Total Maximum Daily Loads of Phosphorus for Lake Quinsigamond and Flint Pond

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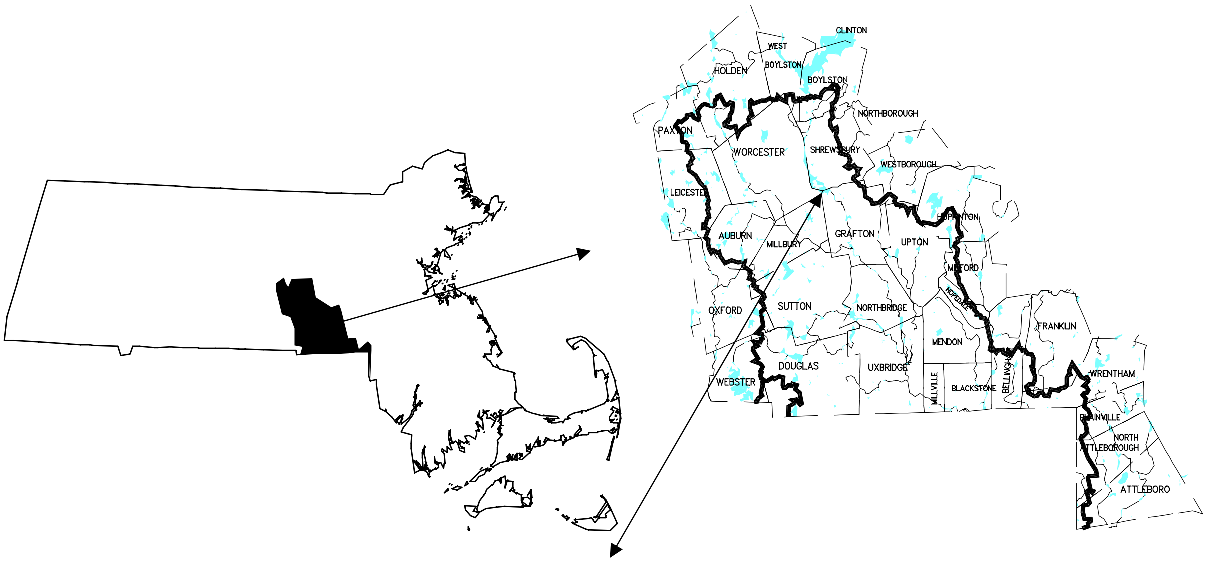
Front Cover

Photograph of Lake Quinsigamond from I-290.

Total Maximum Daily Load of Phosphorus for Lake Quinsigamond & Flint Pond, Grafton, MA.

DEP, DWM TMDL Report MA51050-2002-006 CN 115 May 14, 2002



Location of Blackstone Basin, and Flint Pond in Massachusetts.

Key Feature:	Available Phosphorus TMDLs for two urban lakes in the Blackstone Watershed.
Locations:	Flint Pond, Grafton/Worcester/Shrewsbury (MA51050) and Lake Quinsigamond, Worcester/Shrewsbury (MA51125).
Scope/ Size:	Flint Pond Watershed - 64.2 km^2, Surface area 102.6 Ha (253 ac). Lake Quinsigamond Watershed - 53.95 km^2, Surface area 192 Ha (475 ac).
303d Listing:	Turbidity (Flint Pond) & Noxious Aquatic Plants (Lake Quinsigamond).
Data Sources:	EDP, 1981; McGinn, 1982; Walker, 1981.
Data Mechanisms:	Mass balance of available P, Modeling hypolimnetic oxygen
Monitoring Plan:	Massachusetts Watershed Initiative Five year cycle.
Control Measures:	Stormwater Management, sewer extension and upgrades, macrophyte management, MassHighways BMPs.

Executive Summary

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

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

This report represents a TMDL for Flint Pond and Lake Quinsigamond in the Blackstone River Watershed. Flint Pond is listed on the Massachusetts 303d list for Turbidity due to high phosphorus loadings. Lake Quinsigamond is listed on the Massachusetts 303d list for Nuisance Aquatic Plants, Organic enrichment and low dissolved oxygen due to high phosphorus loadings. The proposed Total Maximum Daily Load (TMDL) is based on the water quality data analysis and modeling reported in Walker (1981) and on the related watershed management plan for Lake Quinsigamond and Flint Pond (McGinn, 1982). Parts of the reports are reproduced in Appendices I and II. The phosphorus model and loading was developed to protect the immediately upstream Lake Quinsigamond and the loading rates are used for Flint Pond as well. The major focus of the report is on the control of algae by reductions in available phosphorus, resulting in additional oxygen in the hypolimnion. Recommendations for control of macrophytes are also discussed. Much of the Flint Pond and some of the coves of Lake Quinsigamond have very dense growths of aquatic macrophytes and this is the cause of the partial support rating for primary contact recreation for both lakes.

The TMDL focuses on a combination of reducing the phosphorus loading to the lake by a combination of improved watershed management techniques aimed at highway runoff and urban stormwater runoff. Sediment control is also required in order for the pond to achieve surface water quality standards. Significant improvements in highway maintenance practices and Best Management Practices (BMPs); paving dirt roads; implementing erosion control measures; and educating the public are required to control sediment and nutrient loading to the lakes. The management plan recommends stormwater controls to control both particulate and dissolved phosphorus. The proposed control effort is predicted to reduce available phosphorus concentrations from 0.016 mg/l to 0.012 mg/l, assuming ten percent of particulate phosphorus is available. Additional aquatic plant management, such as harvesting within boating channels is recommended for Flint Pond.

Because of the limited data available on discrete sources of nutrients within the watershed, a locally organized watershed survey is recommended to target reductions in nonpoint source nutrients and sediments. 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. Funding support to aid in implementation of this TMDL is available under various state programs including section 319 and the State Revolving Fund Program (SRF) and the Department of Environmental Management's Lakes and Pond Grant 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 pollutant 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. In some cases, TMDLs will be used by DEP to set appropriate limits in permits for wastewater and other discharges. In addition to the City of Worcester Phase I stormwater permit, there are two point source stormwater discharges permitted under the National Pollutant Discharge Elimination System (NPDES) in the Flint Pond Watershed. All wastewater discharges in the watershed go to rivers outside of the watershed. There are numerous other Multi-sector NPDES permits for stormwater runoff from various industries, but these are included in overall stormwater waste load allocations.

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 Load (TMDL) for Lake Quinsigamond and Flint Pond is based on studies conducted by Walker (1981) and McGinn (1982). (Parts of the studies are reproduced in Appendices I and II). Lake Quinsigamond is listed on the Massachusetts 303d list for Nuisance Aquatic Plants, organic enrichment and low dissolved oxygen that the studies relate to the high phosphorus loadings. Flint Pond is listed on the Massachusetts 303d list for turbidity although excessive growth of aquatic macrophytes is also a problem in shallow areas. Both of these impacts are probably related to the high phosphorus loadings. The proposed control effort is predicted to reduce available phosphorus concentrations from 0.016 mg/l to 0.012 mg/l for both lakes. Currently the City of Worcester is implementing several programs to reduce the amounts of phosphorus inputs to the lakes. These include a street sweeping program, a catch basin program, a program to find and remove illicit connections to storm sewers and a sewage/stormdrain dual manhole modification program to reduce cross flow between stormwater and sewage transport systems. 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 and the State Revolving Fund Program (SRF) and the Department of Environmental Management's Lakes and Pond Grant Program.

General Background and Rationale

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

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

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

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

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

Target Load: Once the current nutrient loading rate is established, a new, lower rate of nutrient loading must be established which will restore water quality. This target load or TMDL, can be set in a variety of ways. Usually a target concentration in the lake is established and the new load must be reduced to achieve the lower concentration. This target nutrient concentration may be established by a water quality model that relates phosphorus concentrations to water quality required to maintain designated uses or specific water quality standards, such as the four-foot transparency criterion at Massachusetts swimming beaches. Alternatively, the target concentration may be set based on concentrations observed in background reference lakes for similar lake types or from concentration ranges found in lakes within the same ecological region (ecoregions). Various models (equations) have been used for predicting productivity or lake total phosphorus concentrations in lakes from analysis of phosphorus loads. These models typically take into consideration the waterbody’s hydraulic loading rate and some factor to account for settling and storage of phosphorus in the lake sediments. Among the more well known metrics are those of Vollenweider (1975), Dillon-Rigler (1974) and Reckhow (1979). The TMDL must account for the uncertainty in the estimates of the phosphorus loads from the sources identified above by including a margin of safety. This margin of safety can be specifically included, and/or included in the selection of a conservative target, and/or included as part of conservative assumptions used to develop the TMDL.

After the target TMDL has been established, the allowed loading of nutrients is apportioned to various sources which may include point sources as well as private septic systems and various land uses within the watershed. In Massachusetts, few, if any, lakes receive direct point source discharges of nutrients. River impoundments often have upstream point sources, but these will be addressed as part of the appropriate river system. The nutrient source analysis generally will be related to landuse that reflects the extent of development in the watershed. This effort can be facilitated by the use of geographic information systems (GIS) digital maps of the area that can summarize landuse categories within the watershed. The targeted reductions must be reasonable given the reductions possible with the best available technology and Best Management Practices. The first scenario for allocating loads will be based on what is practicable and feasible for each activity and/or landuse to make the effort as equitable as possible.

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

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

Other sources of phosphorus include phosphorus based lawn fertilizers used in residential areas, parks, cemeteries and golf courses and fertilizers used by agriculture. Manure from animals, especially dairies and other confined animal feeding areas is high in phosphorus. In some cases the manure is inappropriately spread or piled on frozen ground during winter months and the phosphorus can leach into nearby surface waters. Over a period of repeated applications of manure to local agricultural fields, the phosphorus in the manure can saturate the ability of the soil to bind phosphorus, resulting in phosphorus export to surface waters. In some cases, cows and other animals including wildlife such as flocks of ducks and geese may have access to surface waters and cause both erosion and direct deposition of feces to streams and lakes. Perhaps the most difficult source of phosphorus to account for is the phosphorus recycled within the lake from the lake sediments. Phosphorus release from shallow lake sediments may be a significant input for several reasons. These reasons include higher microbial activity in shallow warmer waters that can lead to sediment anoxia and the resultant release of iron and associated phosphorus. Phosphorus release may also occur during temporary mixing events such as wind or powerboat caused turbulence or bottom feeding fish, which can resuspend phosphorus rich sediments. Phosphorus can also be released from nutrient ‘pumping’ by rooted aquatic macrophytes as they extract phosphorus from the sediments and excrete phosphorus to the water during seasonal growth and senescence (Cooke et al., 1993; Horne and Goldman, 1994). Shallow lakes also have less water to dilute the phosphorus released from sediment sources and thus the impact on lake water concentrations is higher than in deeper lakes.

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

The most important factor controlling macrophyte growth appears to be light (Cooke et al., 1994). Due to the typically large mass of nutrients stored in lake sediments, reductions in nutrient loadings by themselves are not expected to reduce macrophyte growth in many macrophyte-dominated lakes, at least not in the short-term. In such cases additional in-lake control methods are generally recommended to directly reduce macrophyte biomass. Lake management techniques for both nutrient control and macrophyte control have been reviewed by a Draft Generic Environmental Impact Report (Mattson et al., 1998). The Massachusetts Department of Environmental Protection will endorse in-lake remediation efforts that meet all environmental concerns, however, instituting such measures will rest with communities and the Clean Lakes Program now administered by EPA and, in Massachusetts, the Department of Environmental Management.

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

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

Waterbody Description and Problem Assessment

Description: Lake Quinsigamond and Flint Ponds are adjacent to each other with Flint being immediately downstream of Lake Quinsigamond. Because of the close connections the two lakes are managed as one system. Lake Quinsigamond, (MA51125) is a 192 hectare (475 acre), lake located in an urban area on the border of the City of Worcester and the town of Shrewsbury, Massachusetts in the Blackstone Basin (see map in Appendix IV). The lake is long and narrow with a maximum depth of 85 feet (mean depth 33 feet) and residence time of about one-half year. The lake is very valuable in terms of recreation, being one of the most heavily used high quality cold water lakes in the state. The lake has intensive recreational uses including fishing, boating, water-skiing and swimming, but is starting to show signs of eutrophication. The lake receives stormwater runoff from both the City of Worcester and the Town of Shrewsbury with minor inputs from other towns. The lake also receives stormwater runoff from MassHighways including sections of I-290 which crosses Lake Quinsigamond. Some of the small coves, particularly in the northernmost parts of the lake have very dense growths of aquatic macrophytes. The more serious problem is the development of anoxic conditions in the hypolimnetic waters during the late summer months. High concentrations of available phosphorus allow higher biomass of algae in the lake which settles through the thermocline to the bottom of the lake. As the algae die and decay, the resulting bacteria respiration consumes oxygen in the hypolimnion. According to Walker (1982), the lake has a calculated hypolimnetic oxygen supply ranging from 72 to 140 days compared to the typical 200 days of stratification based on temperature profiles reported in Walker, (1981). The overall median total phosphorus concentration is 0.040 mg/l and the Secchi disk depth is 2.3m (7.5 feet). A synoptic survey by DEP staff on August 10, 1994 reported very dense growths of aquatic macrophytes in many coves with 20 acres of the 475 acre lake (less than 5% of the lake area) listed as non-support for primary and secondary contact recreation. Five non-native plants including *Myriophyllum spicatum, M. heterophyllum, Cabomba caroliniana, Potamogeton crispus, Lytrum salicaria* were noted as threatening to cause further use impairment. The pond was listed on the 1998 Massachusetts 303d list for Nuisance Aquatic Plants (DEP, 1998). The management goal is to achieve 200 days supply of oxygen in the hypolimnion during summer stratification. The overall goal is to restore the uses of the pond for primary and secondary contact recreation by reducing the nuisance aquatic plant growth. This will be accomplished by a combination of reducing the phosphorus loading to the lake and by direct control of macrophytes. The overall goal is consistent with the DEM (1995) report on Lake Quinsigamond which recommended further study of high total phosphorus measurements taken at Billings Brook and at the North Inlet, and high conductivity reported at Coal Mine Brook and O'Hara's Brook.

Flint Pond, (MA51050) is a 107.5 Ha (266 acre) lake located in an urban area on the borders of the City of Worcester and the towns of Shrewsbury and Grafton Massachusetts in the Blackstone Basin. Note that the McGinn (1982) study reports the lake area as 297 acres. The lake is a multi-basin lake with a mean depth of 2.7 meters (9 feet) and a maximum depth of 4.5 meters (15 feet). The north basin (Flint Pond North, 37.4 ha) is separated from Lake Quinsigamond by a stringer dam to the north and is separated from the south basin by Route 20. The south basin (Flint Pond South, 70.1 ha) is itself composed of two distinct basins: the southwestern, or middle, basin has an area of about 38 ha and the southeast basin has an area of about 32 ha. A small flap dam regulates water flow from the southeast basin. Overall, Flint Pond has a water residence time of about 0.07 years. Stormwater runoff to Flint Pond is similar to that described for Lake Quinsigamond, above, with the addition of runoff from MassHighways Route 20 which crosses the pond. The lake has recreational uses including fishing, boating, water-skiing and swimming, but these uses are impaired by the shallow waters and the growth of macrophytes throughout much of the pond (see Figure V-6 in the Appendix). A DEP synoptic survey on July 19, 1994 noted transparency below safety criteria (4 ft. Secchi disk depth) and very dense macrophyte growths throughout the pond. The non-native plants *Cabomba caroliniana* and *Myriophyllum spicatum* were the predominant species of submergents. The lake was reassessed in a shoreline synoptic survey by DEP staff on September 10, 1998. The north basin had dense macrophyte growths over approximately half of the lake area, particularly along the shores (see Figure in Appendix III). The middle basin is mostly open water with dense macrophyte growth along the shore and in coves and the southeast basin in nearly completely covered with dense macrophyte growths. Thus, the macrophyte distribution has apparently changed little in the 16 years between the surveys. Transparency in 1998 was estimated visually to be greater than the 1.2m (4 foot) visibility limit for swimming, thus the greater impairment appears to be the excessive macrophyte growth. Most of the impairment appears to be caused by emergent and floating species including *Pontedaria*, *Decadon and Nympea*, although many other species including the submergents *Ceratophyllum demersum and P. amphifolius* were noted. The non-natives *Lythrum salicaria* and *Cabomba caroliniana* were also noted. The McGinn (1982) report also noted the presence of the non-native *Cabomba caroliniana.*

Based on the 1994 synoptic survey, Flint Pond was listed on the 1998 Massachusetts 303d list for turbidity (DEP, 1998). The overall goal is to restore the uses of the pond for primary and secondary contact recreation by reducing algae and the nuisance aquatic plant growth. This will be accomplished by a combination of reducing the phosphorus loading to the lake and by direct control of macrophytes. GZA GeoEnvironmental of Newton, MA is preparing a report on the feasibility of drawdown as a plant management technique (P. Baril, pers. comm. 1999). Preliminary studies indicate a drawdown of 2.8 feet is possible for Flint Pond, but temporary controls could be placed to maintain water levels in Lake Quinsigamond.

Data Assessment: Lake Quinsigamond and Flint Pond watershed was chosen as a case study for the Nation Urban Runoff Program (NURP), the results of which are presented in EDP, (1981 and related appendices). The runoff data from the NURP study were used to model the effects of phosphorus loading on hypolimnetic oxygen supply in Lake Quinsigamond and Flint Pond. Although the reports cited above and the discussion below are directed mainly at modeling the deeper basins of Lake Quinsigamond rather than the shallow areas found in Flint Pond, the results are assumed to be protective of Flint Pond water quality as well as Lake Quinsigamond. With the shallower depths, Flint Pond has a much faster flushing rate and is thus able to tolerate a higher concentration of nutrients.

The modeling establishing the target nutrient load is described in Walker (1981) and McGinn (1982) and is summarized in the TMDL report for Lake Quinsigamond (DWM, 1999). Modeling is summarized below. First the annual water loading rates are estimated based on the USGS gaging station below Flint pond and on inflows estimated from an earlier EDP modeling study (presumably Meta Systems, 1980). Annual phosphorus loads are estimated as the sum of atmospheric loading, surface water runoff and base flow loadings. The critical model input is available phosphorus loading, which is defined as phosphorus available to algae. The available phosphorus includes dissolved phosphorus and a fraction of particulate phosphorus. The fraction is assumed to be 0.1, but fractions of 0.0 (none of the particulate P is available) to 0.2 (20 percent available) were also modeled.

Next, in-lake phosphorus concentrations were modeled following the typical assumptions used in Vollenweider (1975), Dillon (1975) and others as:

$$P\ \mathrm{mg/m^3} = L/(Q_s+U)$$

Where P = average in lake phosphorus concentration
L = average loading of available phosphorus per unit area lake ($\mathrm{kg/km^2}$-yr)
Q_s= surface water overflow rate (m/yr)
U = effective settling velocity (m/yr) (empirically determined).

The in-lake phosphorus concentration (P) is then used to estimate the Walker (1979) trophic state index (I) as:

$$I = -15.6 + 46.1 \log(P)$$

And then the areal and volumetric hypolimnetic oxygen depletion rate (HODa and HODv, $\mathrm{g/m^2}$-day and $\mathrm{g/m^3}$-day respectively) are estimated as:

$$\mathrm{Log(HODa)} = -3.58 + 0.0204\ I + 2.55 \log(z) - 2.04\ (\log(z))^2$$

And

$HOD_v = HOD_a/z_h$

Where z_h = mean hypolimnetic thickness (m).

Finally, the total days of dissolved oxygen supply in the hypolimnion (TDO) is estimated from:

$TDO = 12/HOD_v$

Where 12 is the assumed average initial oxygen concentration (12 mg/l) in the hypolimnion at the start of spring stratification.

According to Walker (1982), Lake Quinsigamond has a calculated hypolimnetic oxygen supply ranging from 72 to 140 days compared to the typical 200 days of stratification. The goal of modeling is to determine what level of annual phosphorus loading reductions are required in order to extend the oxygen supply in the hypolimnion of Lake Quinsigamond from the current 140 days to 200 days. The overall goal is to restore the uses of the pond for primary and secondary contact recreation by reducing the nuisance aquatic plant growth. This will be accomplished by a combination of reducing the phosphorus loading to the lake and by direct control of macrophytes. The overall goal is consistent with the DEM (1995) report on Lake Quinsigamond which recommended further study of high total phosphorus measurements taken at Billings Brook and at the North Inlet, and high conductivity reported at Coal Mine Brook and O'Hara's Brook.

Pollutant Sources and Natural Background

The McGinn (1982) report concluded that phosphorus is most likely the limiting nutrient. Dissolved phosphorus was determined to be the key to the rate of eutrophication and the hypolimnetic dissolved oxygen depletion rate. Inputs were distributed across several streams and drains (see Table III-21 in the Appendix). Although stormwater was the major source of both dissolved and total phosphorus, base flow inputs were also significant, while the atmosphere inputs were relatively small.

Current stormwater loads by subwatershed are shown in Table III-21 in the Appendix. The distributions of inputs by subwatersheds are similar for the dissolved and total phosphorus fractions. More than half of the inputs of both dissolved and total phosphorus are attributed to three of the subwatersheds: South Meadow Brook (including O’Hara and Bridal Path Drain), Coal Mine and Billings Brook, and Poor Farm Brook (see Figure I-1 in the Appendix).

Because the direct measurement of loading from runoff includes natural background it is difficult to separate this source from anthropogenic sources. Natural background of phosphorus 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.

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. The nearby Town of Grafton had an estimated 20 year growth rate of about 24 percent. Thus, some increase in loadings is likely since the data were collected and the current loadings may be somewhat higher, but this would not change the target concentration or the final TMDL.

A large amount of sand and sediments may be deposited in the lakes from Interstate I-290, however further investigation of MassHighways contributions to sediment loads to the lake are needed.

Water Quality Standards Violations

For Lake Quinsigamond there is a violation of water quality standards for Noxious Aquatic Plants. For Flint Pond there is a violation of water quality standards for turbidity. Considering that the waters listed are a designated Class B water under the Massachusetts Surface Water Quality Standards, the data listed above were judged sufficiently well documented to place the lakes on the Massachusetts 303d list for 1998 (DEP, 1998) with Noxious Aquatic

Plants and Turbidity listed as the respective causes for violation of the Water Quality Standards related to impairment of primary and secondary contact recreation and aesthetics. These Water Quality Standards are described in the Code of Massachusetts Regulations under sections:

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

and

> 314CMR 4.05 (3) b: “These waters are designated as a habitat for aquatic life, and wildlife, and for primary and secondary contact recreation...These waters shall have consistently good aesthetic value.
>
> 1. Dissolved Oxygen:
>
> a. Shall not be less than 6.0 mg/l in cold water fisheries nor less than 5.0 mg/l in warm water fisheries unless background conditions are lower;
>
> b. natural seasonal and daily variations above this level shall be maintained…

and

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

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

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

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

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

TMDL Analysis

Identification of Target: There is no loading capacity *per se* for nuisance aquatic plants. As the term implies, TMDLs are often expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs may be expressed in other terms when appropriate. Considering the retention time for Lake Quinsigamond is about one half year (and probably longer during drier summer months), the TMDL is expressed in terms of allowable annual loadings of phosphorus. Annual loads are appropriate because the growth of phytoplankton in Lake Quinsigamond and macrophytes (mainly in Flint Pond) 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) indicates the lake is in an ecoregion with concentrations of 15-19 ppb, based on spring/fall concentrations, while the phosphorus ecoregion map of Rohm et al., (1995) suggests that typical lakes in this ecoregion would have concentrations between 30 and 50 ppb, based on summer concentrations. Considering the above suggested ranges DEP has set the target "available" TP concentration at 12 ppb, which is roughly comparable to the ranges suggested by the ecoregion ranges above if the fraction of particulate P that is available is assumed to be 0.10, and this target is also in agreement with the analyses of Walker (1981) and McGinn (1982).

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.

Loading Capacity

Unlike Lake Quinsigamond, which already meets the 4-foot transparency requirement for swimming beaches, Flint Pond occasionally does not meet the visibility standard due to algal turbidity. The proposed reduction in phosphorus loading is expected to meet the visibility standard.

The Walker (1981) model estimates that a Total Maximum Daily Load of 1195 kg/yr would meet the target of 12 ppb (0.012 mg/l) of available phosphorus. The lower phosphorus concentrations will lessen the chance of nuisance algal blooms, which may occur as development continues within the watershed.

Wasteload Allocations, Load Allocations and Margin of Safety:

In this case the two lakes are treated as a single system and a single TMDL will be developed for both lakes. DEP chose an additional margin of safety of 5 percent of the total TMDL. In this case, the margin of safety is 1195 kg/yr*.05 or 60 kg/yr. To further account for the uncertainty in the methods and data, an additional margin of safety was built in to the analysis as part of the conservative assumptions used. First, it is assumed that the internal cycling will be reduced as external sources on watershed are reduced, albeit with an undefined lag time for the effect to occur. Second, the groundwater transport and base flow loading of phosphorus will be reduced in the areas of the watershed still served by septic systems as these are connected to the sewer system which is pumped out of the watershed. In addition, remaining septic systems are expected to reduce phosphorus loadings to groundwater and baseflow given the fact that concentrations in wastewater at wastewater treatment plants have been reduced from about 7 mg/L to about 3 mg/L during the past several years. This reduction is attributed to the limits placed on phosphorus content of cleaning agents and is expected to be reduced in the quality of septic tank effluents as it has been in sewered wastewaters and represents an additional margin of safety in this analysis. These two aspects essentially represent “pollution prevention” accomplishments.

Phosphorus loading allocations for atmospheric, base flow and storm flow sources are shown (rounded to the nearest kg/yr) in Table 1. No reduction in atmospheric loading is targeted, because this source is impossible to control on a local basis. Currently no reduction of phosphorus loading from baseflow is considered. The reductions in loading are targeted at 52 percent reductions in storm flow loading of available phosphorus.

The two permitted point source stormwater discharges are from two adjacent industrial facilities owned by the Wyman-Gordon Company. Permit numbers are MA0004341 and MA0001121 both issued for stormwater discharges to Bonnie Brook which is tributary to Flint Pond. These stormwater discharges drain parking areas, roof runoff and process areas. Permit MA0004341 drains approximately 30 acres (12 ha) and Permit MA0001121 drains approximately 20 acres (8 ha). The permits do not include limits for phosphorus, and no phosphorus data is available. Loadings of phosphorus from these sites was estimated based on a simple loading coefficient of 0.905 kg/ha/yr, based on the average of two coefficients for industrial sites summarized in Reckhow et al., (1980). The resulting estimates of 7 and 11 kg/yr for the two NPDES systems are subtracted from the overall stormwater load of phosphorus as shown in the left column of Table 1. Both of the permits and the stormwater (a portion of which are contributed by Worcester which has a Phase I permit) are listed under waste load allocation target of 556 kg/yr. This leaves 579 kg/yr for the load allocation to nonpoint sources as indicated in the right side of Table 1. No reductions are specifically targeted for the NPDES discharges, however, it is recommended that phosphorus be monitored at both sites so phosphorus loadings can be more accurately determined.

Table 1. TMDL PS and NPS Load Allocations.

Source	*Current Available P Loading (kg/yr)*	*Target Available P Load Allocation (kg/yr)*
Load Allocation:		
Atmosphere	88	88
Base Flow	491	491
Waste Load Allocation:		
Storm Flow	1123	538
NPDES MA0001121	7	7
NPDES MA0004341	11	11
Total Inputs	1720	1135

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). In this case the TMDL is:

TMDL = WLA + LA + MOS = 556 kg/yr + 579 kg/yr + 60 kg/yr = 1195 kg/yr.

Modeling Assumptions, Key Input, Calibration and Validation:

Because Flint pond was combined with Lake Quinsigamond in the McGinn (1982) study, there was no separate modeling effort for Flint Pond. The study inherently assumes that modeling and phosphorus controls which are applicable to Lake Quinsigamond, also apply to Flint Pond, immediately downstream. The modeled nutrient concentrations were used in turn to estimate the number of days of hypolimnetic oxygen supply during summer stratification. The nutrient budgets were based on mass balance approach and oxygen depletions were calculated separately for each of three subbasins in the lake and the results averaged based on their respective hypolimnetic volumes. This TMDL is based on the completely mixed model, which assumes homogeneous chemical conditions within the hypolimnion. The key input is the annual loading of available phosphorus which is assumed to be equal to dissolved phosphorus plus a fraction of particulate phosphorus (Fa). Fa is assumed to be equal to 10 percent based on literature estimates. The rate of oxygen depletion is based on the Walker model with available phosphorus as the key input. The model assumes the hypolimnion has a dissolved oxygen concentration of 12 mg/l at the beginning of stratification in the spring. The model calibration results (Table 3-4 in Walker, 1981) indicate the best agreement of predicted and observed conditions generally occurs with an Fa value of 0.10.

There is a wide degree of uncertainty in the modeling estimates of acceptable loading of available phosphorus. Much of this is due to uncertainty in the hydrology. For example, in wet years, the Walker model (1981) estimates that due to increased loading of available phosphorus, a reduction of 78 percent (rather than only 52 percent for normal years) is required to achieve the target conditions. Similarly, a reduction of only 28 percent is required in dry years. The greatest uncertainty, at least in regard to implementation, is the assumptions of what fraction (Fa) of particulate phosphorus is available. This model generally assumed the best estimate of Fa was 0.1 (10 percent). Two alternate assumptions were modeled; Fa=0 and Fa=0.2. The stormwater runoff would have to be reduced by 50 percent in dissolved phosphorus to reach the target under Fa=0 (with no controls needed on particulate P). Alternately, the particulates in stormwater runoff would be targeted for a 49 percent reduction and dissolved phosphorus would have to reduced by only 2 percent under the assumption of Fa=0.2 (see Table III-28 in the Appendix). Thus, although the TMDL target does not change based on the Fa assumptions, the implementation plan probably would change (particulate control vs. dissolved phosphorus control).

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 stratification and decomposition result in hypolimnetic oxygen depletions, water quality in many lakes is generally not sensitive to daily or short term loading, but is more a function of loadings that occur over longer periods of time (e.g. annually). Therefore, seasonal variation is taken into account with the estimation of annual loads. In addition, evaluating the effectiveness of nonpoint source controls can be more easily accomplished on an annual basis rather than a daily basis.

For most lakes, it is appropriate and justifiable to express a nutrient TMDL in terms of allowable annual loadings. The annual load should inherently account for seasonal variations by being protective of the most sensitive time of year. The most sensitive time of year in most lakes occurs during summer, when the frequency and occurrence of nuisance algal blooms and macrophyte growth are usually greatest. Therefore, because the Lake Quinsigamond phosphorus TMDL was established to be protective of the most environmentally sensitive period (i.e., the summer season), it will also be protective of water quality during all other seasons. Additionally, the targeted reduction in annual phosphorus load to Lake Quinsigamond 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

The City of Worcester has done a considerable amount of work to reduce pollution loadings to Lake Quinsigamond in the16 years since the original McGinn (1982) report was published. This year (1998) the City was awarded a NPDES permit MAS010002 for stormwater discharges. Details of the stormwater controls can be found in the permit applications (DPW, 1992 and DPW, 1993). This permit requires the following:

> Street Sweeping Program- Residential streets twice a year; downtown streets weekly or more often.
>
> Catch Basins Cleaning—about 7,000 basins (more than 50 percent of total) will be cleaned and inspected annually. On average, each basin will be cleaned every other year.
>
> Illicit connections—A program to detect and remove illicit connections to the sewer will be carried out.
>
> Dual manhole modification program—Nearly 30 percent of manholes within Worcester are dual manholes; a common structure that provides access to separate sanitary and storm sewer lines. To alleviate cross contamination during high stormwater flows aluminum plates were bolted over the sanitary invert. The sewer system discharges are treated and discharged to the Blackstone River and does not impact Lake Quinsigamond or Flint Pond.

As part of the NPDES stormwater permit the City of Worcester is required to implement both wet and dry weather monitoring to estimate annual, mean and seasonal discharge loadings from all major outfalls and to identify illicit connections and improper discharges. An annual report summarizing the stormwater discharge program must be submitted to both DEP and EPA beginning April 1, 2000. According to a letter (Feb. 1999) provided by J. Buckley of the City of Worcester Department of Public Works, the City has been implementing BMPs since 1994. These include an education program that consists of signage of City waterways, catch basin stenciling, pamphlets, water and sewer bill newsletters, and educational talks with school-age children. Catch basins are now 82% mapped by GIS, there is an extensive street-sweeping program, including a fall leaf sweeping program which collects 60,000 cubic yards. Each catch basin is cleaned on average every two years. Programs specific to Lake Quinsigamond include many updates to the sanitary sewer system and investigations to locate sources of wastewater contamination. There has also been construction of a large Vortechs Separator for the Belmont Street Drain (a 42" outfall which enters Lake Quinsigamond. Additional programs include the Worcester Wetlands Protection Ordinance and the Zone I and Zone II well head protection laws that overlap to protect Lake Quinsigamond. An update of progress on the BMPs related to the NPDES stormwater permit can be found in the Labovites (1998) report to the EPA.

The Lake Quinsigamond Watershed is also included in the DEP DWM and USEPA (1997) TMDL interim report on the Blackstone watershed.

The Town of Shrewsbury, which forms much of the eastern shore of Lake Quinsigamond, has also been active in reducing pollution loadings to Lake Quinsigamond and Flint Pond. Bacterial and sewage contamination were identified in the Tilly Brook culvert and further testing by CDM (1988) found a sewer clogged with grease (which was fixed) but concluded that bacterial contamination was due to overland runoff, probably from animals and natural soil bacteria. The Town of Shrewsbury also takes charge of stormwater detention basins associated with new developments, however, the Town does not presently have a plan to maintain and clean the detention basins.

First and foremost the towns subject to Phase II stormwater regulations (Shrewsbury and part of Grafton) as well as MassHighways should begin the stormwater management plans required under Phase II to reduce discharge of pollutants to the "maximum extent practicable".

MassHighway which maintains the Interstate Highways including I-290, Route 20 and other state roads will also be required to apply for the EPA Phase II General Stormwater NPDES Permit by March 10 of 2003. MassHighways does have a draft Stormwater Handbook (MassHighways 2000) which details BMP installation and maintenance on new construction. It is DEP's understanding that these BMPs have not been fully implemented yet in this and other regions. The regional office of MassHighways has offered to target high priority watersheds in the region for higher frequency of BMPs and maintenance.

To reduce loadings of sediments and associated nutrients to the target level this TMDL will require the following additional minimal, performance standards for roadways within the watershed area of the TMDL (see map in Appendix I). :

1)Visually inspect the roads monthly and sweep as needed. Any solids or "visible roadway accumulation" (debris, sand, dust, etc.) on paved roads must be removed. At a minimum, roads must be swept a least twice a year as soon after snowmelt as possible or by April 1st of each year and again in the fall. It is recommended that future purchases of sweepers should be of the high efficiency design.
2)Inspect catch basins at least twice a year and any other settling or detention basins once a year to measure depth of solids. If solids are one half or more of design volume for solids, then completely remove all solids.
3)Inspect and maintain all structural components of stormwater system on a yearly basis.

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 2. The local citizens within the watershed are 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 watershed field survey to locate and describe sources of erosion and phosphorus within the watershed following methods described in the DEP guidebook "Surveying a Lake Watershed and Preparing and Action Plan" (DEP, 2001). For this survey, volunteers are organized and assigned to subwatersheds to specifically identify, describe and locate potential sources of erosion and other phosphorus sources by driving the roads and walking the streams. Once the survey is completed, the Basin Team will be asked to review and compile the data and make recommendations for implementation. Responsibility for remediation of each identified source will vary depending on land ownership, local jurisdiction and expertise as indicated in Table 3. Town public works departments will generally be responsible for reduction of erosion from town roadways and urban runoff. The Conservation Commission will generally be responsible for ensuring the BMPs are being followed to minimize erosion from construction within the town. A description of funding sources for these efforts is provided in the Program Background section, above.

The major implementation effort would take place during the year 2005 as part of a rotating 5-year cycle, but would continue in the "off years" as well. The major components will focus on stormwater controls within the City of Worcester and the Town of Shrewsbury which control runoff from the western and eastern shores of Lake Quinsigamond, respectively. 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.

The current TMDL proposes a 51 percent reduction in available phosphorus loading from stormwater that may be difficult to achieve. As new housing development expands within the watershed, additional measures are needed to control the associated additional inputs of phosphorus. A proactive approach to protecting the lake may include limiting the types of construction activities allowed, particularly on steep slopes near the lake and tributary streams, changes in zoning laws and lot sizes, requirements that new developments and new roadways include BMPs for runoff control and continuing expansion of the sewer system to eliminate septic systems near the lake. 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.

In addition to the phosphorus controls discussed above, an aquatic plant management program is recommended for Flint Pond. A low-cost option for increasing swimming and boating recreation on this pond is to use targeted harvesting. Mechanical harvesters can be contracted to cut boating channels through some of the dense macrophyte beds in the southern basin. These channels should be connected to the open water areas of the north basin of Flint Pond and Lake Quinsigamond itself. Additional harvesting, possibly by hydroraking, could be used in areas to open up small swimming areas along some shorelines as desired.

Some of the above implementation will be accomplished via a Section 319 grant awarded to the Lake Quinsigamond Commission (LQC) via the Town of Shrewsbury. This grant will address stormdrain mapping, structural BMPs for stormwater entering Lake Quinsigamond, removal of sediment accumulating from Route 20 runoff near Half Moon Bay, operation and maintenance plans for the BMPs and public outreach and education. Also included in the grant are BMPs for another Lake, (Lake Ripple) which is not discussed here.

Table 2. 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 Lake Quinsigamond Watershed Association and Lake Quinsigamond Commission
Develop methodology to calculate loadings from highways	MassHighway
Conduct pilot project to assess loadings and test BMPs on highways	MassHighway
Initiate twice yearly sweeping and catch basin inspection and cleaning program along I-290 and other roadways (see text). Install additional BMPs as needed to address pollutant loadings identified above.	MassHighway, and towns of Shrewsbury and Grafton.
Prepare stormwater management plan for Phase II.	MassHighways, towns of Shrewsbury and Grafton.
Compile and prioritize results of NPS watershed surveys	Watershed Team and Lake Quinsigamond Watershed Association and Lake Quinsigamond Commission
Organize implementation; work with stakeholders and local officials to identify remedial measures and potential funding sources.	Watershed Team and Lake Quinsigamond Watershed Association, City of Worcester, Town of Shrewsbury and Lake Quinsigamond Commission
Write grant and loan funding proposals which include both nonpoint source pollution and aquatic plant management	Lake Quinsigamond Watershed Association, Blackstone Watershed Associations, Towns, Planning Agencies, NRCS and Lake Quinsigamond Commission
Organize and implement education, outreach programs	Lake Quinsigamond Watershed Association, Blackstone Watershed Associations, and Lake Quinsigamond Commission
Implement remedial measures for discrete NPS pollution	See Table 3 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	DEP (year 2 of cycle) and Lake Quinsigamond Watershed Association (annually)

Table 3. Guide to Urban Nonpoint Source Phosphorus and Erosion Controls

Type of NPS Pollution	Whom to Contact	Types of Remedial Actions
Industrial		
Phosphorus Cleaning Agents	Industry Manager	Reuse and reduce or eliminate phosphorus containing cleaning agents.
Floor drains connected to storm sewers	Industry Manager and Regional DEP	Redirect floor drains to sewer system.
Stormdrains	Industry Manager and Regional DEP	Label stormdrains and forbid dumping or washing of chemicals into stormdrains. Add detention/ filtration basins to all stormdrains.
Stormwater runoff	Industry Manager, EPA	Use nonstructural BMPs for reducing stormwater pollution including fertilizer use, street and parking lot sweeping and Pollution Prevention Plans, Multi-sector NPDES permits.
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.
Stormwater Runoff		
Turf Management	Golf Courses, Parks & Recreation Departments	Use non-phosphorus containing fertilizers. Apply fertilizers only after soil tests.
Urban Runoff from public roads	MassHighway, Town or city Dept. Public Works,	Reduce impervious surfaces, institute more frequent street sweeping and catch basin cleaning, install detention basins, dredge and maintain stormwater detention basins, etc.
Unpaved Road runoff	Town or city Dept. Public Works	Pave heavily used roads, divert runoff to vegetated areas, install riprap or vegetate eroded ditches.
Residential 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. Establish a regular septic system inspection program. 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
Other stream or lakeside erosion	Landowner, Conservation Commission	Determine cause of problem; install riprap, plant vegetation.

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

A synoptic survey of the lake from vantage points on the shoreline was conducted by DEP in August of 1994 and as noted that some coves had very dense aquatic vegetation including exotic species such as *Myriophyllum spicatum, M. heterophyllum, Cabomba caroliniana, Potamogeton crispus* and *Lytrium salicaria.* Monitoring by DEP staff will be continued on a regular basis according to the five-year watershed cycle as resources permit. 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 total and available phosphorus concentrations and increases in hypolimnetic oxygen supplies can be re-evaluated and the TMDL modified, if necessary. Additional monitoring by volunteer groups is encouraged.

Public Participation

A preliminary public meeting was held on Nov. 10, 1999 with state and local government representatives and local environmental groups including the Lake Quinsigamond Commission at the DEP office in Worcester to discuss an earlier draft of the TMDL(see Appendix VI). The draft TMDL was announced in the Environmental Monitor for public review and comment. Invitation letters to the final public were sent to town and city officials as well as other environmental groups. The final public meeting was held on October 16, 2001 at 6:30pm at the Donahue Rowing Center on the shore of the lake in Shrewsbury (see Appendix V).

Public Comment and Reply

Comment: Several large development/construction projects such as Shrewsbury High School, and Lincoln Plaza are impacting area waterbodies. Can DEP target these projects for oversight and enforcement?
Reply: DEP is actively monitoring these sites and taking enforcement action where needed. For example: The Town of Shrewsbury has been issue a Notice of Noncompliance (NON_) and one enforcement order for wetland violations. The latest compliance inspection at Shrewsbury High School revealed that the site is about 80% stabilized with permanent vegetation. The remaining areas that require permanent stabilization are the top of the rock face along the access road off Holden St. and some of the road shoulders on the same roadway. The site

contractor has done a better job over the past 3-6 months in controlling storm water runoff quality and quantity and has prevented any direct impacts to Lake Quinsigamond.

At Lincoln Plaza the Department and Worcester Lincoln LLC (property owner) have executed an Administrative Consent Order with Penalties (ACOP) with a $21,500 fine for violations of the Wetlands Protection Act. The fine was a result of repeated occurrences of the discharge of silt-laden runoff from the construction site. The owners have agreed to accelerate their efforts to stabilize all on-site soils and prevent further discharges of silt-laden runoff that impact Coal Mine Brook, one of its tributaries, and Lake Quinsigamond.

Comment: How will the pollution loads be allocated between the town of Shrewsbury and the City of Worcester?
Reply: The pollution loads could be allocated on a basis of watershed area within the municipalities but in this case allocations are made on the basis of landuse rather than corporate boundaries. Rather than focusing on the numeric load, the TMDL focuses implementation on the BMPs that are required to meet the goal of restoring the lake water quality and specifically meeting the target of 12 ppb available phosphorus and the 200 days of hypolimnetic oxygen.

Comment: There are quite a few used car lots along Route 20 in Shrewsbury and Grafton that are potentially contributing phosphorus from their outside car washing activities into Lake Quinsigamond and Flint Pond.
Reply: One suggestion offered at the public meeting would be to develop “phosphate-free” outreach brochures for these used car dealers. Perhaps a town ordinance could be developed which would prohibit phosphate-based soaps from being used. The Town could implement this outreach effort in coordination with the Shrewsbury Police Department’s auto inspection program of these facilities.

Comment: There are (2) NPDES permits for individual point source stormwater discharges from Wyman-Gordon Company. Does the University of Massachusetts Medical Center Campus in Worcester have a NPDES stormwater permit?
Reply: The University of Massachusetts Medical Center is not classified as an industry and is thus not required to have either an individual permit, nor a General Multi-sector stormwater permit.

Comment: What is the monitoring requirement and frequency for Wyman-Gordon Company’s NPDES stormwater permits?
Reply: Wyman-Gordon is required to estimate flow and monitor Total Suspended Solids, Oil and Grease, various metals and pH on a monthly basis. Some of the discharges also require monitoring of trichloroethylene and tetrachloroethylene monthly. Total phosphorus monitoring is not required on the current permit.

Comment: These reports set forth an assumption that highways are significant contributors of nutrients to receiving waters. To our knowledge, the majority of the contaminants contained in highway runoff (especially in particulate form) are associated with the sand used during winter maintenance operations, which is assumed to contain only minor amounts of nutrients. However, conditions may be different along Interstates 290 and 190. It is for these reasons that we need a valid method of calculating nutrient (and other contaminant) loadings from highways. As I have mentioned in the past, MassHighway is working toward developing a research study that would collect data and develop a contaminant loading model for highway runoff. Sometime in the next couple of weeks I would like to provide you with a general scope of work for this study -- for your review and comment.
Reply Response: While sand may be considered low in nutrients, high concentrations of nutrients are known to be associated with highway runoff in both dissolved form and associated with fine sediments that run off the roadway. A review of many highway runoff studies conducted by the Federal Highway Administration (FHWA) reported the Event Mean Concentration for suspended solids was 143 mg/l and that the EMC for PO_4-P was 0.435 mg/l (Driscoll et al., 1990). These levels that are not considered “minor amounts” as EPA generally recommends that phosphorus inputs to lakes be less than 0.050 mg/l. A USGS review of dozens of other reports also indicated substantial biological impacts from highway runoff (Buckler and Granato, 1999). Note that there are more than eight lane miles of Interstate 290 that drain to Lake Quinsigamond or tributaries to the lake and additional areas of Route 20 discharge into Flint Pond. In addition, nutrients are not the sole focus of pollutant runoff from MassHighways.

Highway sand and other solids discharged from roadways are a pollution source that also contributes to infilling of wetlands and lakes.

We are pleased that you have developed scope of work for further research on highway runoff. Unfortunately, the study as written does not currently address the parameters of concern associated with this and other TMDLs (total phosphorus, suspended solids, bedload sediments and bacteria). As previously discussed, DEP would be happy to work with you on a revised scope to address these issues from a statewide prospective. However, DEP cannot delay the development of the TMDLs any further. The Federal Clean Water Act, Federal regulations and EPA policy require us to complete the TMDLs based on best available evidence and that is basis for this TMDL. In order to implement the TMDL in the absence of loading information for specific highways and city streets, DEP has established a set of performance standards for maintenance of all roadways within the affected watershed. We have discussed specific recommendations with the MassHighways District office and have received assurance that efforts will be made to reduce non-point source pollutants from State controlled roadways within the sub-watershed.

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Appendix I Reprint of Walker (1981).

The following pages are selectively reproduced from Walker (1981).

Water Quality Data Analysis, Model Development, and Model Applications for Lake Quinsigamond

prepared for

Meta Systems, Inc.
Environmental Design and Planning, Inc.
Massachusetts Division of Water Pollution Control
U.S. Environmental Protection Agency

Lake Quinsigamond 314/NURP Project

by

William W. Walker, Jr., Ph.D.
Environmental Engineer
1127 Lowell Road
Concord, Massachusetts 01742

May 1981

Table 4-2
Simulation of Alternative Land Uses and Management Strategies
Assuming 10% Particulate Phosphorus Availablility

Land Use: Strategy:*		present A	future A	future B	future C	future D
Available P (mg/m3)	min **	11	11	10	9	9
	mean	16	18	16	13	12
	max	22	23	21	18	17
Trophic State Index	min	32	32	31	29	27
	mean	40	41	39	35	34
	max	46	48	45	42	41
Chlorophyll-a (mg/m3)	min	2.3	2.3	2.1	1.8	1.7
	mean	4.1	4.6	3.9	3.1	2.8
	max	6.1	6.8	5.8	4.7	4.2
Secchi Depth (m)	min	1.9	1.7	2.1	2.3	2.7
	mean	2.5	2.2	2.8	3.0	3.4
	max	3.6	3.4	3.8	4.0	4.3
Days of Oxygen Supply (days)	min	110	102	113	131	140
	mean	149	138	155	182	196
	max	215	209	226	247	263
Trout Space	min	.00	.00	.00	.00	.00
	mean	.05	.03	.06	.14	.20
	max	.30	.27	.34	.41	.46
N/P ratio	min	29	27	30	37	40
	mean	35	33	36	43	45
	max	46	45	48	53	55
Suspended Solids (mg/m3)	min	.7	.8	.5	.5	.3
	mean	1.6	2.0	1.0	1.1	.6
	max	2.4	2.9	1.5	1.6	.9

* Strategies:
A = current conditions
B = 50% reduction in particulates (runoff treatment)
C = 50% reduction in surface runoff volumes and loadings (through watershed management)
D = both B and C combined, i.e. 75% particulate control 50% dissolved loading and surface runoff control

** Statistics based upon 12 years of simulated loadings

Note: Trout Space units in terms of fraction of hypolimnion with oxygen concentration >5 mg/l on September 1.

Table 4-4
Available Phosphorus Loadings Consistent with 200 Days of Hypolimnetic Oxygen Supply

Component *	Hydrologic Year Dry (1965)	 Average mean	 Wet (1972)
Total Outflow	12.6	30.6	53.8
Surface Runoff	7.9	12.2	19.6
Excess Precip.	1.3	1.3	1.3
Base Flow	3.4	17.1	32.9
Fa=0.0			
Available P Load	727	987	1257
Atmospheric Load	88	88	88
Estimated Base Load	92	462	888
Allowable Runoff Load	547	437	281
Existing Total Load	818 (12%)**	1360 (27%)	2203 (43%)
Existing Runoff Load	638 (14%)	810 (46%)	1227 (77%)
Future Total Load	891 (18%)	1420 (30%)	2301 (45%)
Future Runoff Load	711 (23%)	870 (50%)	1325 (79%)
Fa=0.1			
Allowable Available P Load	934	1195	1464
Atmospheric Load	88	88	88
Estimated Base Load	98	491	944
Allowable Runoff Load	748	616	432
Existing Total Load	1092 (14%)	1720 (31%)	2758 (47%)
Existing Runoff Load	906 (17%)	1141 (46%)	1726 (75%)
Future Total Load	1232 (24%)	1868 (36%)	2989 (51%)
Future Runoff Load	1046 (28%)	1289 (52%)	1958 (78%)
Fa=0.2			
Allowable Available P Load	1257	1464	1731
Atmospheric Load	88	88	88
Estimated Base Load	103	520	1000
Allowable Runoff Load	1066	856	643
Existing Total Load	1365 (8%)	2081 (30%)	3314 (48%)
Existing Runoff Load	1174 (9%)	1473 (42%)	2226 (71%)
Future Total Load	1573 (20%)	2316 (37%)	3679 (53%)
Future Runoff Load	1382 (23%)	1708 (50%)	2591 (75%)

* flows in hm3/yr, loads in kg/yr;

** percent reduction in loading required to achieve objective;
"existing" and "future" refer to land use distributions;
Fa = assumed particulate phosphorus availablility ratio

Appendix II Reprint of McGinn (1982).

The following pages are selectively reproduced from McGinn (1982).

WATERSHED MANAGEMENT PLAN

FOR

LAKE QUINSIGAMOND AND FLINT POND
(Worcester, Shrewsbury, Grafton,
Millbury, Bolyston and West
Boylston, Massachusetts)

Prepared by

Massachusetts Department of Environmental Quality Engineering
Office of Planning and Program Management

And

Massachusetts Division of Water Pollution Control
Technical Services Branch
Lakes Section

Joseph M. McGinn, Project Engineer
Principal Investigator

April 1982

This report was prepared with the assistance of the U.S. Environmental Protection Agency through grants to the Massachusetts Department of Environmental Quality Engineering under the Nationwide Urban Runoff Program and the 314 Clean Lakes Program.

LAKE QUINSIGAMOND & FLINT POND

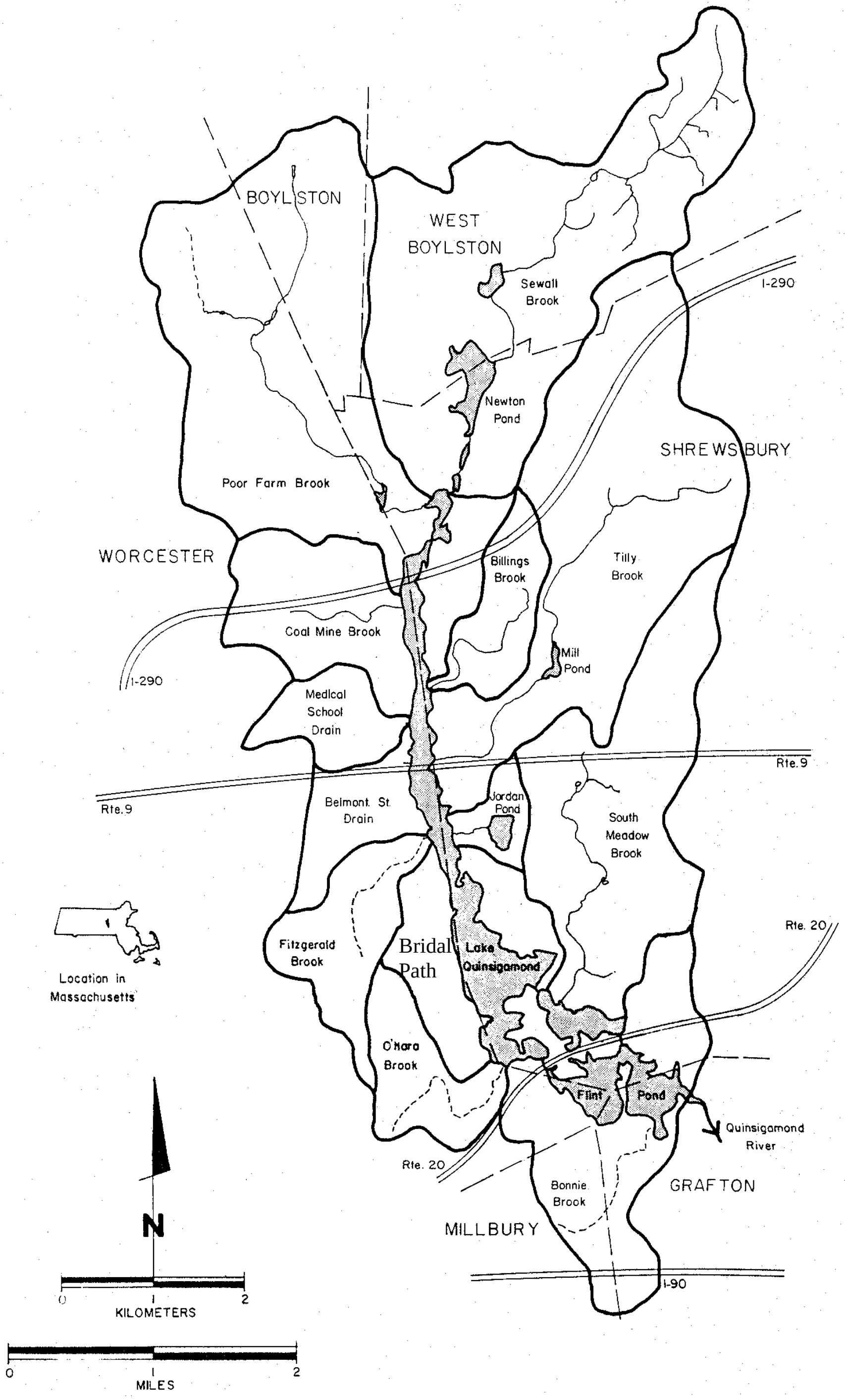


FIGURE I-1

Table III-21

Distribution of Storm Loads (percentage of total loading)

Drainage Area	Flow	TSS	Total Nitrogen	Dissolved Phos.	Total Phos.
Belmont St. Drain (Rt. 9)	6	12	11	7	8
Fitzgerald Brook (Anna St.)	8	8	6	9	9
Jordan Pond Outlet	1	1	3	2	1
Tilly Brook	11	6	6	8	6
Newton Pond Outlet	14	9	9	11	11
Poor Farm Brook	17	17	18	17	19
Coal Mine & Billings Brook	15	17	15	14	16
S. Meadow Brook O'Hara Brk. & Bridle Path Drain	21	21	24	25	21
Bonnie Brook	7	9	8	7	9

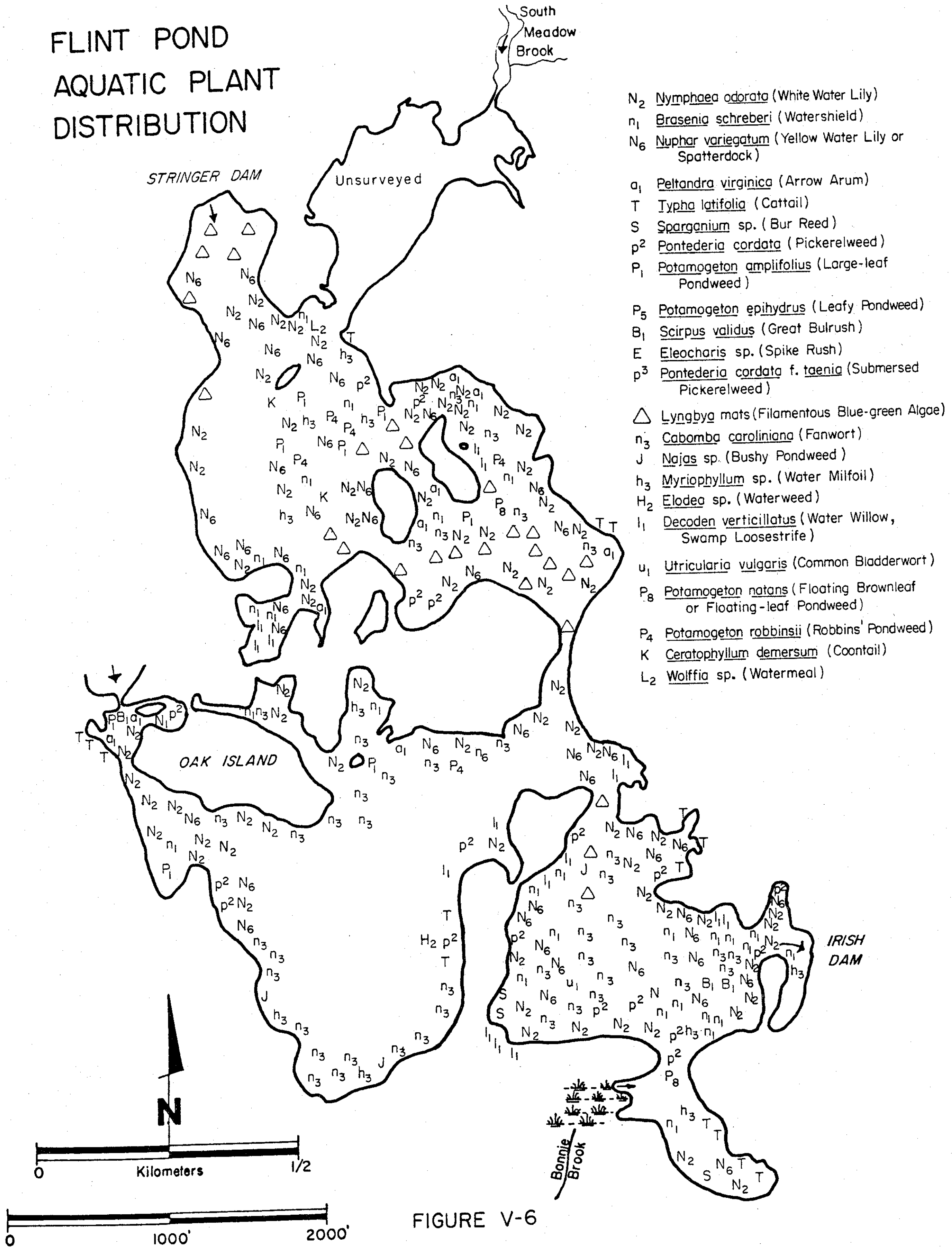

FLINT POND
AQUATIC PLANT
DISTRIBUTION
STRINGER DAM
Unsurveyed
South Meadow Brook
OAK ISLAND
IRISH DAM
Bonnie Brook
N
0 Kilometers 1/2
0 1000' 2000'
N_2 Nymphaea odorata (White Water Lily)
n_1 Brasenia schreberi (Watershield)
N_6 Nuphar variegatum (Yellow Water Lily or Spatterdock)
a_1 Peltandra virginica (Arrow Arum)
T Typha latifolia (Cattail)
S Sparganium sp. (Bur Reed)
p^2 Pontederia cordata (Pickerelweed)
P_1 Potamogeton amplifolius (Large-leaf Pondweed)
P_5 Potamogeton epihydrus (Leafy Pondweed)
B_1 Scirpus validus (Great Bulrush)
E Eleocharis sp. (Spike Rush)
p^3 Pontederia cordata f. taenia (Submersed Pickerelweed)
△ Lyngbya mats (Filamentous Blue-green Algae)
n_3 Cabomba caroliniana (Fanwort)
J Najas sp. (Bushy Pondweed)
h_3 Myriophyllum sp. (Water Milfoil)
H_2 Elodea sp. (Waterweed)
l_1 Decoden verticillatus (Water Willow, Swamp Loosestrife)
u_1 Utricularia vulgaris (Common Bladderwort)
P_8 Potamogeton natans (Floating Brownleaf or Floating-leaf Pondweed)
P_4 Potamogeton robbinsii (Robbins' Pondweed)
K Ceratophyllum demersum (Coontail)
L_2 Wolffia sp. (Watermeal)

FIGURE V-6

Appendix III. Aquatic Vegetation Areas of Dense Vegetation 1998.

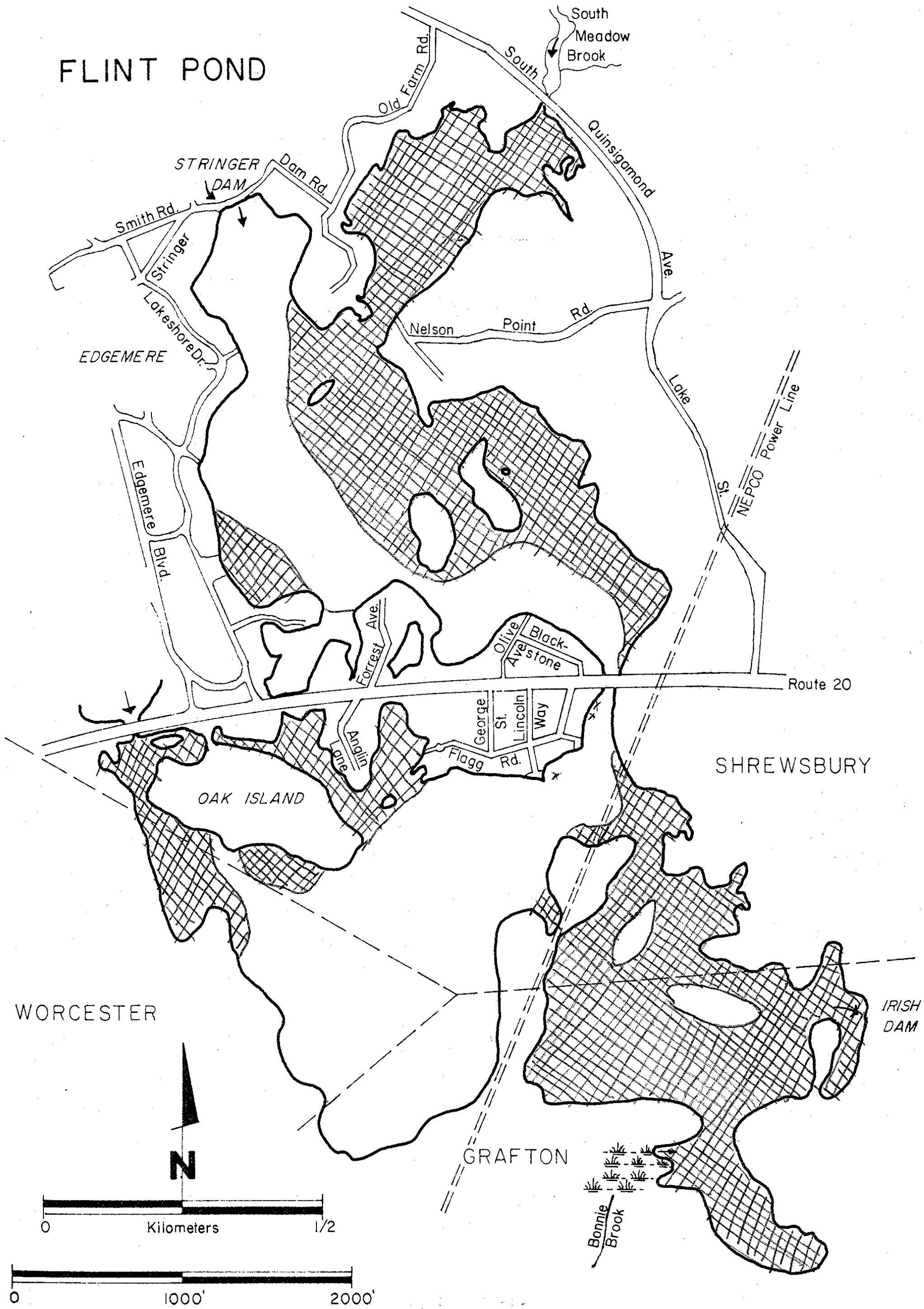
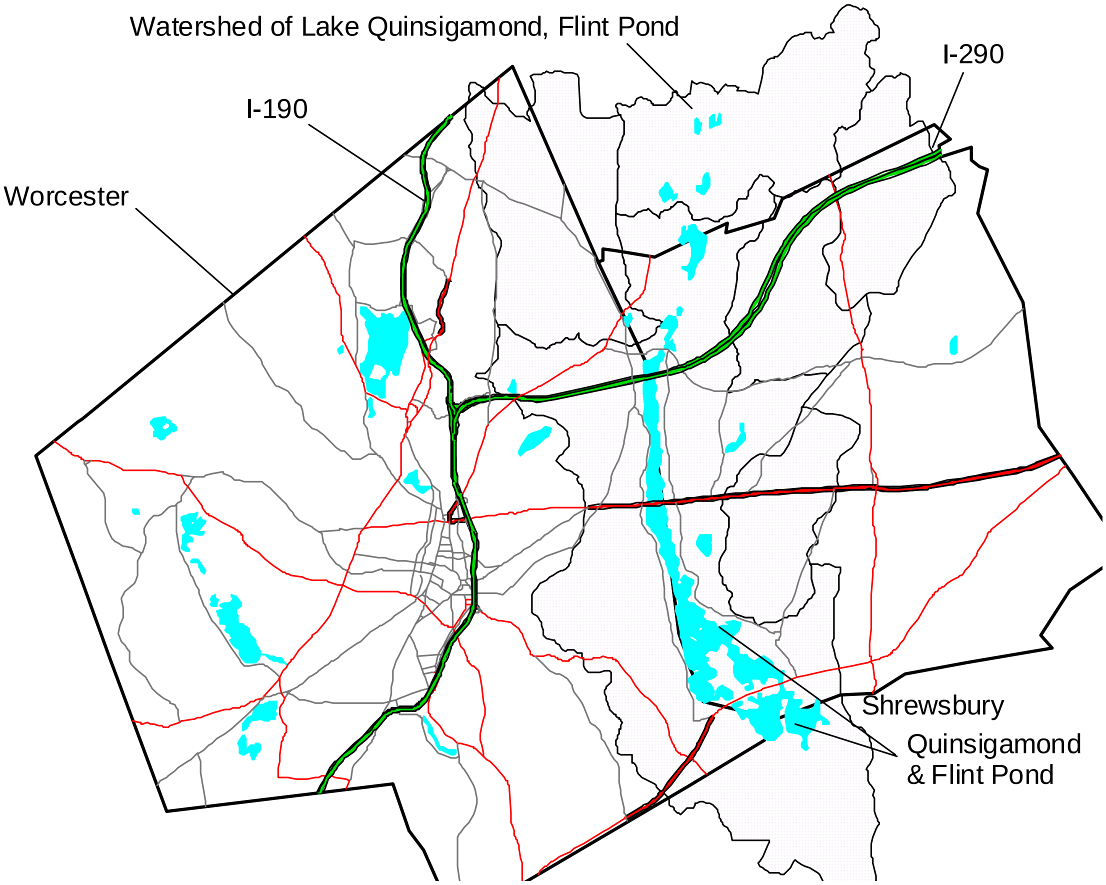
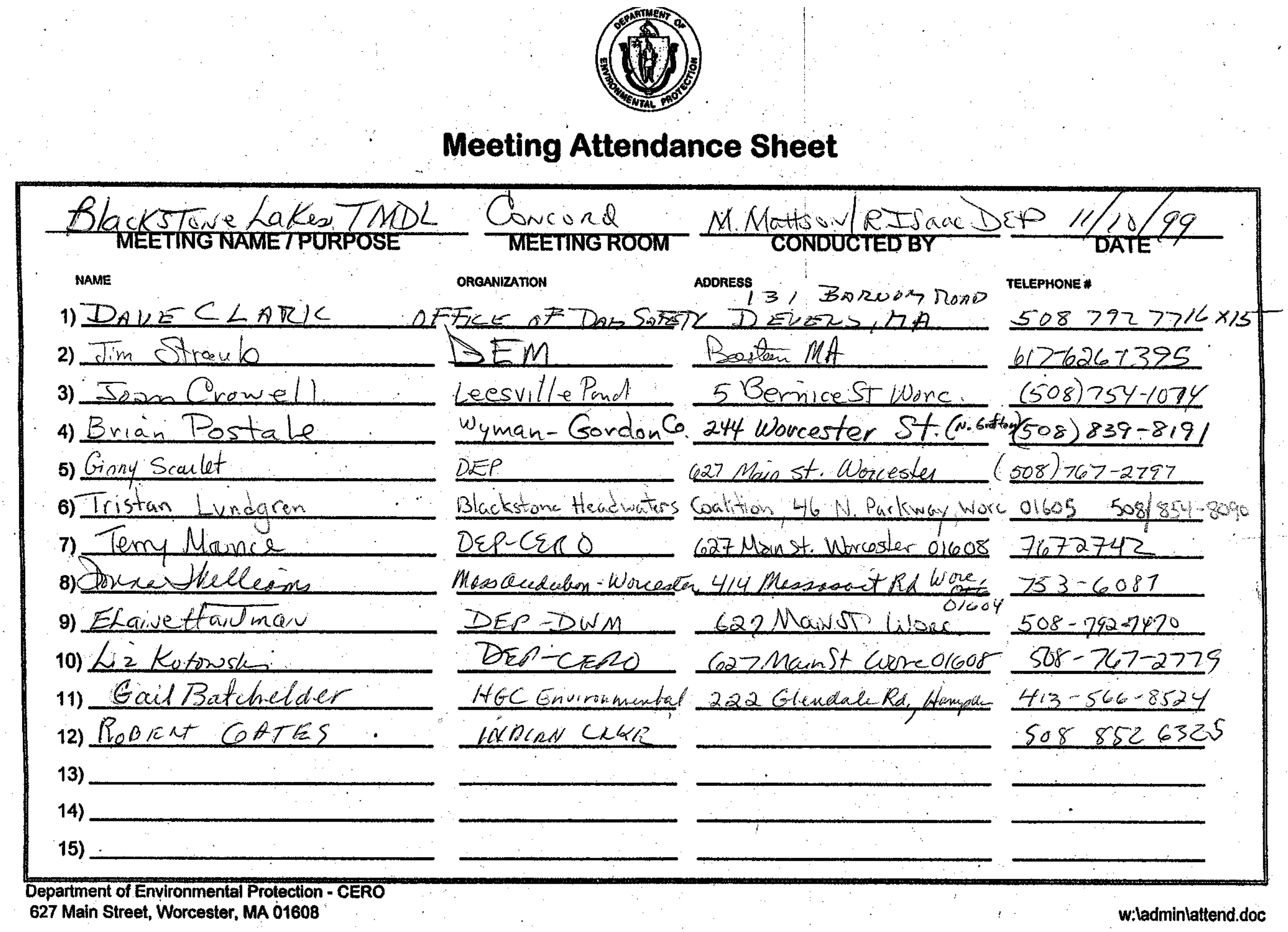


Figure II -1. Aquatic Vegetation Areas of Dense Vegetation. Redrawn from unpublished DWM survey in 1998.

Appendix IV. Watershed Areas within Worcester and Shrewsbury.



Appendix V. Public Meeting Attendance List.



Meeting Attendance Sheet

Blackstone Lakes TMDL
MEETING NAME / PURPOSE

Concord
MEETING ROOM

M. Mattson / R Isaac DEP
CONDUCTED BY

11/10/99
DATE

	NAME	ORGANIZATION	ADDRESS	TELEPHONE #
1)	DAVE CLARK	OFFICE OF DAM SAFETY	131 BARNUM ROAD DEVENS, MA	508 792 7716 x15
2)	Jim Straub	DEM	Boston MA	6176267395
3)	Joan Crowell	Leesville Pond	5 Bernice St Worc.	(508)754-1074
4)	Brian Postale	Wyman-Gordon Co.	244 Worcester St. (N. Grafton)	(508) 839-8191
5)	Ginny Scarlet	DEP	627 Main st. Worcester	(508) 767-2797
6)	Tristan Lundgren	Blackstone Headwaters	Coalition, 46 N. Parkway, Worc	01605 508/854-8090
7)	Terry Mance	DEP-CERO	627 Main St. Worcester 01608	7672742
8)	Donna Williams	Mass Audubon - Worcester	414 Massasoit Rd Worc, 01604	753-6087
9)	Elaine Hartman	DEP-DWM	627 Main St Worc	508-792-7470
10)	Liz Kotowski	DEP-CERO	627 Main St Worc 01608	508-767-2779
11)	Gail Batchelder	HGC Environmental	222 Glendale Rd, Hampden	413-566-8524
12)	ROBERT GATES	INDIAN LAKE		508 852 6325
13)				
14)				
15)				

Department of Environmental Protection - CERO
627 Main Street, Worcester, MA 01608

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Appendix VI. Attendance at Preliminary Meeting.

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: Blackstone Lakes TMDL meeting
Date: 11/10/99 **Place:** CERO

SEE BACKSIDE

Name	Affiliation	phone	email
1 MARK MATTSON	DEP DWM	508 7672868	mark.mattson@state.ma.us
2 Peter Coffin	UMass Extension	831-1723	pcoffin@umext.umass.edu
3 LINCOLN E. PEARSON	LAKE QUINSIGAMOND COMM	756-8709	
4 Lynne Welsh	EOEA-Blackstone	835-4816 X 503	lynne.welsh@state.ma.us
5 DAVE CLARK	OFFICE OF DAM SAFETY	508 792 7716 x15	DAVID.CLARK@STATE.MA.US
6 James Straub	DEM	617 626 1395	Jim.Straub@state.ma.us
7 Joan Crowell	Leesville Pond	(508) 754-1074)	joan.crowell@realtor.com
8 JOSEPH BUCKLEY	WORCESTER DPW	508 799-1980	BUCKLEYJ@CI.WORCESTER.MA.US
9 Chris Scholl	Norton Co	508 795-244	Christopher.C.Scholl@naa.sgna.com
10 ROBERT E. GATES	INDIAN LAKE WATERSHED	508 852 6325	
11 Liz Kotowski	DEP-CERO	508-767-2779	Elizabeth.Kotowski@state.ma.us
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