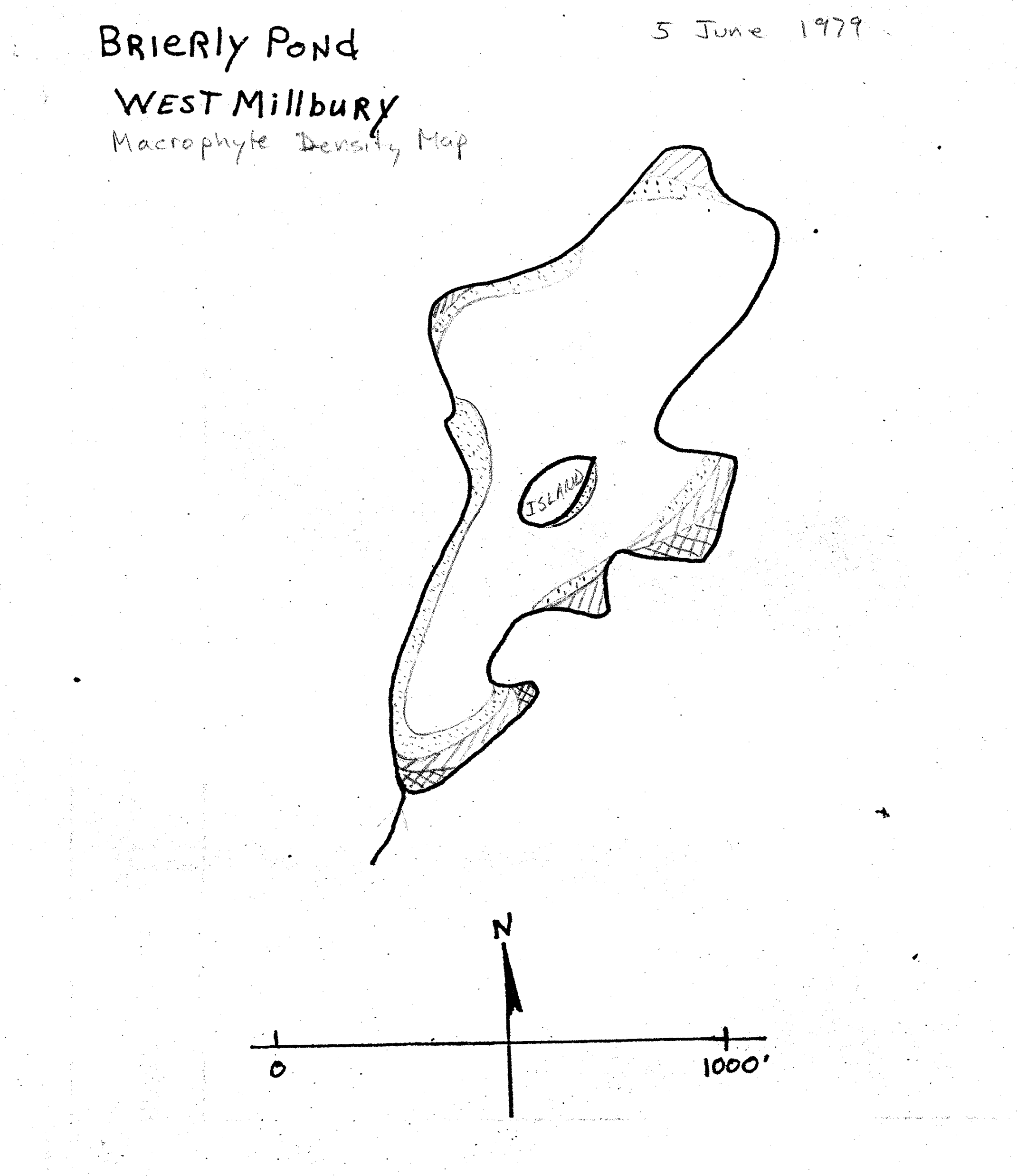

Figure 3a. Brierly Pond Macrophyte density (1979).

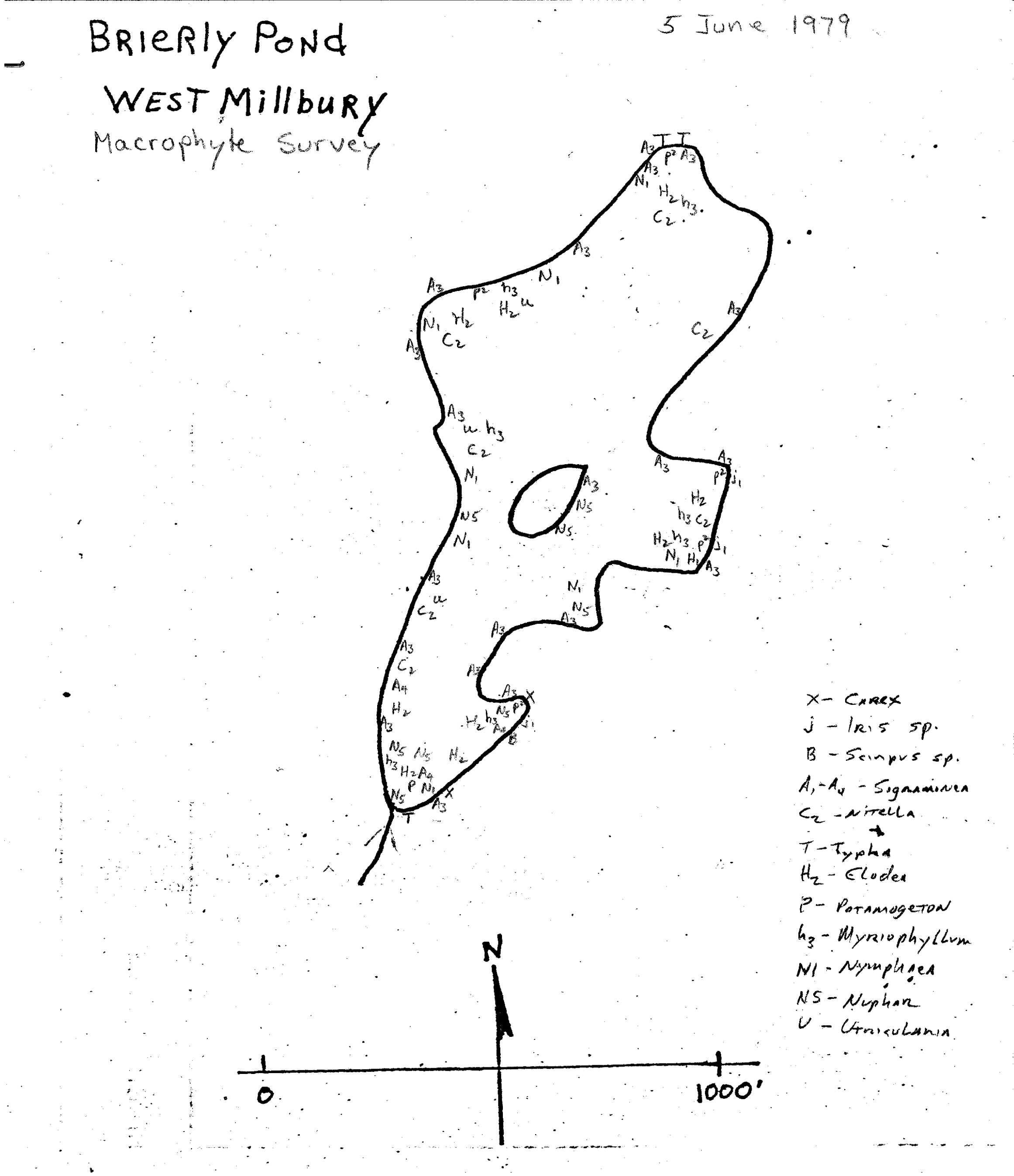

Figure 3b. Brierly Pond Macrophyte Species distributions (1979).

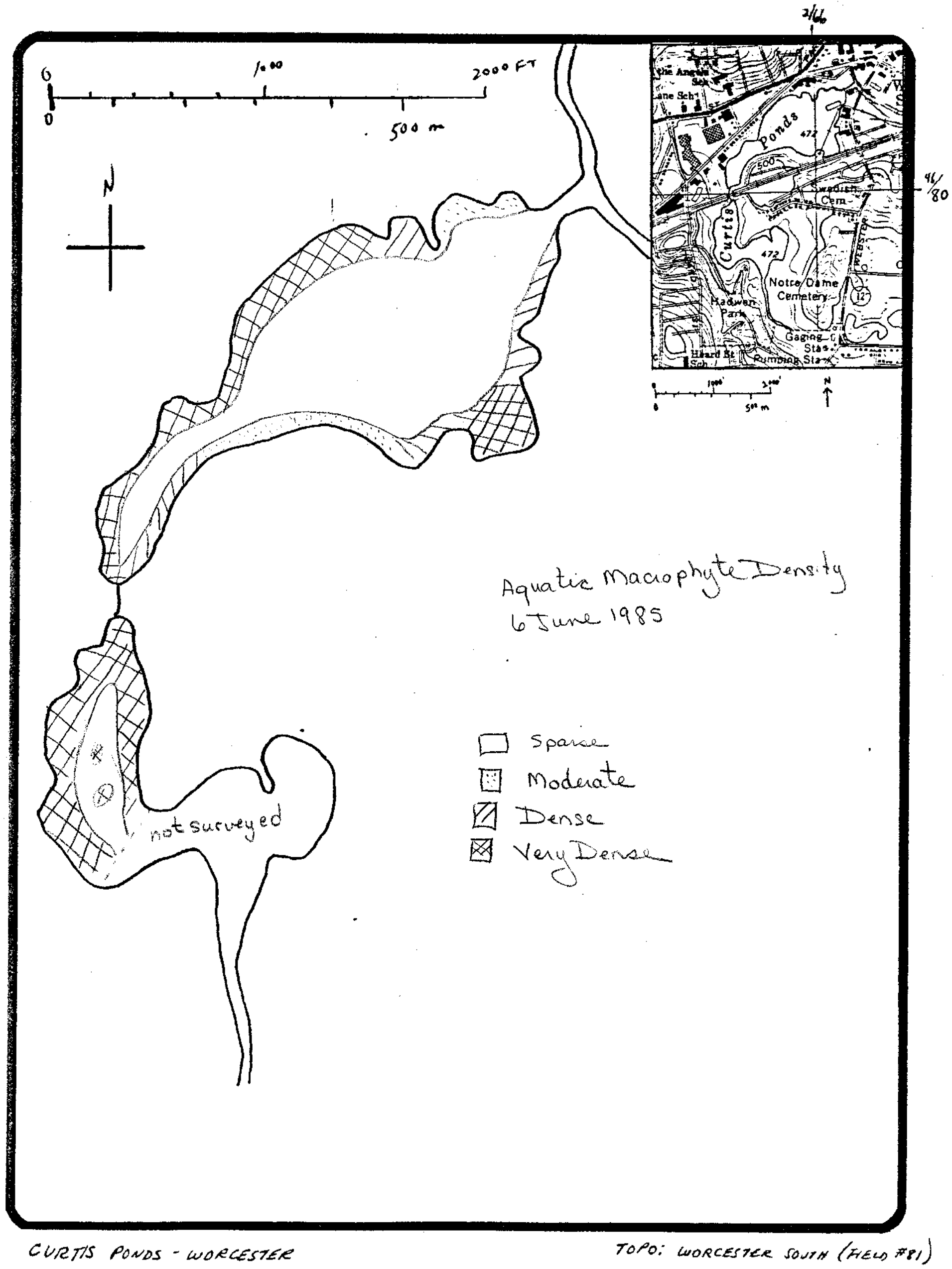

Figure 3a. Curtis Ponds North and South Macrophyte density (1985).

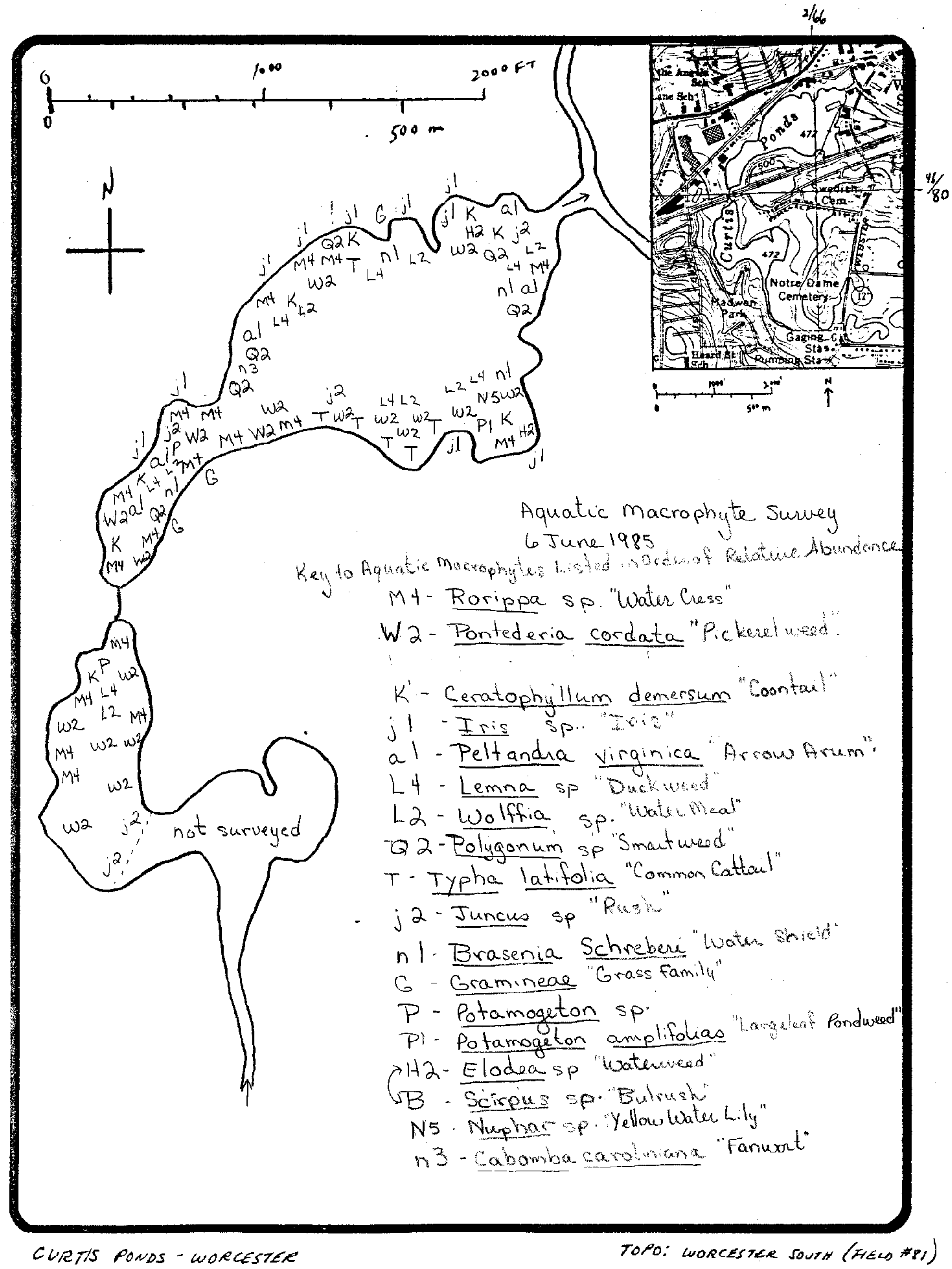

Figure 3b. Curtis Ponds North and South Macrophyte distribution (1985).

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.

There were three NPDES point sources listed in the watersheds of some of the lakes, but further investigation revealed they are no longer official point sources, or in one case will no longer be a point source within two months. The one major industrial discharger (Worcester Spinning and Finishing) has since closed after the factory burned down and it is not expected to reopen. A small wastewater point source for Nazzareth Home for Boys is currently being tied into the sewer system of the Leicester Water District with work expected to be completed within two months. The remaining NPDES site was a general permit for Browning Ferris Industries Inc (BFI) which is now covered under an EPA Muti-Sector Permit and is not considered as a point source in this analysis but is included as industrial (urban) landuse in the model.

Table 2. NPSLAKE model results.

Table 2a. Auburn Pond MA51004.

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	2836.7 Ha (11.0 mi2)
Average Annual Water Load =	17292727.1 m3/yr (19.6 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	2.6 Ha. (6.5ac)
Areal water loading to lake: q=	661.3 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	1438.6 (50.7)	187.0 (26.1)	3596.4	34525.8
Rural category				
Agriculture:	319.3 (11.3)	95.8 (13.4)	3321.7	117963.3
Open land:	106.8 (3.8)	32.0 (4.5)	555.5	12524.9
Residential Low:	244.9 (8.6)	73.5 (10.2)	1347.2	95039.3
Urban category				
Residential High:	306.3 (10.8)	182.6 (25.5)	2562.4	174670.8
Comm - Ind:	245.0 (8.6)	146.1 (20.4)	2443.1	184356.2
Other Landuses				
Water:	106.4 (3.8)	0.0 (0.0)	0.0	0.0
Wetlands:	69.4 (2.4)	0.0 (0.0)	0.0	3676.1
Subtotal	2836.7	717.1	13985.5	624870.6
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Total	2836.7 (100.0)	717.1(100)	13985.5	624870.6

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 27.4 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 34.1 ppb.
Predicted transparency = 1.4 meters.

If all land were forested, P export would be 345.9 kg/yr
And the forested condition lake TP would be 16.4 ppb.

Table 2b. Brierly Pond MA51010

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	1149.2 Ha (4.4 mi2)
Average Annual Water Load =	7005624.4 m3/yr (7.9 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	7.4 Ha. (18.3ac)
Areal water loading to lake: q=	94.5 m/yr.
Homes with septic systems within 100m of lake.=	22.0
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:	577.2 (50.2)	75.0 (27.0)	1443.1	13853.4
Rural category				
Agriculture:	164.5 (14.3)	49.4 (17.7)	1793.5	64697.3
Open land:	62.5 (5.4)	18.8 (6.7)	325.2	1999.2
Residential Low:	119.0 (10.4)	35.7 (12.8)	654.6	46180.7
Urban category				
Residential High:	34.7 (3.0)	76.9 (27.6)	236.9	17826.9
Comm - Ind:	5.2 (0.5)	11.5 (4.1)	51.8	3530.2
Other Landuses				
Water:	167.4 (14.6)	0.0 (0.0)	0.0	0.0
Wetlands:	18.6 (1.6)	0.0 (0.0)	0.0	986.4
Subtotal	1149.2	267.3	4590.9	150214.1
Other P inputs:	NA	0.0 (0.0)		
22.0 Septics:	NA	11.0 (4.0)		
Total	1149.2 (100.0)	278.3(100)	4590.9	150214.1

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 3.8 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 30.0 ppb.
Predicted transparency = 1.6 meters.

If all land were forested, P export would be 125.2 kg/yr
and the forested condition lake TP would be 13.5 ppb.

Table 2c. Curtis Pond North MA51032

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	8442.2 Ha (32.6 mi2)
Average Annual Water Load =	51463888.6 m3/yr (58.3 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	12.6 Ha. (31.0ac)
Areal water loading to lake: q=	409.5 m/yr.
Homes with septic systems within 100m of lake.=	1.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	4438.5 (52.6)	577.0 (35.1)	11096.3	106524.5
Rural category				
Agriculture:	605.9 (7.2)	181.8 (11.1)	5958.0	205489.9
Open land:	475.6 (5.6)	142.7 (8.7)	2472.9	66901.9
Residential Low:	469.3 (5.6)	140.8 (8.6)	2581.4	182107.8
Urban category				
Residential High:	1246.8 (14.8)	407.5 (24.8)	10530.4	713635.7
Comm - Ind:	588.2 (7.0)	192.2 (11.7)	5864.0	435810.8
Other Landuses				
Water:	484.9 (5.7)	0.0 (0.0)	0.0	0.0
Wetlands:	133.0 (1.6)	0.0 (0.0)	0.0	7049.7
Subtotal	8442.2	1642.0	38662.1	1719634.5
Other P inputs:	NA	0.0 (0.0)		
1.0 Septics:	NA	0.5 (0.0)		
Total	8442.2 (100.0)	1642.5(100)	38662.1	1719634.5

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 13.1 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 26.0 ppb.
Predicted transparency = 1.8 meters.

If all land were forested, P export would be 1017.2 kg/yr
and the forested condition lake TP would be 16.1 ppb.

Table 2d. Curtis Pond South MA51033

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	8216.1 Ha (31.7 mi2)
Average Annual Water Load =	50085260.7 m3/yr (56.7 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	5.7 Ha. (14.0ac)
Areal water loading to lake: q=	884.8 m/yr.
Homes with septic systems within 100m of lake.=	1.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	4390.0 (53.4)	570.7 (35.5)	10974.9	105358.9
Rural category				
Agriculture:	605.3 (7.4)	181.6 (11.3)	5951.1	205243.2
Open land:	467.3 (5.7)	140.2 (8.7)	2430.1	64722.8
Residential Low:	469.3 (5.7)	140.8 (8.8)	2581.4	182107.8
Urban category				
Residential High:	1127.1 (13.7)	385.0 (23.9)	9277.1	636528.7
Comm - Ind:	552.8 (6.7)	188.8 (11.7)	5511.4	409769.9
Other Landuses				
Water:	471.2 (5.7)	0.0 (0.0)	0.0	0.0
Wetlands:	133.0 (1.6)	0.0 (0.0)	0.0	7049.7
Subtotal	8216.1	1607.1	36884.9	1612895.1
Other P inputs:	NA	0.0 (0.0)		
1.0 Septics:	NA	0.5 (0.0)		
Total	8216.1 (100.0)	1607.6(100)	36884.9	1612895.1

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 28.4 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 26.5 ppb.
Predicted transparency = 1.8 meters.

If all land were forested, P export would be 989.5 kg/yr
and the forested condition lake TP would be 16.3 ppb.

Table 2e. Dorothy Pond MA51039

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	959.9 Ha (3.7 mi2)
Average Annual Water Load =	5851660.1 m3/yr (6.6 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	59.9 Ha. (148.0ac)
Areal water loading to lake: q=	9.8 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	377.4 (39.3)	49.1 (13.4)	943.6	9058.3
Rural category				
Agriculture:	1.6 (0.2)	0.5 (0.1)	19.6	723.8
Open land:	79.8 (8.3)	24.0 (6.6)	415.2	10387.8
Residential Low:	12.4 (1.3)	3.7 (1.0)	68.4	4822.6
Urban category				
Residential High:	335.4 (34.9)	228.0 (62.4)	2866.9	200571.6
Comm - Ind:	88.7 (9.2)	60.3 (16.5)	884.6	61394.3
Other Landuses				
Water:	58.7 (6.1)	0.0 (0.0)	0.0	0.0
Wetlands:	5.9 (0.6)	0.0 (0.0)	0.0	310.7
Subtotal	959.9	365.5	5198.2	287269.0
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Total	959.9 (100.0)	365.5(100)	5198.2	287269.0

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.6 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 26.2 ppb.
Predicted transparency = 1.8 meters.

If all land were forested, P export would be 116.4 kg/yr
and the forested condition lake TP would be 8.3 ppb.

Table 2f. Eddy Pond MA51043

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	240.9 Ha (0.9 mi2)
Average Annual Water Load =	1468475.3 m3/yr (1.7 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	54.3 Ha. (134.0ac)
Areal water loading to lake: q=	2.7 m/yr.
Homes with septic systems within 100m of lake.=	4.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	106.3 (44.1)	13.8 (11.2)	265.7	2551.1
Rural category				
Agriculture:	11.4 (4.7)	3.4 (2.8)	100.1	3255.0
Open land:	2.8 (1.2)	0.9 (0.7)	14.8	127.9
Residential Low:	24.4 (10.1)	7.3 (5.9)	134.0	9453.4
Urban category				
Residential High:	14.5 (6.0)	29.8 (24.2)	94.1	7278.2
Comm - Ind:	32.0 (13.3)	65.7 (53.5)	319.2	30768.8
Other Landuses				
Water:	40.7 (16.9)	0.0 (0.0)	0.0	0.0
Wetlands:	8.7 (3.6)	0.0 (0.0)	0.0	463.6
Subtotal	240.9	120.9	927.9	53898.0
Other P inputs:	NA	0.0 (0.0)		
4.0 Septics:	NA	2.0 (1.6)		
Total	240.9 (100.0)	122.9(100)	927.9	53898.0

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.2 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 15.3 ppb.
Predicted transparency = 3.1 meters.

If all land were forested, P export would be 24.9 kg/yr
and the forested condition lake TP would be 3.1 ppb.

Table 2g. Green Hill Pond MA51056

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	57.1 Ha (0.2 mi2)
Average Annual Water Load =	348330.1 m3/yr (0.4 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	13.0 Ha. (32.0ac)
Areal water loading to lake: q=	2.7 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs from golf course fertilizer =	64.4 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	17.6 (30.7)	2.3 (21.1)	43.9	421.5
Rural category				
Agriculture:	0.5 (0.9)	0.2 (1.4)	6.5	241.2
Open land:	28.0 (49.0)	8.4 (77.5)	145.5	8337.0
Residential Low:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Urban category				
Residential High:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	11.1 (19.4)	0.0 (0.0)	0.0	0.0
Wetlands:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Subtotal	57.1	10.8	195.9	8999.7
Other P inputs:	NA	64.4 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Total	57.1 (100.0)	75.2(100)	195.9	8999.7

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.7 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 44.2 ppb.
Predicted transparency = 1.1 meters.

If all land were forested, P export would be 6.0 kg/yr
and the forested condition lake TP would be 3.5 ppb.

Table 2h. Howe Reservoir MA51071

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	195.1 Ha (0.8 mi2)
Average Annual Water Load =	1189086.9 m3/yr (1.3 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	5.3 Ha. (13.0ac)
Areal water loading to lake: q=	22.6 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	112.6 (57.7)	14.6 (14.1)	281.4	2701.6
Rural category				
Agriculture:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Open land:	40.9 (21.0)	12.3 (11.8)	212.5	8505.5
Residential Low:	0.9 (0.4)	0.3 (0.3)	4.8	336.5
Urban category				
Residential High:	25.8 (13.2)	66.1 (63.7)	246.5	16010.7
Comm - Ind:	4.1 (2.1)	10.5 (10.1)	41.0	3574.4
Other Landuses				
Water:	3.5 (1.8)	0.0 (0.0)	0.0	0.0
Wetlands:	7.3 (3.7)	0.0 (0.0)	0.0	385.0
Subtotal	195.1	103.8	786.2	31513.7
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Total	195.1 (100.0)	103.8(100)	786.2	31513.7

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 2.0 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 50.9 ppb.
Predicted transparency = 0.9 meters.

If all land were forested, P export would be 24.0 kg/yr
and the forested condition lake TP would be 11.8 ppb.

Table 2i. Jordan Pond MA51078

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	71.5 Ha (0.3 mi2)
Average Annual Water Load =	435796.4 m3/yr (0.5 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	8.1 Ha. (20.0ac)
Areal water loading to lake: q=	5.4 m/yr.
Homes with septic systems within 100m of lake.=	10.0
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:	19.5 (27.3)	2.5 (2.6)	48.9	469.1
Rural category				
Agriculture:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Open land:	2.6 (3.6)	0.8 (0.8)	13.5	311.8
Residential Low:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Urban category				
Residential High:	34.8 (48.6)	75.3 (76.2)	378.9	23405.0
Comm - Ind:	7.0 (9.8)	15.2 (15.4)	69.8	4755.1
Other Landuses				
Water:	7.6 (10.6)	0.0 (0.0)	0.0	0.0
Wetlands:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Subtotal	71.5	93.8	511.1	28940.9
Other P inputs:	NA	0.0 (0.0)		
10.0 Septics:	NA	5.0 (5.1)		
Total	71.5 (100.0)	98.8(100)	511.1	28940.9

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 1.2 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 67.6 ppb.
Predicted transparency = 0.7 meters.

If all land were forested, P export would be 8.3 kg/yr
and the forested condition lake TP would be 5.7 ppb.

Table 2j. Mill Pond MA51105

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	702.9 Ha (2.7 mi2)
Average Annual Water Load =	4284652.3 m3/yr (4.9 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	6.5 Ha. (16.0ac)
Areal water loading to lake: q=	66.1 m/yr.
Homes with septic systems within 100m of lake.=	5.0
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:	409.7 (58.3)	53.3 (19.4)	1024.3	9833.6
Rural category				
Agriculture:	9.0 (1.3)	2.7 (1.0)	80.1	2614.9
Open land:	53.7 (7.6)	16.1 (5.9)	279.1	7817.3
Residential Low:	41.4 (5.9)	12.4 (4.5)	227.5	16050.8
Urban category				
Residential High:	119.9 (17.1)	125.6 (45.8)	1051.0	69904.5
Comm - Ind:	58.8 (8.4)	61.6 (22.5)	586.2	55082.6
Other Landuses				
Water:	4.8 (0.7)	0.0 (0.0)	0.0	0.0
Wetlands:	5.5 (0.8)	0.0 (0.0)	0.0	292.3
Subtotal	702.9	271.6	3248.3	161596.1
Other P inputs:	NA	0.0 (0.0)		
5.0 Septics:	NA	2.5 (0.9)		
Total	702.9 (100.0)	274.1(100)	3248.3	161596.1

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 4.2 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 46.5 ppb.
Predicted transparency = 1.0 meters.

If all land were forested, P export would be 90.0 kg/yr
and the forested condition lake TP would be 15.3 ppb.

Table 2k. Newton Pond MA51110

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	1099.8 Ha (4.2 mi2)
Average Annual Water Load =	6704524.0 m3/yr (7.6 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	19.4 Ha. (48.0ac)
Areal water loading to lake: q=	34.5 m/yr.
Homes with septic systems within 100m of lake.=	15.0
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:	675.3 (61.4)	87.8 (26.7)	1688.3	16208.0
Rural category				
Agriculture:	34.6 (3.1)	10.4 (3.2)	304.5	10450.1
Open land:	98.9 (9.0)	29.7 (9.0)	514.3	12227.8
Residential Low:	110.0 (10.0)	33.0 (10.0)	605.1	42688.1
Urban category				
Residential High:	104.7 (9.5)	127.8 (38.9)	811.6	57702.1
Comm - Ind:	26.9 (2.4)	32.8 (10.0)	268.0	10461.7
Other Landuses				
Water:	35.8 (3.3)	0.0 (0.0)	0.0	0.0
Wetlands:	13.5 (1.2)	0.0 (0.0)	0.0	717.9
Subtotal	1099.8	321.5	4228.0	150937.9
Other P inputs:	NA	0.0 (0.0)		
15.0 Septics:	NA	7.5 (2.3)		
Total	1099.8 (100.0)	329.0(100)	4228.0	150937.9

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 1.7 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 31.9 ppb.
Predicted transparency = 1.5 meters.

If all land were forested, P export would be 136.6 kg/yr
and the forested condition lake TP would be 13.3 ppb.

Table 2l. Pondville Pond MA51120

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	1933.8 Ha (7.5 mi2)
Average Annual Water Load =	11788698.9 m3/yr (13.4 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	16.6 Ha. (41.0ac)
Areal water loading to lake: q=	71.0 m/yr.
Homes with septic systems within 100m of lake.=	5.0
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:	1198.6 (62.0)	155.8 (34.5)	2996.4	28765.3
Rural category				
Agriculture:	285.6 (14.8)	85.7 (19.0)	2976.6	106016.9
Open land:	40.1 (2.1)	12.0 (2.7)	208.3	2627.0
Residential Low:	197.5 (10.2)	59.2 (13.1)	1086.2	76625.2
Urban category				
Residential High:	58.8 (3.0)	84.6 (18.8)	369.3	29042.9
Comm - Ind:	35.8 (1.8)	51.5 (11.4)	356.6	15023.4
Other Landuses				
Water:	60.2 (3.1)	0.0 (0.0)	0.0	0.0
Wetlands:	57.4 (3.0)	0.0 (0.0)	0.0	3039.8
Subtotal	1933.8	448.9	8152.5	263254.9
Other P inputs:	NA	0.0 (0.0)		
5.0 Septics:	NA	2.5 (0.6)		
Total	1933.8 (100.0)	451.4(100)	8152.5	263254.9

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 2.7 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 28.1 ppb.
Predicted transparency = 1.7 meters.

If all land were forested, P export would be 236.1 kg/yr
and the forested condition lake TP would be 14.7 ppb.

Table 2m. Smiths Pond MA51156

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	2525.8 Ha (9.8 mi2)
Average Annual Water Load =	15397261.4 m3/yr (17.4 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	8.1 Ha. (20.0ac)
Areal water loading to lake: q=	190.2 m/yr.
Homes with septic systems within 100m of lake.=	18.0
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:	1641.4 (65.0)	213.4 (36.6)	4103.4	39393.1
Rural category				
Agriculture:	121.5 (4.8)	36.5 (6.3)	964.9	29908.9
Open land:	142.3 (5.6)	42.7 (7.3)	740.0	13083.5
Residential Low:	108.2 (4.3)	32.5 (5.6)	595.0	41971.2
Urban category				
Residential High:	211.9 (8.4)	167.3 (28.7)	1405.5	107352.8
Comm - Ind:	102.6 (4.1)	81.0 (13.9)	1023.1	82457.7
Other Landuses				
Water:	178.5 (7.1)	0.0 (0.0)	0.0	0.0
Wetlands:	19.4 (0.8)	0.0 (0.0)	0.0	1027.0
Subtotal	2525.8	573.3	8831.9	315194.3
Other P inputs:	NA	0.0 (0.0)		
18.0 Septics:	NA	9.0 (1.5)		
Total	2525.8 (100.0)	582.3(100)	8831.9	315194.3

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 7.2 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 30.0 ppb.
Predicted transparency = 1.6 meters.

If all land were forested, P export would be 302.6 kg/yr
and the forested condition lake TP would be 15.6 ppb.

Table 2n. Southwick Pond MA51157

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	211.0 Ha (0.8 mi2)
Average Annual Water Load =	1286506.6 m3/yr (1.5 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	17.2 Ha. (42.4ac)
Areal water loading to lake: q=	7.5 m/yr.
Homes with septic systems within 100m of lake.=	7.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	127.6 (60.4)	16.6 (15.4)	318.9	3061.5
Rural category				
Agriculture:	17.2 (8.2)	5.2 (4.8)	177.6	6158.5
Open land:	6.1 (2.9)	1.8 (1.7)	32.0	92.2
Residential Low:	6.8 (3.2)	2.0 (1.9)	37.5	2645.3
Urban category				
Residential High:	30.4 (14.4)	76.1 (70.9)	167.0	14149.9
Comm - Ind:	0.9 (0.4)	2.1 (2.0)	8.5	579.6
Other Landuses				
Water:	21.6 (10.3)	0.0 (0.0)	0.0	0.0
Wetlands:	0.4 (0.2)	0.0 (0.0)	0.0	21.8
Subtotal	211.0	103.9	741.5	26708.8
Other P inputs:	NA	0.0 (0.0)		
7.0 Septics:	NA	3.5 (3.3)		
Total	211.0 (100.0)	107.4(100)	741.5	26708.8

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.6 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 30.4 ppb.
Predicted transparency = 1.6 meters.

If all land were forested, P export would be 24.6 kg/yr
and the forested condition lake TP would be 6.9 ppb.

Table 2o. Stoneville Pond MA51160

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	4690.8 Ha (18.1 mi2)
Average Annual Water Load =	28595282.5 m3/yr (32.4 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	17.4 Ha. (43.0ac)
Areal water loading to lake: q=	164.3 m/yr.
Homes with septic systems within 100m of lake.=	3.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	2850.7 (60.8)	370.6 (38.2)	7126.7	68416.4
Rural category				
Agriculture:	284.3 (6.1)	85.3 (8.8)	2608.2	86500.1
Open land:	214.5 (4.6)	64.3 (6.6)	1115.3	18134.8
Residential Low:	210.6 (4.5)	63.2 (6.5)	1158.5	81729.5
Urban category				
Residential High:	554.4 (11.8)	282.5 (29.1)	4189.3	299739.7
Comm - Ind:	200.4 (4.3)	102.1 (10.5)	1998.4	144813.3
Other Landuses				
Water:	346.5 (7.4)	0.0 (0.0)	0.0	0.0
Wetlands:	29.4 (0.6)	0.0 (0.0)	0.0	1555.9
Subtotal	4690.8	968.1	18196.5	700889.8
Other P inputs:	NA	0.0 (0.0)		
3.0 Septics:	NA	1.5 (0.2)		
Total	4690.8 (100.0)	969.6(100)	18196.5	700889.8

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 5.6 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 26.7 ppb.
Predicted transparency = 1.8 meters.

If all land were forested, P export would be 561.0 kg/yr
and the forested condition lake TP would be 15.4 ppb.

Table 2p. Shirley Street Pond MA51196

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	2321.3 Ha (9.0 mi2)
Average Annual Water Load =	14150684.2 m3/yr (16.0 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	6.9 Ha. (17.0ac)
Areal water loading to lake: q=	205.6 m/yr.
Homes with septic systems within 100m of lake.=	30.0
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:	1078.4 (46.5)	140.2 (20.9)	2696.0	25881.5
Rural category				
Agriculture:	78.0 (3.4)	23.4 (3.5)	656.2	21465.2
Open land:	303.1 (13.1)	90.9 (13.6)	1575.9	41590.0
Residential Low:	162.2 (7.0)	48.6 (7.3)	891.9	62917.9
Urban category				
Residential High:	489.6 (21.1)	272.4 (40.6)	4678.3	310567.9
Comm - Ind:	143.5 (6.2)	79.8 (11.9)	1430.4	76842.3
Other Landuses				
Water:	39.0 (1.7)	0.0 (0.0)	0.0	0.0
Wetlands:	27.7 (1.2)	0.0 (0.0)	0.0	1465.5
Subtotal	2321.3	655.4	11964.9	541212.4
Other P inputs:	NA	0.0 (0.0)		
30.0 Septics:	NA	15.0 (2.2)		
Total	2321.3 (100.0)	670.4(100)	11964.9	541212.4

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 9.7 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 37.7 ppb.
Predicted transparency = 1.3 meters.

If all land were forested, P export would be 293.1 kg/yr
and the forested condition lake TP would be 16.5 ppb.

Water Quality Standards Violations:

Fifteen of the 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). The remaining lake, Southwick Pond in Leicester is a Class A surface water as it is tributary to a Public Water Supply (Lynde Brook Reservoir) for the City of Worcester. Noxious Aquatic Plants is the most common pollutant/stressor listed for the lakes (see Table 1). Five of the lakes are listed for turbidity. 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….

The Code of Massachusetts Regulations (CMR) for Class A waters include 314 CMR 4.05(3)(a):

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

1. Dissolved Oxygen-

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

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

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

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

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

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

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

TMDL Analysis

Identification of Target: There is no loading capacity *per se* for nuisance aquatic plants. As the term implies, TMDLs are often expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs may be expressed in other terms when appropriate. For these cases, the TMDLs are expressed in terms of allowable annual loadings of phosphorus because the growth of phytoplankton and macrophytes responds to changes in annual rather than daily loadings of nutrients. The target in-lake total phosphorus concentration chosen is based on consideration of the typical concentrations expected in lakes in the region. The phosphorus ecoregion map of Griffith et al. (1994) is based on spring/fall concentrations, while the phosphorus ecoregion map of Rohm et al., (1995) is based on summer concentrations. Table 3 shows the ecoregion expected TP concentrations for both spring and summer, and the target TP that was chosen for each lake. The TP predicted by the NPSLAKE model and the surface TP concentrations are also shown for comparison. Note that according to the Carlson Trophic State analysis (Carlson,1977) a lake should have total phosphorus concentrations of about 40 ppb to meet the 4-foot transparency requirement for swimming beaches in Massachusetts. The target should be set lower than this to allow for a margin of safety. The lower phosphorus concentrations will lessen the chance of nuisance algal blooms, which may occur as macrophyte biomass is reduced by direct controls. In some cases, such as Eddy Pond, the target is the same, or nearly the same as the current modeled total phosphorus concentration so little if any reductions are required.

In the case of Smiths Pond, the ecoregion ranges for total phosphorus suggested a target as low as 10 ppb, but this was impossible to achieve in such a large watershed and small lake, as even the forest loading would exceed this target. In this case, a higher target of 20 ppb was chosen, and this was still considered to be well below the 40ppb limit above and thus still contains a margin of safety. In the case of Green Hill Pond the target was substantially higher than the model predicted total phosphorus concentrations. In this case, the model is likely to greatly underestimate surface total phosphorus concentrations because the large area of "open land" land use in the watershed. While open land is typically rather low in phosphorus export, is in this case, the land use is comprised of a large, fertilized golf course which is likely to result in much higher actual loadings of phosphorus to the pond. To account for this sourc, we assumed the golf course would have phosphorus export similar to the 2.6 kg/ha/yr reported for the 75th percentile of pastures exports reported in Reckhow et al., (1980), and thus we added the equivalent of 64.4 kg/yr to the budget as phosphorus fertilizer runoff in Table 2g above. The golf course is operated by the City of Worcester and recently began implementing Integrated Pest Management BMPs which are expected to reduce phosphorus loading to the pond (M. O'Brien, pers. comm.).

Shallow areas in 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). No recent data on surface total phosphorus concentrations was available for most lakes.

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)
MA51004	Auburn Pond	15-19	30-50	34	NA	25
MA51010	Brierly Pond	15-19	30-50	30	NA	25
MA51032	Curtis Ponds	15-19	30-50	26	NA	25
MA51033	Curtis Ponds	15-19	30-50	27	NA	25
MA51039	Dorothy Pond	15-19	30-50	26	33	25
MA51043	Eddy Pond	15-19	10-14	15	NA	15
MA51056	Green Hill Pond	15-19	30-50	44.2	NA	25
MA51071	Howe Reservoirs	15-19	30-50	50.9	NA	25
MA51078	Jordan Pond	15-19	30-50	67.6	NA	25
MA51105	Mill Pond	15-19	30-50	46.5	NA	25
MA51110	Newton Pond	15-19	30-50	31.9	NA	25
MA51120	Pondville Pond	15-19	30-50	28.1	NA	25
MA51156	Smiths Pond	5-9	10-14	30	NA	20
MA51157	Southwick Pond	5-9	10-14	30.4	NA	10
MA51160	Stoneville Pond	15-19	30-50	26.7	NA	25
MA51196	Shirley Street Pond	15-19	30-50	37.7	NA	25

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 controled. To control eutrophication, the Carlson Trophic State Index (TSI) (Carlson,1977) predicts a lake should have total phosphorus concentrations of about 40 ppb to meet the 4-foot transparency requirement for swimming beaches in Massachusetts and targets are set lower than this. Due to the lack of data on mean depth and other parameters, a simple water quality model was used to link watershed phosphorus loading to in-lake total phosphorus concentration targets. Based on the NPSLAKE model phosphorus loading output and predicted water runoff volumes, an estimated in-lake total phosphorus (TP) concentration was derived based on the Reckhow (1979) model:

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

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

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

Wasteload Allocations, Load Allocations and Margin of Safety:

For most lakes, point source wasteload allocation is zero. The margin of safety is set by establishing a target that is below that expected to meet the 4-foot swimming standard (about 40 ppb). Thus, the TMDL is the same as the target load allocation to nonpoint sources as indicated in the right side of Table 4. Loading allocations are based on the NPSLAKE landuse modeled phosphorus budget. Note that if lakes have surface TP concentrations that are much larger than that predicted by the NPSLAKE model, internal sources of phosphorus, such as the sediments, may also be a contributing source of phosphorus to the surface waters and should be considered for further evaluation and control.

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

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

TMDL = WLA + LA + MOS

Table 4. TMDL Load Allocations by Lake.

Table 4a. Auburn Pond MA51004 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	187	187
Agriculture	96	61
Open Land	32	20
Residential (Low den.)	74	47
Residential (High den.)	183	116
Comm. Indust.	146	93
Septic System	0	0
Other	0	0
Total Inputs	717	523

Table 4b. Brierly Pond MA51010 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	75	75
Agriculture	49	38
Open Land	19	14
Residential (Low den.)	36	27
Residential (High den.)	77	59
Comm. Indust.	12	9
Septic System	11	8
Other	0	0
Total Inputs	278	231

Table 4c. Curtis Pond North MA51032 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***

Load Allocation		
Forest	577	577
Agriculture	182	172
Open Land	143	135
Residential (Low den.)	141	133
Residential (High den.)	408	385
Septic System	1	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	192	182
Total Inputs	1644	1584

Table 4d. Curtis Pond South MA51033 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation		
Forest	571	571
Agriculture	182	169
Open Land	140	129
Residential (Low den.)	141	130
Residential (High den.)	385	356
Septic System	1	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	189	175
Total Inputs	1609	1530

Table 4e. Dorothy Pond MA51039 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	49	49
Agriculture	1	0
Open Land	24	23
Residential (Low den.)	4	4
Residential (High den.)	228	217
Comm. Indust.	60	57
Septic System	0	0
Other	0	0
Total Inputs	366	350

Table 4f. Eddy Pond MA51043 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	14	14
Agriculture	3	3
Open Land	1	1
Residential (Low den.)	7	7
Residential (High den.)	30	29
Comm. Indust.	66	65
Septic System	2	2
Other	0	0
Total Inputs	123	121

Table 4g. Green Hill Pond MA51056 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	2	2
Agriculture	0	0
Open Land	8	5
Residential (Low den.)	0	0
Residential (High den.)	0	0
Comm. Indust.	0	0
Septic System	0	0
Other (golf course fertilizer)	64	40
Total Inputs	75	48

Table 4h. Howe Reservoir MA51071 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	15	15
Agriculture	0	0
Open Land	12	5
Residential (Low den.)	0	0
Residential (High den.)	66	27
Comm. Indust.	11	4
Septic System	0	0
Other	0	0
Total Inputs	104	51

Table 4i. Jordan Pond MA51078 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	3	3
Agriculture	0	0
Open Land	1	0
Residential (Low den.)	0	0
Residential (High den.)	75	27
Comm. Indust.	15	5
Septic System	5	2
Other	0	0
Total Inputs	99	37

Table 4j. Mill Pond MA51105 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	53	53
Agriculture	3	1
Open Land	16	7
Residential (Low den.)	12	5
Residential (High den.)	126	54
Comm. Indust.	62	27
Septic System	3	1
Other	0	0
Total Inputs	275	148

Table 4k. Newton Pond MA51110 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	88	88
Agriculture	10	7
Open Land	30	21
Residential (Low den.)	33	23
Residential (High den.)	128	90
Comm. Indust.	33	23
Septic System	8	5
Other	0	0
Total Inputs	330	257

Table 4l. Pondville Pond MA51120 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	156	156
Agriculture	86	71
Open Land	12	10
Residential (Low den.)	59	49
Residential (High den.)	85	71
Comm. Indust.	52	43
Septic System	3	2
Other	0	0
Total Inputs	453	402

Table 4m. Smiths Pond MA51156 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	213	213
Agriculture	37	18
Open Land	43	20
Residential (Low den.)	33	16
Residential (High den.)	167	79
Comm. Indust.	81	39
Septic System	9	4
Other	0	0
Total Inputs	583	389

Table 4n. Southwick Pond MA51157 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	17	17
Agriculture	5	1
Open Land	2	0
Residential (Low den.)	2	0
Residential (High den.)	76	15
Comm. Indust.	2	0
Septic System	4	1
Other	0	0
Total Inputs	108	35

Table 4o. Stoneville Pond MA51160 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation		
Forest	371	371
Agriculture	85	76
Open Land	64	57
Residential (Low den.)	63	57
Residential (High den.)	283	254
Septic System	2	1
Other	0	0
Waste Load Allocation		
Comm. Indust.	102	92
Total Inputs	970	908

Table 4p. Shirley Street Pond MA51196 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Forest	140	140
Agriculture	23	13
Open Land	91	53
Residential (Low den.)	49	28
Residential (High den.)	272	157
Comm. Indust.	80	46
Septic System	15	9
Other	0	0
Total Inputs	670	446

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

For most lakes, it is appropriate and justifiable to express a nutrient TMDL in terms of allowable annual loadings. The annual load should inherently account for seasonal variations by being protective of the most sensitive time of year. The most sensitive time of year in most lakes occurs during summer, when the frequency and occurrence of nuisance algal blooms and macrophyte growth are usually greatest. Therefore, because these phosphorus TMDLs were established to be protective of the most environmentally sensitive period (i.e., the summer season), it will also be protective of water quality during all other seasons. Additionally, the targeted reduction in annual phosphorus load to the ponds will result in the application of phosphorus controls that also address seasonal variation. For example, certain control practices such as stabilizing eroding drainage ways or maintaining septic systems will be in place throughout the year while others will be in effect during the times the sources are active (e.g., application of lawn fertilizer).

Implementation

Considering the lack of information on discrete sources of phosphorus to the lake the implementation plan will of necessity include an organizational phase, an information gathering phase, and the actual remedial action phase. Phosphorus sources 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 “A Citizen’s Guide to Lake Watershed Surveys. How to Conduct a Nonpoint Source Phosphorus Survey” by Williams, (1997). 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 2000 as part of a rotating 5-year cycle, but would continue in the “off years” as well. The major components for each lake will focus on the major sources of nutrients as summarized in Table 7. This will usually include urban BMPs in urban areas and septic system inspections and other rural BMPs in rural areas. Additional nutrient and erosion control will focus on enforcement of the wetlands protection act by the local Conservation Commission and various Best Management practices supported by the National Resource Conservation Service (NRCS formerly SCS). Best Management Practices (BMPs) for logging are presented in Kittredge and Parker (1995) and BMPs for general nonpoint source pollution control are described in a manual by Boutiette and Duerring (1994), BMPs for erosion and sediment control are presented in DEP (1997). The Commonwealth has provided a strong framework to encourage watershed management through the recent modifications to on-site septic system regulations under Title 5 and by legislation requiring low phosphorus detergents. All of these actions will be emphasized during the outreach efforts of the Watershed Team.

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

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

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

Table 5. Proposed Tasks and Responsibilities

Tasks	Responsible Group
TMDL development	DEP
Public comments on TMDL, Public meeting	DEP and Watershed Team
Response to public comments	DEP
Organization, contacts with Volunteer Groups	Watershed Team
Develop guidance for NPS watershed field survey.	DEP
Organize and implement NPS watershed field survey	Watershed Team and Local Watershed Association
Compile and prioritize results of NPS watershed surveys	Watershed Team and Local Watershed Association
Organize implementation; work with stakeholders and local officials to identify remedial measures and potential funding sources.	Watershed Team and Local Watershed Association
Write grant and loan funding proposals	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
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.

Table 7. Suggested Implementation by Lake

Lake Name -> Implementation Suggested	Auburn Pond	Brierly Pond	N. Curtis Pond	S. Curtis Pond	Dorothy Pond	Eddy Pond	Green Hill Pond	Howe Reservoir	Jordan Pond	Mill Pond	Newton Pond	Pondville Pond	Smiths Pond	Southwick Pond	Stoneville Pond	Shirley Street
Public Education	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NPS Survey	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lake Management Plan	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Forest BMPs																
Agriculture BMPs																
Residential BMPs	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Septic System Maintenance																
Urban BMPs	X		X	X	X	X		X	X	X	X	X	X		X	X
Highway BMPs	X		X	X	X	X						X	X	X	X	
In-Lake Management	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Other (Gravel pits, golf courses, see text)							X	X			X					X

Reasonable Assurances

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

Water Quality Standards Attainment Statement

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

Monitoring

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

Public Participation

Notices of the public meeting were sent to several offices (Selectmen or Mayors office, Conservation Commission, Board of Health and Public Works Department) in each city or town having a portion of the shoreline within its corporate boundaries. Announcements of the meeting were published in the Environmental Monitor, on the Internet at Townboard.org as well as on DEP's web site. The Worcester Telegram and Gazette newspaper was requested to publish the meeting notice in their community bulletin board. After the meeting, we found out that this did not happen because the Telegram and Gazette felt this should have been published as a legal notice.

The meeting was held on May 22, 2001, at the Millbury Senior Center and was scheduled from 6:30 to 9:00 p.m. The meeting actually began about 7:00 p.m. to allow for any latecomers given that only a few people attended (list attached as Appendix I). The meeting adjourned at 9:00 p.m. with a request for written comments by June 22, 2001. No formal written comments were received within the 30-day comment period. The following is a summary of the comment and reply discussion held during the public meeting.

Russell Isaac and Mark Mattson made the presentation providing a brief general overview of the TMDL process and then a more detailed discussion of the draft TMDL. The entire presentation took approximately 40 minutes after which questions and discussions took place. Because several of the public were from the Dorothy Pond Association, much of the discussion focused on their pond, but many of the issues apply to most lake and ponds. Dorothy Pond does have a large population of aquatic vegetation and a variety of in-lake control measures have been tried with some but limited success. Efforts have included herbicide, draw-down and harvesting. Based on the information presented by the Association, it seems as though a more refined approach to harvesting could improve the results. Specifically, deeper harvesting in selected areas (such as boat access channels to open water) could provide more long-lasting results compared to shallow harvesting of the whole pond. The Association is investigating dredging, but this is an expensive and challenging option. Several suggestions for funding options (DEM Harbors, Rivers and Inland Waterways grant program and the U.S. Army Corps of Engineers) and a stepwise approach to the problem (starting with initial sediment chemistry sampling, followed by limited dredging of northern basin near the highway) were also suggested.

Dorothy Pond people also believe that drainage from the Massachusetts Turnpike contributes to the problem especially since no catch basins or other controls are provided to remove solids such as sand from the drainage. Dave Webster of the United States Environmental Protection Agency Region 1 indicated that towns subject to Phase II Storm water regulations are obligated to address highways in their towns (and the Massachusetts Turnpike Authority is also subject to the Phase II Storm water regulations). Lynne Welsh of EOEA asked if the obligation to address highway runoff also applied under Phase I storm water regulations. We checked into this and found that both Phase I and Phase II storm water regulations make regulated entities, such as state highway departments operating in urban areas, responsible for their discharge, even if it discharges to the city or town's storm water system. Regulated towns and cities are responsible for any discharge from their system. Phase I regulates large and medium cities (e.g., Worcester and Boston), industrial facilities and large construction sites. Phase II will regulate small municipalities and storm water systems operated by other public bodies (Massachusetts Highway Department and Massachusetts Turnpike Authority) within the U.S. Census Bureau urbanized areas, as well as small construction sites.

Another comment from the public noted the difficulty in obtaining state and federal grant funds if the application is directed toward education and outreach for the individual public as opposed to organizations and schools. It was suggested that the person contact Brian Duval (the DEP Regional Nonpoint Source Coordinator) who could help with fashioning a proposal that would have a better chance of being funded.

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Appendix I. Public Meeting Attendees.

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: Northern Blackstone Lakes TMDL Public Meeting
Date: 5/22/01 **Place:** Millbury MA
MARK MATTSON Russ Isaac Leading

	Name	Affiliation	phone	email
1	Beverly Nafold			
2	Kenneth Acholae	Dorothy Pond	508 757 2575	
3	Gary Pothier	"	508-865-5248	
4	Michelle Decoteau	MWC & Millbury Open Space Committee	(508) 865-6150	michele@
5	Lynne Welsh	EDEA - MWI	508 792 7423 x 503	commonwaters.org
6	Michael Toomey	SCA Suite 101 382 W. MAIN ST NORTHBOROUGH MA 01532		
7	Philip Nyberg	Ramshorn Pond Assoc. PO Box 13 W. Millbury, MA 01586		
8	Lisa Bennes	Dorothy Pond	791-1614	
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