Total Maximum Daily Loads of Phosphorus for Lake Boon

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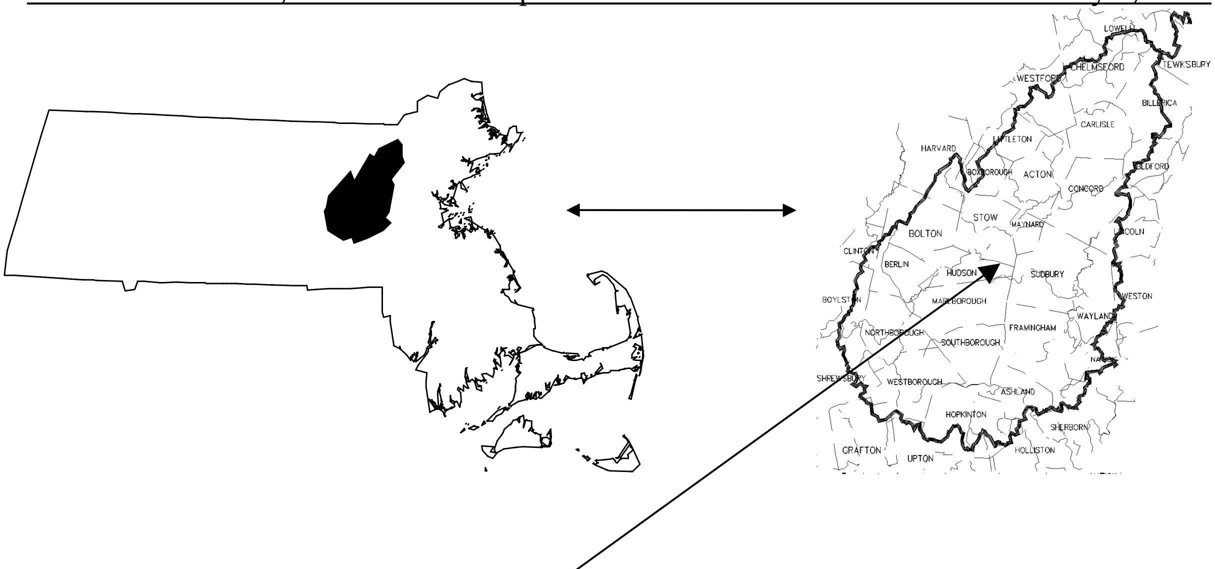
Front Cover

Photograph of Lake Boon

Total Maximum Daily Load of Phosphorus for Lake Boon, (Boons Pond) Hudson and Stow, MA. (MA82011)

DEP, DWM TMDL Report MA82011-2002-017 CN 119 February 4, 2002



Location of Concord Basin, and the Lake Boon in Massachusetts.

Key Feature:	Phosphorus TMDL assessment of a lake with nuisance aquatic plants.
Location:	Hudson, Stow, MA - EPA Region 1
Scope/Size:	Watershed 684 Ha, Surface area 66. Ha (163 ac)
Land Type:	New England Upland
Land Uses:	Forest 54%, Residential 23%, Water 15%, Other, 8%
303d Listing:	Noxious Aquatic Plants
Data Sources:	ESS (1999) and CDM (1987)
Data Mechanisms:	Lake Phosphorus Models, Best Professional Judgment
Monitoring Plan:	Massachusetts Watershed Initiative Five-Year Cycle.
Control Measures:	Watershed Management, Septic system maintenance, Macrophyte Management.

Executive Summary

The Massachusetts Department of Environmental Protection (DEP) is responsible for monitoring the waters of the Commonwealth, identifying those waters that are impaired, and developing a plan to bring them back into compliance with the Massachusetts 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, based on the ESS (1999) lake study as well as the earlier CDM (1987) Diagnostic/ Feasibility (D/F) study and on the Notini and Morrison (1981) Diagnostic/ Feasibility (D/F) study, represents a TMDL for Lake Boon (also known as Boons Pond) in the Concord River Watershed. Lake Boon is listed on the Massachusetts 303d list for Nuisance Aquatic Plants and lake water quality may be threatened by high phosphorus loadings. The report generally concludes that the excessive macrophyte growth in the pond is due to both natural conditions associated with flooded shallow areas after the lake was dammed and anthropogenic nutrient enrichment from the pond's watershed. Plant harvesting operations, if targeted to high use areas, and the proposed drawdown, may be sufficient to control macrophytes without the need for additional measures. The pond is threatened with high phosphorus loadings that can result in algal blooms and water quality degradation, thus a protective TMDL for phosphorus has been established.

This TMDL and all of the previous studies over the past twenty years have made nearly identical recommendations. A summary of these recommendations include: 1) watershed management to limit development, particularly on small lots close to the lake, 2) that the town begin a mandatory septic system inspection and maintenance program, 3) public education and a stormwater runoff control program, 4) a macrophyte management program including drawdown, and/or targeted weed harvesting and/or herbicide treatment, and 5) Monitoring. Although some plant management has occurred, steps to limit nutrient inputs have not. The proposed control effort is predicted to reduce total phosphorus concentrations to 0.020 mg/l. 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 most cases, authority to regulate nonpoint source pollution and thus successful implementation of this TMDL is limited to local government entities and will require cooperative support from local volunteers, lake and watershed associations, and local officials in municipal government. Those activities can take the form of expanded education, obtaining and/or providing funding, and possibly local enforcement. Funding support to aid in implementation of this TMDL is available on a competitive basis under various state programs including the Section 319 Grant Program, the State Revolving Fund Program (SRF), and the Department of Environmental Management's Lakes and Pond Small Grants Program.

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Introduction
Section 303(d) of the Federal Clean Water Act requires each state to (1) identify waters for which effluent limitations normally required are not stringent enough to attain water quality standards and (2) to establish Total Maximum Daily Loads (TMDLs) for such waters for the 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 used by the local Executive Office of Environmental Affairs Basin Team (see below) to guide watershed management plans in the basin. In some cases, TMDLs will be used by DEP to set appropriate limits in permits for wastewater and other discharges. Currently, no point source discharges are permitted in the Lake Boon Watershed, however there are discharges downstream and those point source discharges must be consistent with this TMDL.

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 Boon is based on a Nutrient and Limnological Investigation conducted by ESS(1999) and the Diagnostic Feasibility Study of CDM (1987). Parts of the study are reproduced in Appendix I. Lake Boon (MA82011) is listed on the Massachusetts 303d list for Nuisance Aquatic Plants and lake water quality may be threatened by high phosphorus loadings. The Executive Summary of the limnology study (ESS 1999; see Appendix I) concludes that the pond has both excessive macrophyte growth and occasionally high populations of algae. Apparently, the lake has more of an aquatic plant problem than in the earlier CDM (1987) Diagnostic/Feasibility Study that reported less dense cover of aquatic plants, but higher total phosphorus levels. The ESS (1999) study shows the nonnative fanwort is now densely covering a large area of the lake. The ESS (1999) study identified stormwater as a large percentage of the phosphorus inputs while the CDM (1987) study targeted septic systems specifically. The proposed control effort is predicted to reduce total phosphorus concentrations from 0.026 mg/l to 0.020 mg/l. 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 Descriptions and Problem Assessment

Description: Lake Boon, also known as Boons Pond, (MA82011) is a 163 acre lake located in the towns of Hudson and Stow Massachusetts in the Concord Basin at approximately 71°30’5”W, 42°24’11”N. The lake has a maximum depth of 23 feet (7m) and a mean depth of 10.7 feet (3.3m) and consists of three basins. The largest, deepest basin is in the north, followed by another large basin in the south that leads to the smaller eastern basin. The outlet, located in the northwestern edge of the lake, is an earthen dam with a weir and flashboards. According to Notini and Morrison (1981), the lake was enlarged by the construction of a dam sometime around 1847. The outlet empties into the Assabet River about 600 feet downstream. The many summer cottages along the shore have now been turned into year-round homes. The relatively small watershed consists mainly of forest and wetlands with residential areas concentrated around the lake. The lake has two public access points, including a boat ramp in the southeast and the Stow town beach on the east side of Lake Boon. Further information on the lake management is available in Appendix III.

The CDM (1987) study reported that the small eastern basin is covered in dense growth of fanwort *(*Cabomba *caroliniana)* and that the two major basins have limited growths of a variety of aquatic macrophytes including water lilies, milfoil, bladderwort and pondweed (see Figure 2-11A in Appendix II). The more recent ESS (1999) study reported fanwort as expanding in distribution and the overall percent cover of aquatic macrophytes is more extensive in recent years (compare Figures in Appendix I and Appendix II). Thus, the aquatic weed problem is worsening in the lake. The lake was listed on the 1998 Massachusetts 303d list for Nuisance Aquatic Plants (DEP, 1998). The overall goal is to restore the uses of the lake 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.

Pollutant Sources and Natural Background

Neither the CDM (1987) D/F study nor the ESS (1999) limnology study examined the issue of limiting nutrients in detail, however, they did base the trophic analysis on the assumption of phosphorus limitation. It should be noted that light may also limit macrophyte growth in deep water.

Several methods were used to estimate the annual phosphorus load to the pond. Notini and Morrison (1981) used both a land use export method which estimated loading between 119 and 896 kg/yr, as well as direct measurements which resulted in an estimate of 212 kg/yr (excluding septic inputs). The CDM (1987) study used the land use method to estimate phosphorus loading at 600 kg/yr (including 375 kg/yr for septic system inputs). As noted in the CDM appendix of 1988 (see CDM (1987), they also back calculated loading from the Vollenwieder (1975) model to estimate loadings based on total phosphorus concentrations from three different years. This resulted in phosphorus loading estimates of 635, 159 and 60 kg/yr based on the total phosphorus concentrations of 120, 30 and 10 ppb for the years 1979, 1980 and 1986. The low estimate based on 1986 TP concentrations appears to be an anomaly. When septic inputs are considered, the CDM (1987) land use based estimate and the Notini and Morrison (1981) landuse estimates agree fairly well. These estimates are higher than the ESS (1999) study that used both field measurements and modeling to estimate a yearly loading of 249 kg/yr. Part of the reason for the lower estimate was due to differences in the size of the assumed watershed. The ESS (1999) study excluded White Pond and related watershed, while CDM (1987) included it. The ESS (1999) study used flow from seepage meters combined with dissolved phosphorus concentrations to estimate groundwater inputs (including, presumably, septic system inputs).

It appears the major differences between the phosphorus loading results of the studies was due to differences in approach and differences in hydrology between the years of the studies. The summer of 1998, when the ESS (1999) study measured stormwater inputs, was exceptionally wet with nearly twice the long-term average flow according to the USGS gage at the nearby Assabet River at Maynard (USGS, 1990). The higher flows would make groundwater inputs appear small in comparison and would tend to show stormwater as an important source of water. The CDM (1987) and Notini and Morrison (1981) studies were conducted across two years each but included the summer of 1986 and 1979 respectively, which both started as dry summers but ended somewhat above the long-term average in flow, but the flows in those summers were not nearly as high as the ESS (1999) study noted above.

A more important factor in comparing the studies is to note that the ESS (1999) was a much smaller study due to limited funds available and only sampled stream water five times during the summer months. The average stream water concentration of 0.11mg/l is greatly influenced by a single water sample with a concentration of 0.52 mg/l taken in August (see Table 5 in Appendix II). If that one stream water sample taken on 8/24/98 were removed from the analysis, the average stream TP concentration drops from 0.11 to less than 0.01 mg/l, or a 90 percent decrease. Because stormwater phosphorus loading are the product of concentration times flow, the stormwater loading estimate of 203 kg/yr calculated by ESS (1999) could be much lower if that one sample were removed. Thus, there is great uncertainty in the stormwater loading estimate. On a year of 'average' water flow the typical stream water loading of phosphorus is likely to be less than the 203 kg/yr estimated here. However, to be conservative during wet years, this estimate will be used in the TMDL analysis.

The septic system inputs are another source of discrepancy between the studies. The CDM(1987) study assumed 1.6 kg/person of phosphorus were generated by septic system discharges with 75 percent of this being retained in the septic system or within the soils. However, the 1.6 kg/person figure was derived from an old reference dated 1980, and it is well known that due to the phosphorus ban the discharge of total phosphorus per person is closer to 0.5 kg/person/yr (Reckhow et al., 1980). Thus, a more accurate estimate for septic system phosphorus loading is (0.5/1.6) of 375 kg/yr or about 117 kg/yr. This is still much higher than the total groundwater phosphorus inputs of 24.44 kg/yr estimated in the ESS (1999) study that presumably would include septic system inputs along with other groundwater inputs. However, the method used by ESS (1999) to estimate groundwater inputs, flows from seepage meters multiplied by concentrations from porewater samples, while appropriate for general groundwater, is unlikely to capture the major septic system phosphorus sources from failing systems which would tend to emerge as a discrete, but very localized spring. This conclusion is also supported by the Notini and Morrison (1981) report, which noted many plumes from a septic snooper survey of the lake. Thus, the value of 117 kg/yr for septic system inputs estimated above, will be added to the phosphorus sources in the TMDL analysis.

The major sources of Total Phosphorus differed between the reports, but it appears the major sources include stormwater runoff and septic system inputs. Atmospheric sources and internal sources were considered relatively minor.

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

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 City of Stow had an estimated 20 year growth rate of about 64 percent, while the city of Hudson had an estimated 20 year growth rate of about 13 percent. Thus, some increase in loading is likely since the data were collected, but this would not change the target concentration or the final TMDL.

Water Quality Standards Violations

In consideration 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 lake on the Massachusetts 303d list for 1998 (DEP, 1998) with Noxious Aquatic Plants listed as the cause 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 both sections:

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

nutrients. Activities which result in the nonpoint source discharge of nutrients to lakes and ponds shall be provided with all reasonable best management practices for nonpoint source control.

and

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

1. Dissolved Oxygen:

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

and

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

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

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

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

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

TMDL Analysis

Identification of Target: There is no loading capacity *per se* for nuisance aquatic plants. As the term implies, TMDLs are often expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs may be expressed in other terms when appropriate. For this case, the TMDL is 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) 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 and that the Secchi disk depths are above the 4 foot swimming standard, DEP has set the target TP concentration at 20 ppb. Any value lower than this would be difficult to attain given the forested nature of most of the watershed and a higher value may allow algal blooms, potentially leading to violations of the four-foot transparency standard for swimming. This target loading represents a 23 percent a reduction in total phosphorus concentrations.

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.

The many sheltered shallow bays 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. To some extent, the proliferation of aquatic macrophytes in the pond is a natural condition resulting from the availability of shallow, nutrient rich sediments being flooded when the lake was enhanced by a dam. Thus reducing the supply of external phosphorus may not meet the goals of the TMDL without additional management in the lake as discussed below.

Loading Capacity

If this reduction is applied to the current total loading rate of 366 kg/year an estimated target loading rate of 282 kg/year is calculated. Note that the lake already meets the 4-foot transparency requirement for swimming beaches and the proposed reduction in phosphorus loading would likely increase the transparency even more. The lower phosphorus concentrations will lessen the chance of nuisance algal blooms, which may occur as macrophyte biomass is reduced by direct controls.

Wasteload Allocations, Load Allocations and Margin of Safety:

DEP chose a margin of safety of 10 percent of the total TMDL. In this case, the margin of safety is 282 kg/yr* 0.10 or 28 kg/yr. Point source loading is zero, which leaves 254 kg/yr for the load allocation to nonpoint sources as indicated in the right side of Table 1. Loading allocations are based on the measured phosphorus budget; not the landuse modeled phosphorus budget.

Phosphorus loading allocations for each subbasin and other sources are shown (are rounded to the nearest kg/yr) in Table 1. No reduction in atmospheric loading of 10 kg/yr is targeted, because this source is impossible to control on a local basis. The reduction of phosphorus loading from all other sources is proportionately divided based on a target reduction rate of 31.5 percent.

Table 1. TMDL Load Allocations.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Direct Precipitation	10	10
Groundwater	24	16
Septic Systems	117	80
Dry weather runoff	8	5
Wet weather runoff	204	141
Internal Release	3	2
Total Inputs	366	254

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 = 0 kg/yr + 254 kg/yr + 28 kg/yr = 282 kg/yr.

Modeling Assumptions, Key Input, Calibration and Validation: No models currently exist to predict a reduction of nuisance aquatic macrophytes as a result of phosphorus controls, therefore, no macrophyte models were used. Control of nuisance aquatic macrophytes is based on established literature and best professional judgment. In-lake nutrient concentrations were modeled to estimate how nutrient management may reduce in-lake nutrient concentrations and reduce the probability of algal blooms in the future. The five phosphorus models used in the ESS (1999) report resulted in a range of predicted loadings that varied by more than factor of three and included both the current loading rate and the target loading rate as rates to predict current total phosphorus. Thus there is considerable uncertainty of both the current loading rate and the target loading rate. However, it is reasonable to assume that the percentage reduction of phosphorus proposed here will result achieving the target concentration.

The lake phosphorus models are typically based on assumptions of a single compartment, fully mixed open system which was calibrated on north temperate lakes. The models were designed for use on algal dominated lakes and concentrations of lake phosphorus may be difficult in lakes with large areas dominated by macrophytes such as Lake Boon. Otherwise, Lake Boon falls within the typical range of the calibration datasets for lake area, areal hydraulic loading, and areal loading of phosphorus.

There is some concern over the interpretation of the data of the earlier reports. The high in-lake Total Phosphorus reported by Notini and Morrison (1981) are probably an artifact of the poor limit of detection used by the Division of Water Pollution Control lab (Wall Experiment Station) prior to 1990. As noted above, the ESS (1999) study was conducted during a wet summer period with limited data collection, and thus may overestimate stormwater contributions. The septic system inputs estimated by CDM (1987) are also subject to revision as noted above. However, the new estimate of 0.5 kg/yr with 25 percent reaching the lake (0.125 kg/person/yr) described above, while still somewhat high, is in better agreement with the estimate used in the NPSLAKE model of Mattson and Isaac (1999) of 0.5 kg/house/yr (assuming 3-4 people per house).

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

For most lakes, it is appropriate and justifiable to express a nutrient TMDL in terms of allowable annual loadings. The annual load should inherently account for seasonal variations by being protective of the most sensitive time of year. The most sensitive time of year in most lakes occurs during summer, when the frequency and occurrence of nuisance algal blooms and macrophyte growth are usually greatest. Therefore, because the Lake Boon 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 Boon 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 most recent study by ESS (1999) recommended a management program that included three parts: aquatic weed control, nutrient control, and monitoring. The ESS (1999) report proposed a herbicide (Sonar) treatment directed against the fanwort at a total cost of about $40,000 which included permitting and monitoring expenses. ESS (1999) also proposed a trial drawdown of 2 feet (11% exposure) with monitoring, followed by a 4-foot drawdown (23% exposure) with monitoring and permitting costs of about $14,000. A dredging feasibility study was also proposed for about $8,000, although final costs for dredging even a portion of the lake could cost between $500,000 and $2,000,000.

For nutrient control the ESS (1999) report recommended a septic system inspection and maintenance program targeted at homes within 300 feet, educational brochures for residents and possibly a workshop, and to further investigate control of stormwater runoff within the watershed (compare to the watershed NPS field survey, below). A general monitoring program was also recommended by ESS (1999) with an annual cost of $6,000, not including special monitoring associated with plant control techniques.

It should be noted that over the past twenty years there have been many reports and recommendations for the management of Lake Boon which apparently have not been followed. The Metropolitan Area Planning Council published two reports: A management program for Lake Boon and the Lake Boon Summary Report in 1979 (MAPC 1979a,b) which addressed land use and zoning issues and nutrient inputs from runoff and septic systems. The Massachusetts Division of Water Pollution Control published a Diagnostic/Feasibility Study for Boons Pond in 1981 which made many recommendations on regulating conversion of seasonal homes, restricting speed boats, controlling nutrients, a septic tank maintenance and inspection program and examining drawdowns and harvesting of weeds (Notini and Morrison, 1981). In 1987 Camp Dresser McKee (CDM) conducted another year long Diagnostic/Feasibility study on Boons Pond. Again the recommendations were weed harvesting and a watershed management plan which included a septic system inspection and maintenance program and public education to reduce stormwater runoff (CDM, 1987). In 1999 another Diagnostic/Feasibility study entitled "A Nutrient and Limnological Investigation of Lake Boon" was conducted by Environmental Science Services (ESS 1999). This study also made many recommendations including weed control with the use of herbicides and drawdown, and nutrient control focusing on septic systems inspection and maintenance, public education and other measures to reduce stormwater runoff. Despite the many reports from various studies making the same recommendations there is little progress. Summer cottages continue to be converted to homes, additional homes continue to be built on small lot sizes, no comprehensive septic system inspection and maintenance program has been established and speed boats continue to stir up the bottom sediments. This TMDL report makes essentially the same recommendations as the four previous studies: zoning to limit development near the lake, pubic education to find and reduce stormwater runoff from streets and lawns and reduce boat speed, start a septic system inspection and maintenance program, explore the use of drawdowns, possibly combined with finding new sources of drinking water for residents with shallow wells. For the short term explore the use of herbicides such as Sonar combined with plant replacement (see below) to determine long-term effectiveness, impacts and costs. Harvesting is considered difficult to conduct due to the limitation of 6 foot cutting depth and the presence of many stumps in the shallow areas. It should be noted that most of these items are under the jurisdiction of local officials and town bylaws.

The proposed Sonar treatment does offer an opportunity for experimentation with a long-term holistic approach to plant management. Recent attempts at plant replacement show some signs of promise (K.Wagner, pers. comm.), but need more field trials and experimentation. In Lake Boon, some of the low growing non-nuisance plants already present in the lake such as *Nitella* and *Najas*, could be held in a plastic enclosures away from the herbicide treatment areas and then replanted in marked areas after treatment has removed *Cabomba*. By monitoring the new planting we hope we can gain some insight into long-term species replacement within a lake. This type of experimental treatment is fundable under both the DEM Lakes and Ponds Grant program and under the DEP 319 grants program. Caution should be used to make sure no nuisance plants are moved from lake to lake if this experimental treatment is employed. As noted above, *Nitella* and *Najas* are already present in Lake Boon.

Another option to consider is creation of benthic barrier boating lanes to allow motor boats to traverse the thick macrophyte beds and reach open water areas. Such barriers could be semi-permanent if coarse rock is applied over the barrier and the barrier kept clean of new organic sediments by turbulence of the boat propwash. These additional alternatives are potentially fundable as part of a grant application.

Considering the lack of information on discrete sources of phosphorus to the lake the NPS implementation plan will of necessity include an organizational phase, an information gathering phase, and the actual remedial action phase. Phosphorus sources cannot be reduced or eliminated until the sources of phosphorus are identified. Because many of the nutrient sources are not under regulatory control of the state, engagement and cooperation with local citizens groups, landowners, local officials and government organizations will be needed to implement this TMDL. The Massachusetts Department of Environmental Protection will use the Watershed Basin Team as the primary means for obtaining public comment and support for this TMDL. The proposed tasks and responsibilities for implementing the TMDL are shown in Table 2. 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 “Surveying a Lake Watershed and Preparing an Action Plan” by 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. 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 2003 as part of a rotating 5-year cycle, but would continue in the “off years” as well. The major components will focus on septic system inspection, maintenance and upgrades as required under Title 5 with the Board of Health as the lead agency. 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 Town may seek opportunities to get selected areas dredged at reduced cost.

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

As new housing development expands within the watershed, additional measures are needed to control 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 control 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 the goals of the TMDL and continued macrophyte management is an essential part of the implementation plan. The recommended approach involves targeting high use areas in the eastern basin for intensive harvesting and leaving remaining areas in the eastern basin as a natural area for fish and wildlife habitat. The high use areas may include small private swimming areas, areas around boat docks and boat channels from docks and through macrophyte beds out to open water in the southern and northern areas.

Table 2. Proposed Tasks and Responsibilities

Tasks	Responsible Group
TMDL development	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 Boon Groups*
Compile and prioritize results of NPS watershed surveys	Watershed Team and Lake Boon Groups
Explore creation of a "Watershed District" for management of water, sewer, and/or lake	Towns, Watershed Team and Lake Boon Groups
Replace shallow wells with deeper wells or install water supply.	Town of Stowe, Homeowners
Organize implementation; work with stakeholders and local officials to identify remedial measures and potential funding sources.	Watershed Team and Lake Boon Groups and local Conservation Commission
Write grant and loan funding proposals	Lake Boon Groups, SuAsCo Watershed Associations, Towns, Planning Agencies, NRCS
Explore new treatment options for macrophyte control including plant replacement and benthic barrier boating channels.	Lake Boon Groups, SuAsCo Watershed Associations, Towns,
Organize and implement education, outreach programs	Lake Boon Groups, SuAsCo Watershed Associations,
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 Boon Groups (annually)

*Friends of Lake Boon, Lake Boon Association and Lake Boon Commission.

Table 3. 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.
Manure leaching	Landowner and NRCS and UMass Extension	Conduct soil P tests; obtain estimate of phosphorus in manure. Apply no more manure than required by soil P test. Install manure holding structure. Do not apply on frozen ground or near surface waters.
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. 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
Urban Runoff	Landowner, Town or city Dept. Public Works	Reduce impervious surfaces, institute street sweeping program, batch basin cleaning, install 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.
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 programs 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 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 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

On December 16, 1999 the Massachusetts Department of Environmental Protection gave a summary of a pre-draft version of the TMDL report and received comments from the following: the SuAsCo Watershed Coalition including Mike Fleming, the EOEA Basin Team Leader, and members of the Organization for the Assabet, Friends of Lake Boon, the Lake Boon Commission, the Lake Boon Association and local Conservation Commission members. A list of attendees is provided in Appendix IV. The Department also received comments on the pre-draft from the author of the ESS (1999) study.

The official public meeting to discuss the draft TMDL was announced in the Environmental Monitor and in direct mailed letters to local officials, planning agencies, local associations and interested local residents. The public meeting was held on December 11, 2001 from 6:30-9:00 pm at the Old Town Hall in Stow. Public comment and replies are listed below. Attendance at the public meeting is noted in Appendix V.

Public Comment and Reply

Comment: Why did DEP approve a deviation from the regulations of 440 gpd per acre in approving of the Wildlife Woods Housing Development located close to the shore of Lake Boon?

Response: The regulation of new construction, such as the building permits, zoning regulation and enforcement of Title 5 is under the control of local authorities, not DEP. In cases where there are nitrogen sensitive areas (for example, housing lots with both drinking water wells and on-site sewage disposal systems) DEP restricts the amount of sewage design flow to 440 gallons per day per acre. The regulations under 314CMR 15.216, specify that the nitrogen loading limits may be calculated in the aggregate, including undeveloped, adjacent land that has development and/or conservation restrictions. In this case, Wildlife Woods has a total of 48 acres of developed land and 70 acres of open space, totaling 118 acres. They were thus able to meet the nitrogen-loading limit of 440 gallons/day/acre. There was no deviation from the regulations. DEP does not have the authority to otherwise deny the application if it meets the regulations. The Town of Stow does have the authority to impose further restrictions on development via zoning regulations and local regulations of the Board of Health, which may be more restrictive than the state Title 5 regulations, if the town chooses to exercise that authority.

Comment: Why did DEP approve septic waste from a whole cul-de-sac of homes in the Wildlife Woods development concentrated into one small area of land near the lake?
Response: The plans for Wildlife Woods indicate all homes are on separate, not shared systems. We believe the comment may refer to a stormwater drainage area located near the lake, but such stormwater systems are not septic systems. According to the Title 5 regulations, the local Health Department has authority to permit installation of septic systems and they have the responsibility to check that all septic system leach fields in the development meet the required 50-foot setback from surface waters. The Town of Stow does have the authority to impose further restrictions on development via zoning regulations, and local regulations of the Board of Health, which may be more restrictive than the state Title 5 regulations, if the town chooses to exercise that authority.

Comment: Why was the recent Watershed Initiative Grant for lake improvements submitted by the Lake Boon Commission rejected for funding?
Response: Staff from DEM, the agency that reviewed the proposals, responded that the project received low scores for the following reasons: 1) Herbicide application accounted for 77% of requested state funding, which did not meet requirements of a watershed approach, and 2) The project proposed to establish a joint committee comprised of representatives from the LBC and the Towns of Stow and Hudson, however no letters of support from these towns were received.

Comment: Why is the margin of safety (MOS) in the Phosphorus TMDL calculation added instead of subtracted?
Response: The margin of safety must be included in the overall Total Maximum Daily Load to account for uncertainty as shown in the TMDL equation below:
TMDL = WLA + LA + MOS
Where TMDL= Total Maximum Daily Load
WLA= Waste Load Allocation = amount allocated to point sources.
LA = Load Allocation = amount allocated to nonpoint sources
MOS= Margin of Safety.
Now, consider that WLA = 0 because there are no point sources. To determine how much pollution is allocated to runoff from nonpoint sources, the MOS is subtracted from both sides of the equation to yield:

TMDL – MOS = LA
Thus, because the MOS is part of the TMDL, it must be subtracted from the TMDL to obtain the Load Allocation (LA), which is the limit for the nonpoint source discharge in the watershed.

Comment: Why are bioremediation treatments (e.g. bacteria additions) not recommended for Lake Boon?
Response: As part of the Draft Generic Environmental Impact Report on Lake Management in Massachusetts (Mattson et al., 1998) we reviewed biological treatments for lake management and found some literature documentation of effectiveness for fish, insects and other biological treatments. However, despite the claims of various suppliers of bacterial treatments, we did not find any peer reviewed scientific reports which document significant effectiveness of bacterial additions to lakes for control of algae or macrophytes. This is supported by a more recent review of Holden, et al. (2001). Thus, we can not recommend bacterial treatments at this time.

Comment: Is there any state or federal funding assistance available to the Town of Stow to help create a septic management district?
Response: The State Revolving Fund (SRF) provides nearly Ten Million dollars annually in loans to help communities defray the costs of water quality planning, the DEP 319 grant program provides funds for implementation of nonpoint source projects and the Community Septic Management Program provides small grants for Title 5 planning and capital funds for repairs. Many Massachusetts towns have set up watershed, sewer or septic management districts (e.g. Leicester, Spencer, Dracut, Stockbridge, Essex, Tisbury, Duxbury, Gloucester, and Concord). A more complete list and description were sent to John Toole of the Lake Boon Commission.
Comment: The Organization for the Assabet River (OAR) has recently filed legislation to remove phosphate from automatic dishwashing detergents. Should we be doing this at Lake Boon?

Response: Yes, although this is probably not a large source of phosphorus, every little bit helps. In areas such as lake Boon where there are sandy soils and septic systems very close to surface waters, reducing the loading of phosphorus to septic systems is recommended. There are some brands of automatic dishwashing detergent that are low in phosphates and have less than 1 percent phosphate content.

Comment: How would a drawdown of Lake Boon potentially affect phosphorus loadings?
Response: A drawdown would probably not influence phosphorus loadings significantly.

Comment: What are the Phase II Stormwater NPDES permit requirements for Stow?
Response: Recently enacted regulations under the Federal Clean water Act, known as Phase II Stormwater Rule, will require at least 189 municipalities in Massachusetts, as well as certain government agencies, to obtain permits for stormwater discharges. The permit under Phase II requires of regulated small municipal separate storm sewer systems (MS4s) to develop and implement a stormwater management program that covers six areas:

1. Public education; 2. Public participation; 3. Illicit discharge detection and elimination; 4. Construction site runoff control; 5. Post-construction stormwater management for new development or re-development; and 6. Municipal good housekeeping.

In preparing for the new Phase II Stormwater requirements, communities should reinforce their existing municipal powers. Working in tandem with your Town DPW, planning board, and conservation commission, communities should examine existing bylaws and regulations to determine what powers already exist, which board has the authority, and where are new authorities and bylaws are needed. For additional assistance, please contact: DEP's Phase II Coordinator's: Ginny Scarlet (508) 767-2797 Email: ginnyscarlet@state.ma.us
Linda Domizio (508) 767-4005 Email: lindadomizio@state.ma.us

Comment (Note several comments were received on this issue, as well as supporting documentation for the Lake Boon application for the 2002 DEM Lakes and ponds Grant Program. The comments are summarized here.): From past experience with the weed-harvesting experiment, we found that the harvesters generally harvest between 2 and 6 foot depths, but there are many areas in Lake Boon over 6 feet deep or shallower than 2 feet. In addition, the many stumps in shallow areas resulted in weed harvesting to be viewed as an ineffective, high maintenance, tedious, labor intensive process, which many felt spread the plants by fragmentation. The general feeling is that harvesting would be impractical if not impossible in many areas of the lake. The more recent lake study by ESS recommended herbicides as well as drawdown. In addition, the consultant writing the drawdown Notice of Intent (Lycott Inc.) indicated that drawdown would result in many private wells going dry and for this reason herbicides were recommended. For these reasons many residents respectfully request that you include herbicide treatment in your Final TMDL Report for Lake Boon.
Response: The policy for lake management in Massachusetts states that management should focus on long-term rather than short-term treatments. There are still options available for long-term treatments and these include resolving the shallow well issue related to drawdowns and also the possibility of creating semi-permanent boating channels by means of benthic barriers to provide access through macrophyte beds to the open water area. It should be noted that the close proximity of septic systems and very shallow private well does raise concerns about human health risks. The shallow wells noted above should be inspected and moved or drilled deeper to both reduce the risk of bacterial contamination and to insure safe drinking water and that a minimal drawdown of 2-4 feet does not impact water supplies to residents. The Department recognizes that commercially available harvesters may not work satisfactorily in Lake Boon and herbicides will be included as an option for rooted plant control in the final TMDL. However, further research should be conducted to extend the length of time herbicide treatment are effective. The Department suggests further research be made to introduce plantings of non-nuisance species (see text) after treated areas are cleared of nuisance species, otherwise the *Cabomba* will most likely quickly reinfest those areas in 2-3 years.

References

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

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

CDM, 1987. Final Report. Diagnostic/Feasibility Study Lake Boon, Hudson and Stow, Massachusetts. Camp Dresser and McKee Inc. in association with IEP Inc. Includes Appendix for final report dated June 1988.

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

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

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

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

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

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

ESS. 1999. A Nutrient and Limnological Investigation of Lake Boon. Hudson/Stow, MA. Environmental Science Services, Inc. Wellesley, MA.

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

Holden, C.W., W. Jones and J. Taggart. 2001. Managing Lakes and Reservoirs. N. Am. Lake Manage. Soc. And Terrene Inst. In Coop.EPA, Madison WI.

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

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

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

MAPC, 1979a. A management program for Lake Boon. Metropolitan Area Planning Council. Boston. MA.

MAPC, 1979b. Lake Boon Summary Report. Metropolitan Area Planning Council. Boston, MA.

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

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

Notini, B.R. and J. Morrison. 1981. Boons Pond Diagnostic/Feasibility Study. Mass. Dept. Env. Qual. Eng., Westborough, MA. Pub No. 12396-147-68-5-80-CR.

Reckhow, K.H. 1979. Uncertainty Analysis Applied to Vollenweider's Phosphorus Loading Criterion. JWPCF 51(8):2123-2128.

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

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

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

USGS. 1998. Water Resources Data for Massachusetts and Rhode Island. Water Year 1998. US Geological Survey Water-Data Report MA-RI-98-1.

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

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

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

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

Willliams, S. 1997.   A Citizen's Guide to Lake Watershed Surveys. How to Conduct a Nonpoint Source Phosphorus Survey. COLA Congress of Lake Associations, Hampen ME and Maine Dept. of Environ. Prot. Pub. # DEPLW-41-A97.

Appendix I Reprint of ESS (1999).

The following pages are selectively reproduced from ESS (1999) A Nutrient and Limnological Investigation of Lake Boon Hudson, Stow, Massachusetts.

ESS ENVIRONMENTAL SCIENCE SERVICES, INC.

ENVIRONMENTAL SCIENTISTS, ENGINEERS, AND PLANNERS

A NUTRIENT AND LIMNOLOGICAL INVESTIGATION OF LAKE BOON
Hudson/Stow, Massachusetts

Prepared For:

Lake Boon Commission
16 Gately Avenue
Hudson, Massachusetts 01749

Prepared By:

Environmental Science Services, Inc.
888 Worcester Street, Suite 240
Wellesley, Massachusetts 02482

ESS Project No. L090

March 31, 1999

272 West Exchange Street, Suite 101, Providence, Rhode Island 02903
Telephone: (401) 421-0398 Facsimile: (401) 421-5731 E-Mail: essri@ultranet.com

888 Worcester Street, Suite 240, Wellesley, MA 02482
Telephone: (781) 431-0500 Facsimile: (781) 431-7434 E-Mail: essma@ultranet.com

Web Site: www.essgroup.com

A NUTRIENT AND LIMNOLOGICAL INVESTIGATION OF LAKE BOON HUDSON/STOW, MASSACHUSETTS EXECUTIVE SUMMARY

Environmental Science Services, Inc. (ESS) conducted a nutrient and limnological investigation of Lake Boon and the watershed draining into the lake during the summer and fall of 1998. The primary goal of this investigation was to determine the relative contribution of various nutrient sources to the lake. A second goal was to accurately assess Lake Boon's current water quality for the purpose of comparison to previous studies that were conducted during the past 20 years. The most recent data consists of limited water quality information gathered in 1997; the last full study of the lake was conducted in 1987. The information gathered was used to provide viable management alternatives and associated costs for improving the quality of the lake. A lake and watershed management plan has been prepared for the Lake Boon Commission.

The physical, chemical, and biological characteristics of the lake were assessed and the hydrologic and pollutant contributions from the watershed were monitored. The lake is comprised of three main basins that are physically distinct but hydrologically interconnected by narrow passageways. Portions of Lake Boon are deep and relatively free of aquatic plants while other areas of the lake are very shallow, full of organic sediments and dominated by invasive plant species at nuisance levels. The lake has no permanent tributaries; however, three small intermittently flowing tributaries deliver surface water to the lake during wetter periods and following larger storm events. These tributaries drain a mixture of primarily forest, wetland, and residential land. In addition to these main tributaries, Lake Boon also receives a significant amount of storm water runoff as sheet flow and from storm drains serving roads and residential areas adjacent to the lake. Surface water inputs in response to storms comprise nearly 50 percent of the annual water load, while surface water inputs during dry weather account for less than 12 percent of annual water input.

Phosphorus is believed to be the nutrient that controls primary productivity in this system. Phosphorus concentrations in the main tributary (the only tributary that flowed during the study) are relatively low during dry weather but high to extremely high during storms. This tributary is believed to be representative of other wet weather contributions, underscoring the importance of runoff to total nutrient loading. Phosphorus contributions from groundwater represent an additional source of nutrients to Lake Boon. Groundwater flow to the lake was determined to be approximately 23 percent of total water input on an annual basis. Groundwater sources were determined to be delivering nearly 10 percent of the total phosphorus load to the lake. These and other nutrient sources to the lake were modeled to predict a total phosphorus load to the lake of 186 kg/yr. This phosphorus load is above the permissible phosphorus load of 151 kg/yr and indicates that water quality impacts are likely to occur on a regular basis, particularly during extended dry periods when the effect of these nutrients will be fully expressed.

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In addition, particularly high levels of nitrogen found in the organic bottom sediments in this relatively shallow system appear capable of supporting a dense rooted plant community, and nuisance growths are severe throughout a significant portion of the lake. Both native and non-native plant species achieve excessively high densities throughout the southern and eastern basins of the lake. The rooted species, fanwort and water milfoil, and the small floating species, duckweed and watermeal, are the primary problem plants, achieving great densities over more than 50 percent of the total lake area and impairing both habitat value and recreational use of the lake. Growths of these plants accelerate the sedimentation process, thereby increasing buildup of sediment and associated nutrient reserves in the lake. The buildup, in turn, facilitates further plant growth and can negatively impact water quality as these nutrients are released to the water column. This cycle of productivity cannot be broken by watershed management alone. Management will also need to include some form of in-lake remediation to address the existing plant growth and the accumulation of soft sediment.

Although, management goals should be discussed further among Town officials, the Lake Boon Commission, and members of the community, to date, perceived needs have been developed into the following four objectives:

1. Reduce aquatic plant growths to levels appropriate for habitat, recreational use, and safety considerations.

2. Minimize impacts from watershed activities with the goal of improving in-lake water quality and protecting future water quality.

3. Curtail excessive sediment, nutrient and related pollutant inputs associated with storm events, thereby improving aquatic conditions and maintaining acceptable water quality.

4. Establish a cost-effective monitoring program that provides early warning of potential problems and that tracks the progress of any implemented management measures in achieving stated goals.

Lake and watershed management options have been reviewed in light of these objectives. The vascular plant community of the lake would best be managed through chemical treatment with the herbicide fluridone. Chemical treatment is not the best option for long-term control but may be the most cost effective and appropriate means by which to achieve the goal of reducing aquatic weed biomass in Lake Boon over the short term. The results of this treatment could be maximized with a limited (2-4 foot) annual drawdown to maintain open areas in shallow coves and along shorelines. Water level control hinges on the status of the outlet structure, and further inspection of this structure is needed. Education of watershed residents regarding their influence on water quality and implementation of simple management practices that could be developed and distributed as a brochure may sufficiently reduce pollutant loading to Lake

Boon. These behavioral modifications could be enough to lower phosphorus loading below the permissible load of 151 kg/yr.

Costs for these management program elements will depend upon their level of application. Chemical treatment of Lake Boon with fluridone could cost as much as $40,000 and would need to be repeated at least every three years. An additional $2,000 is likely for permitting this action. Drawdown costs are likely to be negligible once initiated and could be performed as maintenance on an annual basis. An initial investigation of a 2 foot trial drawdown is recommended ($10,000) to determine the impact on shallow wells near the lake shore. Initial permitting costs for the drawdown would be on the order of $4,000. Watershed management actions will carry highly variable costs ranging from relatively small out-of-pocket costs by homeowners for increased treatment system pumping, to over $5,000,000 to construct sewer lines. An educational brochure for watershed residents could be prepared for approximately $3,000 describing actions that should be taken at the local level.

At this time, a short-term program is recommended to meet the stated objectives. The short-term program addresses all of the above-described objectives for the lowest overall cost. An overall cost for the short-term program on the order of $60,000 is envisioned. In addition, the short-term program could be initiated immediately. The program would focus on the control of plant growth through herbicide application and drawdown. At this time only minor improvements in water quality are required and these may be achieved through the distribution and implementation of actions described in an educational brochure.

Once the short-term program has been implemented, it will be beneficial to establish some form of annual monitoring to assess its effectiveness and to establish a database for the lake and incoming waters. This will allow tracking of management progress and provide warning of potential problems. The associated expense is minimal ($6,000/yr) by comparison with management costs.

Chemical treatments and annual drawdowns may be the most efficient means for reducing plant densities in Lake Boon; however, dredging of selected portions of the lake would be beneficial over the long-term. Similarly, if annual monitoring indicate that the pollutant load to the lake has not been sufficiently reduced through the behavioral modifications outlined in the educational brochure, additional actions will be required. Although not warranted at this time, these additional actions (the long-term program) may include the creation of storm water detention facilities to intercept storm water runoff from the tributaries and any future development in the watershed, and could potentially include the installation of sewer lines. Costs for this long-term program would be on the order of $7,000,000, but could be implemented incrementally, as funding becomes available.

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Table 5. Water quality data for Lake Boon, Stow/Hudson, Massachusetts

Site	Date	Sample Type (Dry or Wet)	Total Alkalinity (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Ammonium Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Total Phosphorus (mg/L)	Dissolved Phosphorus (mg/L)	Total Suspended Solids (mg/L)	Fecal Coliform (MF) (per 100 ml)
LB-1s	7/22/98	Dry	11	0.75	0.01	<0.01	0.01	<0.01	NA	<10
	8/20/98	Dry	12	0.6	<0.01	<0.01	0.02	0.02	NA	<10
	9/24/98	Dry	16	0.84	0.13	<0.01	0.02	0.01	NA	<10
LB-1b	7/22/98	Dry	11	0.95	0.03	<0.01	0.04	0.03	NA	NA
	8/20/98	Dry	20	1.18	0.05	0.01	0.06	0.04	NA	NA
	9/24/98	Dry	NA	NA	NA	NA	NA	NA	NA	NA
LB-2s	7/22/98	Dry	11	0.74	<0.01	<0.01	0.02	0.01	NA	<10
	8/20/98	Dry	10	0.66	<0.01	< 0.01	0.02	0.01	NA	<10
	9/24/98	Dry	10	0.58	0.01	<0.01	0.02	<0.01	NA	<10
LB-T	7/22/98	Dry	5	0.1	0.02	1.31	<0.01	<0.01	1	70
	8/20/98	Dry	7	0.08	0.02	1.16	0.01	<0.01	1	40
	9/24/98	Dry	7	<0.2	0.02	1.04	0.02	0.02	2	30
	8/24/98	Wet	3	3.3	0.58	1.06	0.52	0.16	230	-
	10/8/98	Wet	-	0.35	0.04	0.95	<0.01	<0.01	4	680

NA = Not Applicable to Sampling Station

LB-1s = Lake Boon Water Quality Sampling Station 1 at Surface (Figure 6)
LB-1b = Lake Boon Water Quality Sampling Station 1 at Bottom (Figure 6)
LB-2S = Lake Boon Water Quality Sampling Station 2 at Surface (Figure 6)
LB-T = Lake Boon at the Main Tributary (Figure 6)

J:\L090\Tab_4&5 - [Table 5]

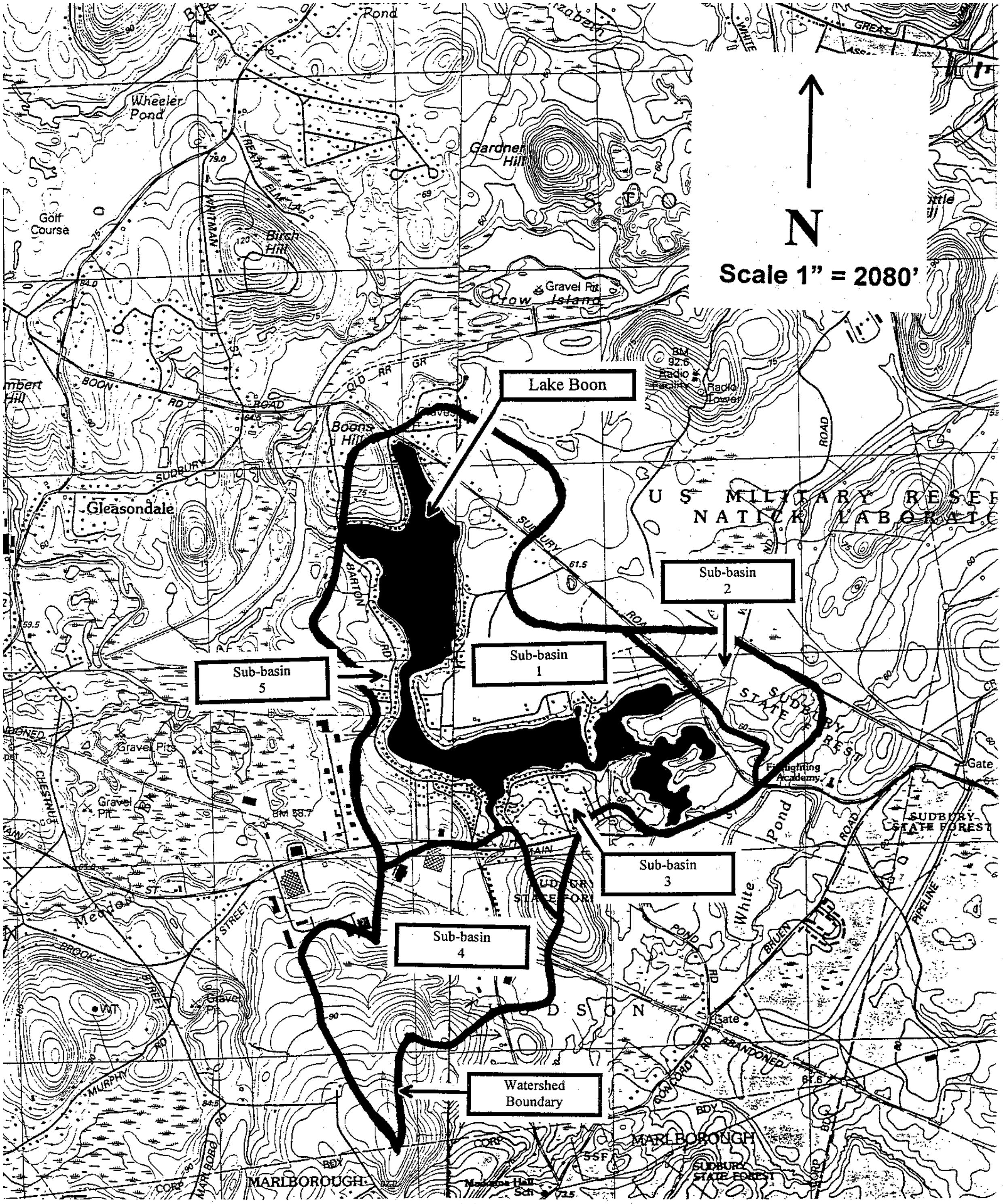


Figure 1. Watershed and watershed sub-basins for Lake Boon, Hudson/Stow, Massachusetts.

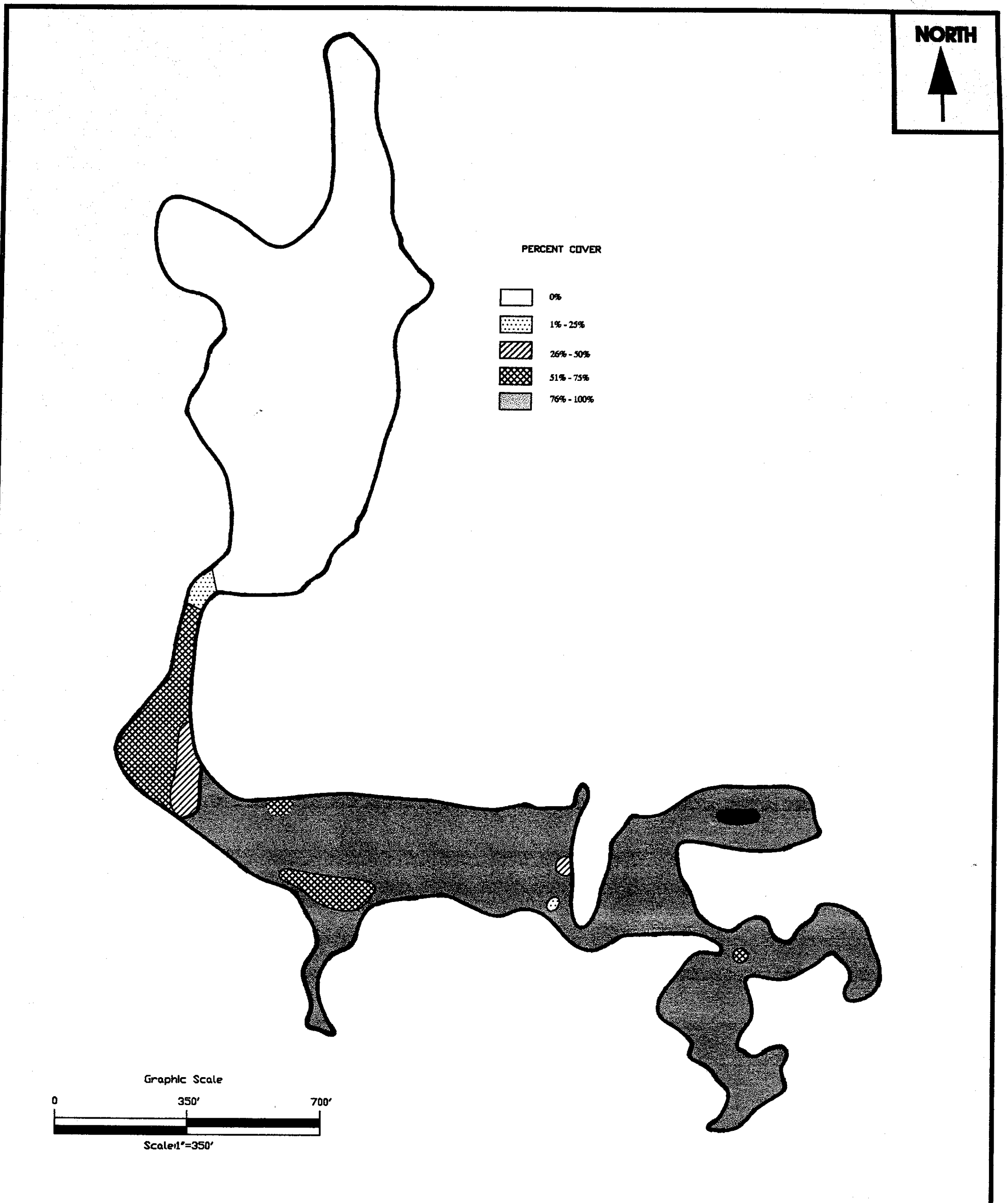


Figure:10

Percent Plant Cover
Lake Boon
Hudson/Stow, Massachusetts

ESS
ENVIRONMENTAL SCIENCE SERVICES, INC.
Wellesley, Massachusetts
ENVIRONMENTAL SCIENTISTS, ENGINEERS, AND PLANNERS

SCALE: AS SHOWN   Dwg. # LO90_f10
DATE: January, 1999

Table 12. Annual phosphorus loads (kg/yr) for Lake Boon listed by source as derived from both field measurements and modeling.

Source	Phosphorus Loads (kg/yr)	Phosphorus Loads (%)
Direct Precipitation	9.99	4.0%
Ground Water Inseepage	24.44	9.8%
Surface Water		
Dry Weather	7.59	3.0%
Wet Weather	203.60	81.8%
Internal Release (from sediments)	3.39	1.4%
Total Annual	249.01	100.0%

J:\L090\Tbs12-14 - [Tab_12]

Table 13. Maximum, mean and minimum expected phosphorus loading to Lake Boon listed by sub-basin as determined from land use modeling within each of the watershed's sub-basins

Maximum	Sub-Basin 1	Sub-Basin 2	Sub-Basin 3	Sub-Basin 4	Sub-Basin 5	Total for Watershed
Industrial	0.0	0.0	0.0	41.3	50.4	91.8
Commercial	0.0	0.0	0.0	51.7	16.9	68.6
Residential	275.6	0.0	143.5	63.3	155.8	638.1
Agriculture	10.1	9.1	10.1	0.0	0.0	29.3
Forest	68.9	26.7	16.9	68.9	14.5	196.0
Total Load	354.6	35.8	170.5	225.2	237.7	1,023.8
Attenuation Coefficient	0.8	0.2	0.8	0.2	0.8	
Adjusted Total Load	**283.7**	**7.2**	**136.4**	**45.0**	**190.1**	**662.4**

Mean	Sub-Basin 1	Sub-Basin 2	Sub-Basin 3	Sub-Basin 4	Sub-Basin 5	Total for Watershed
Industrial	0.0	0.0	0.0	12.7	15.5	28.1
Commercial	0.0	0.0	0.0	15.8	5.2	21.0
Residential	84.5	0.0	44.0	19.4	47.8	195.6
Agriculture	3.1	2.8	3.1	0.0	0.0	9.0
Forest	19.9	7.7	4.9	19.9	4.2	56.7
Total Load	107.5	10.5	52.0	67.9	72.6	310.5
Attenuation Coefficient	0.8	0.2	0.8	0.2	0.8	
Adjusted Total Load	**86.0**	**2.1**	**41.6**	**13.6**	**58.1**	**201.3**

Minimum	Sub-Basin 1	Sub-Basin 2	Sub-Basin 3	Sub-Basin 4	Sub-Basin 5	Total for Watershed
Industrial	0.0	0.0	0.0	1.3	1.5	2.8
Commercial	0.0	0.0	0.0	1.6	0.5	2.1
Residential	8.4	0.0	4.4	1.9	4.8	19.5
Agriculture	0.3	0.3	0.3	0.0	0.0	0.8
Forest	1.7	0.6	0.4	1.7	0.4	4.7
Total Load	10.4	0.9	5.1	6.4	7.2	29.9
Attenuation Coefficient	0.8	0.2	0.8	0.2	0.8	
Adjusted Total Load	**8.3**	**0.2**	**4.1**	**1.3**	**5.7**	**19.5**

J:\L090\Tbs12-14 - [Tab_13]

Appendix II Reprint of CDM (1987).

The following pages are selectively reproduced from CDM (1987). Final Report. Diagnostic/Feasibility Study Lake Boon. Hudson, Stow, Massachusetts.

FINAL REPORT

DIAGNOSTIC/FEASIBILITY STUDY

LAKE BOON

Hudson and Stow, Massachusetts

August 1987

Camp Dresser & McKee Inc.
in association with
IEP, Inc.

SUMMARY

1. Lake Boon is a diverse waterbody with two larger open water basins, and several shallow, vegetated basins. The lake is a well-used recreational resource for the people of Hudson and Stow, supporting a Town bathing beach and swimming, boating, and fishing activity throughout the year.

2. Dense growth of floating leaved and submerged aquatic plants interfere with recreation in the shallow eastern basins of the lake, and shallower areas of the second basin. The primary nuisance species is Camboba, not a native of the area. Water milfoil is another nuisance species present, but it does not appear to have expanded since the DWPC (1981) study. However, it has the potential to expand rapidly.

3. Moderate to high populations of blue-green algae occur during the summer, contributing to borderline transparency problems. Dissolved oxygen is limited in deeper waters during summer stratification, but is not of sufficient magnitude to impact fisheries or phosphorus recycling. No problems with bacterial contamination were noted.

4. Lake Boon has a low flushing rate with limited water inflows due to the large volume of the lake compared to the area of the watershed, and the prevalence of groundwater storage in the watershed area.

5. The major controllable sources of phosphorus from the Lake Boon watershed is surface runoff from shoreline residential properties and nutrient export from shoreline septic systems. The sandy character and high water table of shoreline soils limit their function to attenuate phosphorus.

6. To address the main problem of dense aquatic vegetation and the secondary problem of reducing phosphorus in the water column, various combinations of alternatives were developed. Four options were then evaluated in more detail and the proposed project was then selected.

7. The selected option includes the following components:

a. One year only contracted hydroraking to provide interim relief from nuisance aquatic vegetation. It may also have limited carryover benefits since hydroraking removes the roots of aquatic vegetation as well as upper portions. This will cost approximately $38,000. If funded by the DEQE Clean Lakes Program at 75%, the Town's share will be $9,500.

b. The purchase of a medium sized weed harvester to be maintained and operated by the towns of Hudson and Stow on an annual basis. This harvester will cut and remove nuisance aquatic vegetation, improving the recreational potential of Lake Boon. The weed harvester will cost about $50,000, of which $12,500 is the Towns' share. Annual costs, which are not fundable under the Clean Lakes Program, will be approximately $18,000.

c. The implementation of a watershed management plan to include a septic system pumping program; revisions to the Towns' by-laws on cesspool conversion; and a public education program. This portion of the project is vital to the preservation of Lake Boon. Without it, the lake will deteriorate to a "pea soup" condition. This portion of the project will cost $30,000 total, with $7,500 being the Towns' share. There will also be an annual cost of up to $10,000 for the first few years of implementation.

d. A 3-year monitoring program as required by the DEQE Clean Lakes Program to determine the effectiveness of the project. This is estimated to cost about $50,000 total, of which $12,500 is the Towns' share.

8. The total cost of the project is $168,000 including the state required monitoring program, with the Towns' share $42,000. Annual costs will be an additional $28,000.

9. This project will not return Lake Boon to a "pristine" condition. However, without these preservation efforts, nuisance aquatic vegetation and algae blooms will increase rapidly over the next few years to a point where recreation is severely inhibited. This project should be implemented as soon as possible if the lake is to be preserved.

Table 2-10 Lake Boon, Nutrient Budget

A) **Non-Point Source Loading**

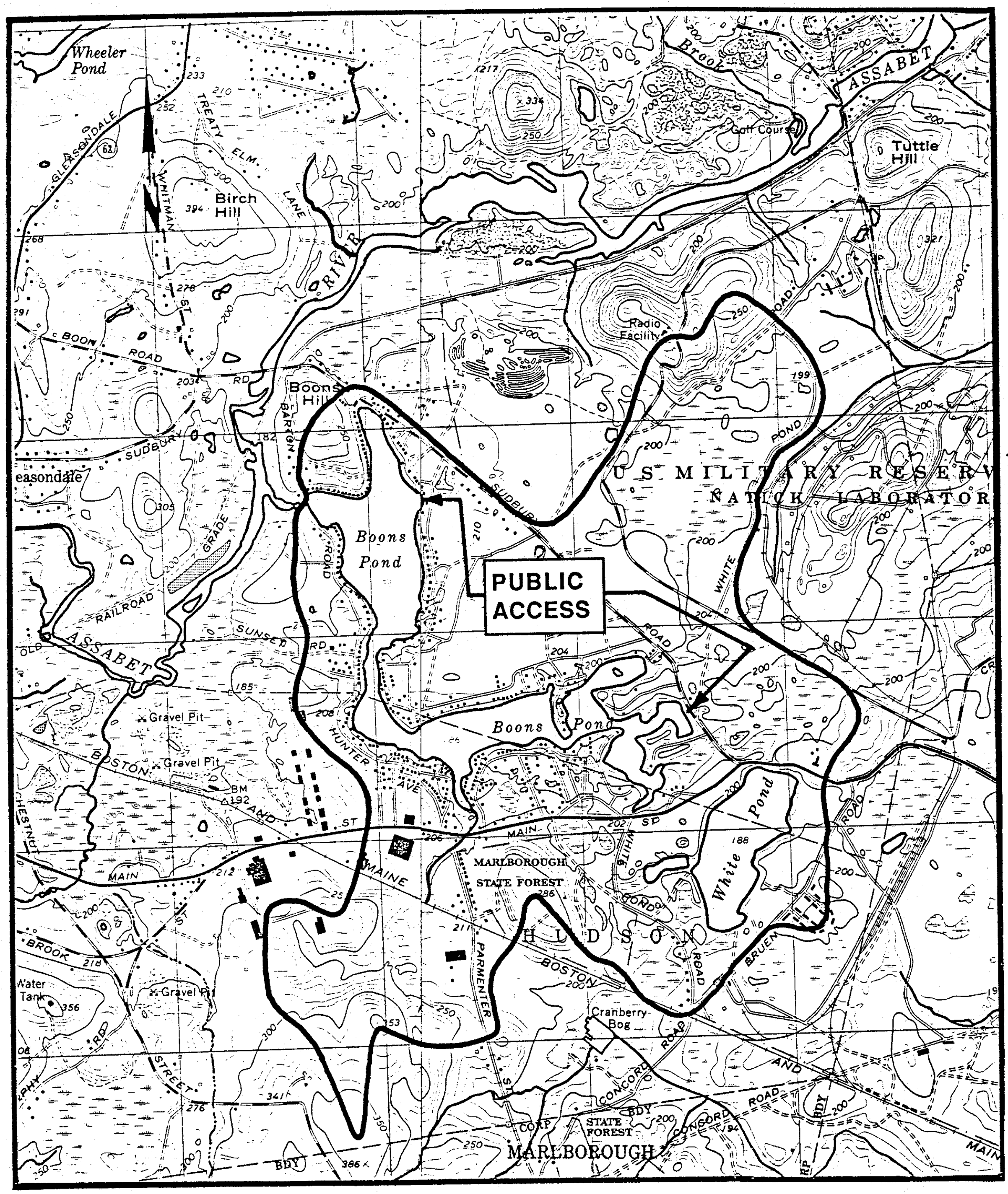
Land Use	-Phosphorus Loading (kg/yr)- Low	Most Likely	High	% Watershed	% Loading
Residential	42	51	71	18	23
Industrial	21	53	60	3	24
Forest/Wetlands	37	73	110	65	34
Open Land	3	9	16	1	4
Atmospheric*	20	33	79	13	15
TOTAL	123	219	336	100%	100%

B) **Septic System Loading**

No inputs	0 kg/yr
Most likely**	375 kg/yr
Worst case	1500 kg/yr

C) **Internal Release 6.5 kg/yr**

*accounts for direct precipitation onto waterbodies
**assumes 75% attenuation of phosphorus by soils



	SCALE IN FEET 0 500 1000 2000	**LAKE BOON** DIAGNOSTIC FEASIBILITY STUDY TOWNS OF HUDSON AND STOW MASSACHUSETTS	CAMP DRESSER & McKEE INC. in association with IEP, INC.	**FIGURE 2-2** **PUBLIC ACCESS**

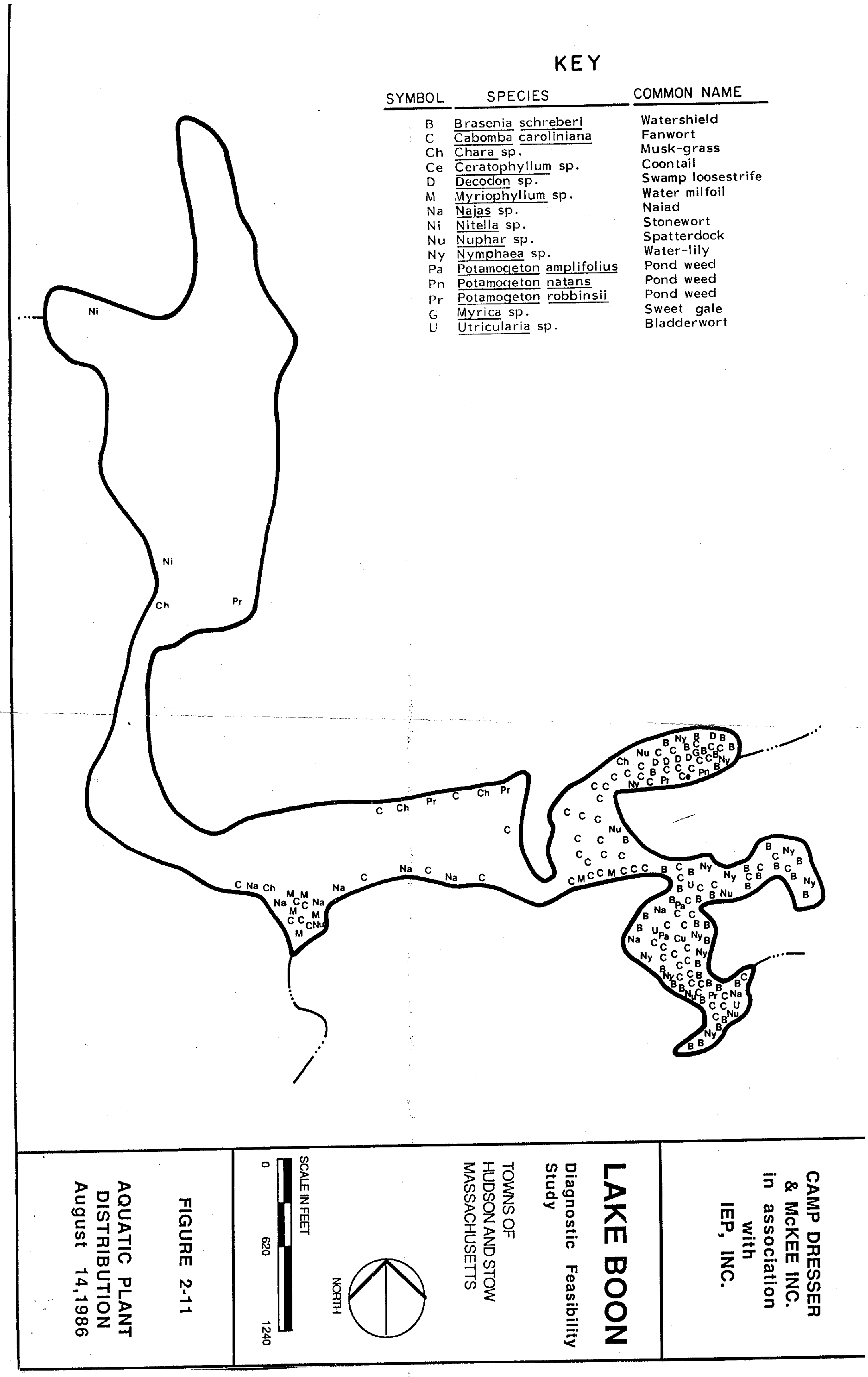
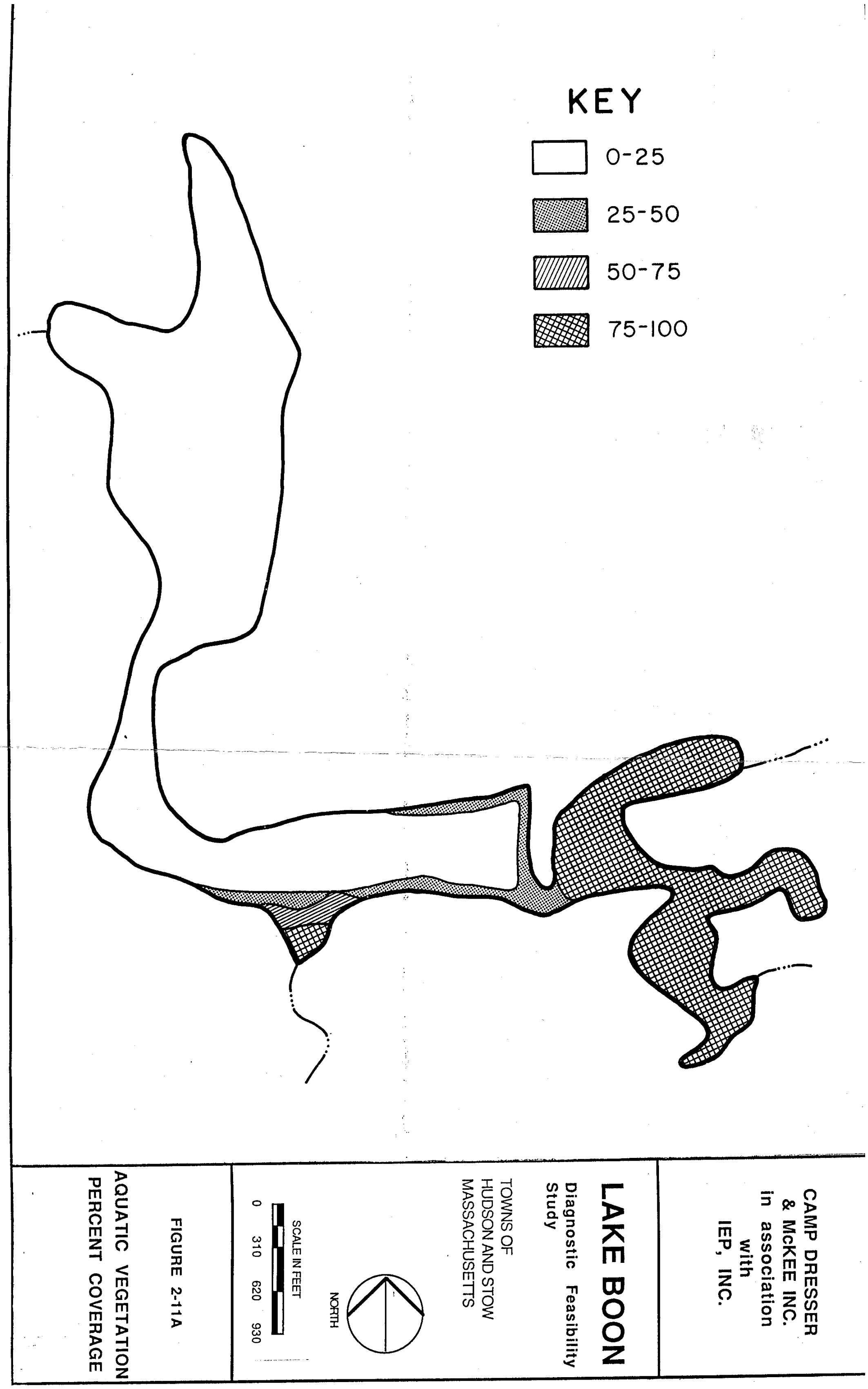


FIGURE 2-11
AQUATIC PLANT DISTRIBUTION
August 14,1986


KEY
0-25
25-50
50-75
75-100
CAMP DRESSER
& McKEE INC.
in association
with
IEP, INC.
LAKE BOON
Diagnostic Feasibility
Study
TOWNS OF
HUDSON AND STOW
MASSACHUSETTS
NORTH
SCALE IN FEET
0 310 620 930
FIGURE 2-11A
AQUATIC VEGETATION
PERCENT COVERAGE

Appendix III Lake Management Survey Form.

Preliminary Lake Management Survey For Municipalities, ConComms and Lake Associations

This information will be used to help develop Total Maximum Daily Load Reports as part of the Federal Clean Water Act requirements under section 303(d) and to help develop funding priorities. If you are unsure of the accuracy of your answer to any question then add a question mark? and provide a name and phone number that we can call for further information on the subject. Add a separate page with additional comments if you wish.

Return to: Dr. Mark D. Mattson, Dept. Environmental Protection, DWM, 627 Main St. 2nd Fl
Worcester, MA 01608 (508) 767-2868 email mark.mattson@state.ma.us

---

Type of Waterbody: Lake Town: Hudson/Stow Lake Name: Lake Boon
ID number: Pollutant Stressor:
Comments:

---

1)Your Name and position title: David Andrews & D. Schumann Friends of Lake Boon Phone: 508-568-9004 email: dandrews@concord.com

2)Name of Municipality or Lake or Watershed Association and address:

3)Describe any unique or valuable features of the lake (ownership, historic, watersupply, only beach in town, in a park, tourist attraction, rare species etc.) Man made ≈1860, only beach in Stow

4)Roughly estimate daily public use (# of people on lake during the day) during summer months for each of the following activities:
a) Boating 60 b) Fishing 20 c)Swimming 30 d)Sightseeing, picnic 10 e)other

5)Does the lake have a dam at the outlet? Yes X No ____ If yes, how high? (ie how many vertical feet of water does the dam hold back? 12 ft.) Is the lake level adjustable from the dam? (i.e., splash boards, gate, or valve?) and are they in good working order to conduct a drawdown? Yes Are annual drawdowns conducted? used to be until ≈1980 If yes, how many feet? used to be 2 ft
Who owns the dam ? Town of Stow

6)How many public bathing beaches are present? (where): 1 in Stow

7)How many other beaches (e.g. resorts) are used by public (where): Ø

8)Are there current problems with swimming in the lake? a) bacteria, b)transparency <4ft c) weeds d)no serious problems e)other Have the beaches been closed last year due to any of above causes? Yes
High bacteria count at town beach - we think due to feeding Geese at that beach, given mess on shore + bacteria count right after a heavy rain.

9)How many public boatlaunches are available? (where): 2 in Stow

10)How many other boat launches (e.g. resorts) are used by the public? Ø

11)Are there current problems with boating or fishing on lake? a)weeds along shore b) weeds cover on ____% of lake surface c)fish kills d) exotic weeds (list) e)boating noise f) boating turbidity, g) algae blooms h) low oxygen i)no serious problems, Other problems? Explain.

- dangerous behavour, no enforcement of state regs.
- erosion of shore, we think due to high speeds too close to shore (within 50 feet is usual), and high volume of boats.

Appendix IV Preliminary TMDL Meeting list.

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

ARGEO PAUL CELLUCCI
Governor

JANE SWIFT
Lieutenant Governor

BOB DURAND
Secretary

LAUREN A. LISS
Commissioner

MEETING ATTENDEES LIST

Meeting: Lake Boon TMDL preliminary meeting
Date: Dec 16 1999 **Place:** SVT office Maynard

	Name	Affiliation	phone	email
1	Mark Mattson	DEP DWM	508 767 2868	mark.mattson@state.ma.us
2	DICK GELPKE	UMASS/BOSTON	617-287-5288	RICHARD.GELPKE@UMB.EDU
3	George King	"	978 369-[illegible]	
4	Barbara Mudd	SuAsCo WA	" 369-6878	MMudd@AOL.Com
5	Sue Flint	OAR	369-3956	oar@ma.ultranet.com
6	Deb Schumann	FLB	568-8691	deb@stow-web.com
7	Ted Wickwire	Water Qual/Quant Task Force SuAsCo	617-523-4459	WTWick4011@AOL.com
8	Mike Fleming	EOEA/MWI	978 368-0126 ext116	mike.fleming@state.ma.us
9	Matt Liebman	OAR, Acton Con. Comm	978 635-9652	liebman.matt@epa.gov
10	Barbara Offenhartz	OAR	781 237 5958	podo@worldnet.att.net
11	Roger Duchesneau	FLB	978 568 0794	rogerd@ieee.org
12	CONRAY WHARFF	LAKE BOON COMMISSION	978 562 9412	wateR@ULTRANet.com
13	Barbara Clancy	Friends of Lake Boon	978-562-1378	Lbcdog@aol.com
14	Don Hawkes	Lake Boon Assoc.	978-562-6630	lhawkes105@aol.com
15	[illegible]	Ashland/[illegible]	(508) 881-8108	—
16	Nancy Bryant	SuAsCo Coalition	978-461-0735	Suasco@compuserve.com
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This information is available in alternate format by calling our ADA Coordinator at (617) 574-6872.

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Appendix V. Official TMDL Public Meeting list.

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

JANE SWIFT
Governor

LAUREN A. LISS
Commissioner

BOB DURAND
Secretary

#1

MEETING ATTENDEES LIST

Meeting: LAKE BOON TMDL Public Meeting
Presenters: MARK MATTSON, MIKE DIBARA DEP
Date: 12/11/01 Place: STOW old TOWN HALL

Name	Affiliation or address	phone or email
1) Jaffe	19 Hale Rd	jaffe@ll.mit.edu
2) Don Hawkes	Pres-Lake Boon Assoc.	Lhawkes105@aol.com
3) MARK S. Carrig	PO Box 332 Stow	tcar@ma.ultranet.com
4) Dan Nicholson	281 Sudbury Rd	dan_nick@hotmail.com
5) Barbara Clancy	201 Barton Rd Stow	Lbcdog@aol.com
6) Pat Walrath	State Rep	Rm 481 State House
7) BARBARA ERNST	210 BARTON RD STOW	bernst@cia.net
8) LORI HAWKES	9 DAWES Rd. Stow	Lhawkes105@aol.com
9) Matt Gunderson	Beacon-Villager	
10) Roger Duchesneau	98 N. Shore Dr Stow	rogerd@ieee.org
11) David Gray	12 Pine Point Rd, Stow	dmgray@juno.com
12) Chris Gorney	Riverways-DFWELE	christopher.carney@state.ma.us
13) David Siewierski	178 Barton Rd	
14) WES FISHER	200 BARTON RD	Wesfisher@aol.com

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

#2

JANE SWIFT
Governor

LAUREN A. LISS
Commissioner

BOB DURAND
Secretary

MEETING ATTENDEES LIST

Meeting: LAKE BOON TMDL public meeting
Presenters: DEP
Date: 12/11/01 Place: STOW OLD TOWN HALL

Name	Affiliation or address	phone or email
1) [illegible]	779 Great Rd	897-9649
2) Patricia Perry	STOW Cons. Com.	978-897-8615 conservation@ci.stow.ma.us
3) John C. Toole	Chair Lake Boon Commission	978-562-7582 JOHN JTToole@aol.com
4) CONRAY WHARFF	LAKE BOON COMMISSION	978 562 9412 CWHARFFE@EARTHLINK.NET
5) David Webster	EPA	617-918-1791
6)		
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