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IEP inc.

DIAGNOSTIC/FEASIBILITY STUDY

LAKE MASSAPOAG

SHARON, MASSACHUSETTS

March 1984

Prepared For

Town of Sharon
Sharon, Massachusetts

Prepared By

IEP, Inc.
Northborough, Massachusetts

ERRATA

DIAGNOSTIC/FEASIBILITY STUDY
LAKE MASSAPOAG
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line 21: indicate the lake is phosphorus-limited
page 26: Table 4 is reproduced and included in the map pocket for clarification of manganese data
page 76: Figure 26 is reproduced and attached for clarification of the key
page 88: corrected Table 21 attached
pages 91 and 92: Other Nutrient Sources

The only other nutrient source noted at Lake Massapoag was that of gull and waterfowl excreta. At Lake Massapoag, gulls dominate the bird population year round, and other waterfowl inhabit the Lake in accordance with migration patterns. Their numbers vary collectively in response to wind or ice cover. To obtain a worst case value for annual phosphorus loading from gull and waterfowl excreta, it was assumed that the maximum number of birds inhabiting Lake Massapoag year-round was 200. Using values for bird nutrient loading (Bedard, Therriault and Berube, 1980) of 152 mg (dry weight) per bird per day results in an annual total phosphorus loading of 11 kg/year.

It is unlikely that this maximum number of birds inhabits the Lake year-round. Data from in-lake sampling stations are not indicative of either fecal loading or nutrient concentrations inconsistent wtih tributary inputs. Personnel from the Division of Water Pollution Control and IEP, Inc. have not noted the presence of waterfowl or gulls in even small numbers during the frequent sampling surveys, watershed inspections and meetings in Sharon.

If it can be documented that populations of roosting and nesting gulls/waterfowl exceed 50 birds per day on a year-round basis, or become a nuisance to bathers or shoreline homeowners, there may be justification for further study of this issue. However, such an investigation is beyond the scope of the present Diagnostic/Feasibility Study.

page 106 line 19: Based upon the results of the nutrient budget, a conservative estimate

page 106 line 22: approximately 44% of the total loading
page 107 line 9: The conventional, standard long-term approach
line 12: Metropolitan District Commission
page 110: Table 26 is reproduced and attached for clarification of total cost figures
page 112 line 7: it is the present policy of MDC to accept
page 114 line 18: The estimated capital cost is $300,000, with an annual operation
line 43: impacts of septic systems
page 116 line 1: systems, and the initiation of an inspection/
page 117 line 18: the Lake. Field observations and sampling of
page 118 line 10 investigated in conjunction with the development of a plan
page 122 line 1: However, the implementation
page 125 line 18: control of future increases in water pollution. Such regulation
page 127 line 14: are associated with the stream's headwaters
line 46: this wetland area, a series of calculations was made to determine
page 128 line 1: calculations indicate
line 5: inflow from inlet 13 has been prepared (see Figure 31).
line 23: of organic soils; $222,220 for dredging
page 131 line 7: construction of a weir
page 132 add line 10: retention pond is not recommended for this area.
page 133 line 11: this page reprinted and attached
page 135 line 46: this adaptive land form structure may have influenced Lantz's results (Table 28)
page 139 line 34: Mechanical harvesting of nuisance aquatic vegetation
page 142 line 27: and long-term reductions in macrophytic densities attributable
page 143 lines 20 and 21: The recommended continuing program of fall/winter drawdown of two feet would allow for limited sediment excavation
page 149 line 14: The projected costs
page 150: cost estimates based on 1983 data
page 153 lines 31 and 32: (beyond the achievable two foot drawdown).
page 154 line 10: During May and June, outflow should be approximately
line 12: are below the USFWS spring criterion of
page 156: Table 31 is reproduced and attached for clarification of key
page 157 line 15: At minimum the filing
page 158 line 22: inspection maintenance program
line 25: A 1988 target date for project completion is estimated
page 159 line 23: the remainder of the year. Algae sampling in-lake should be conducted

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1.0 OVERVIEW AND SUMMARY: LAKE MASSAPOAG DIAGNOSTIC/FEASIBILITY STUDY

Lake Massapoag, located in the Town of Sharon in southeastern Massachusetts, has been the subject of a diagnostic/feasibility study conducted by IEP, Inc. and the Massachusetts Division of Water Pollution Control. The following report is the result of this study, and details the existing conditions of the lake and its watershed; and develops a management program to ensure the future viability of Lake Massapoag as a recreational resource.

Lake Massapoag is a natural waterbody which has been enhanced to its present size of just over four hundred acres. It has a maximum depth of 45 feet, and is bathymetrically composed of a single major basin with a gently sloping shoreline. Opportunities for recreational uses are well developed. Two public beaches and a boat ramp, in addition to summer camps and private beaches, boat landings and mooring areas, provide access to Lake Massapoag for swimming, boating and fishing. The lake supports a warm-water fishery, and is stocked annually with rainbow trout by the Massachusetts Division of Fisheries and Wildlife.

The topography and geology of the relatively small watershed are typical of southern New England glaciated terrain: highlands composed of igneous bedrock and till, and low-lying areas filled with stratified drift and swamp deposits. The watershed is largely forested, with residential development as the secondary land use.

Lake Massapoag receives inflow from two major tributaries, one of them named Sucker Brook; and from several small, intermittent streams and storm drains. On the average, precipitation is evenly distributed throughout the year, but may vary considerably in a given month from year to year. Runoff tends to be highest in late winter and early spring due to melting snow and frozen ground conditions. Groundwater inflow provides a significant contribution to the lake.

The diagnostic study of Lake Massapoag entailed a year of water quality sampling of the lake and its tributaries, and a review of past water quality data. The physical, chemical and biological testing of the lake revealed characteristics typical of a northern temperate dimictic lake in a mesotrophic state. Lake Massapoag stratifies in the summer; and is subject to weeks or months of ice cover in winter, with spring and fall turnovers contributing to mixing of the lake water. The water quality of Lake Massapoag as revealed by the intensive sampling in 1981-1982 is generally good. Review of past water quality data did not reveal significant trends in any of the parameters studied. However, historical data and undocumented reports of several biological parameters, including nuisance algae and aquatic weed growth, indicate an accelerated trend toward eutrophication.

Periodic algal blooms have been reported, and occasionally documented (June 1981). Blooms of algae are neither chronic nor continuous in the lake; and the variability in both populations and problem species indicates a range of possible causes. Excessive runoff during unusually wet weather may flush nutrients into the lake; the duration of winter ice cover or summer stratification may occasionally result in nutrient release from sediment; and seasonal drawdown may increase the general availability of nutrients for algal growth by reducing macrophyte competition.

An increase in growth of nuisance aquatic weeds in shallow shoreline areas in the 1960's and 1970's spurred the initiation of a fall/winter drawdown program for weed control. Beginning in 1976, annual drawdown of the lake water level by two or more feet has been attempted. It appears that overwinter drawdown has helped control the spread of watermilfoil, once the dominant nuisance species in Lake Massapoag. Other types of aquatic vegetation, which are less likely to interfere with recreational activities in the lake, have become more prevalent.

The hydrologic budget for Lake Massapoag indicates that the primary source of water is surface runoff; but that both groundwater inflow and precipitation on the lake are important components. Massapoag Brook is the primary route for water outflow from the lake. The nutrient dynamics of Lake Massapoag indicates the lake is phosphorus-limited. The phosphorus budget reveals that the major source of phosphorus loading is the watershed surface, which incorporates all sources of phosphorus entering tributary streams and direct runoff. Watershed sources include leaching of rock and soil, landfill leachate, septic systems near tributaries, decomposing vegetation, fertilizer, and sediment. Some of these sources are controllable, and some are not. Shoreline septic systems, those within 300 feet of the shoreline, are also a significant source of phosphorus loading to Lake Massapoag; and are amenable to control measures. Other sources of phosphorus are groundwater and the atmosphere; however, their contribution is relatively minor, and uncontrollable.

Based upon the hydrologic and nutrient budget calculations, several models were employed to calculate and predict the trophic status of Lake Massapoag. Model results were compared to in-lake measurements in order to confirm the results. The trophic state of Lake Massapoag is currently in a mesotrophic to borderline mesotrophic-eutrophic range. Using population projections for the Town of Sharon, and assuming that existing septic systems are not upgraded or replaced, the calculated future trophic status (year 2000) of the lake is clearly eutrophic. The goal of the lake and watershed management program should be to prevent future eutrophication of Lake Massapoag by reducing and limiting phosphorus loading, so as to improve and maintain water quality suitable for the variety of recreational uses which the lake currently supports.

The second phase of the diagnostic/feasibility study developed a lake and watershed management program to address the stated goal. Various methods for controlling phosphorus loading to Lake Massapoag were studied to determine their feasibility and relative cost-effectiveness. A six point program, including a range of effective management strategies, is recommended.

- .watershed management practices to reduce dispersed, controllable sources of phosphorus such as detergents, fertilizers, vegetation and other litter

- .a long-range sewage disposal option to reduce/eliminate nutrient loading from shoreline septic systems, with interim measures for immediate implementation

- .wetland protection and enhancement to maintain and increase the pollution attenuation value of existing wetland areas in the watershed

- .landfill leachate control to eliminate nutrient, micro-nutrient and pollutant entry into Sucker Brook from the municipal landfill

- .continued seasonal drawdown to manage aquatic weed populations, with supplemental weed harvesting as desired

- .further monitoring to better define the algal population dynamics in the lake, with the goal of documenting conditions which trigger algal blooms

With implementation of the recommended measures, the future trophic status (year 2000) of Lake Massapoag is projected to improve to a condition of borderline mesotrophic-oligotrophic. Several aspects of the lake and watershed management program may begin immediately; but some will require extensive planning and engineering studies before implementation can proceed. In order to facilitate implementation, the following steps are recommended:

- .formation of a Lake Massapoag watershed association to heighten public awareness, facilitate the dissemination of information, and support implementation of management practices

- .request for assistance to the Division of Conservation Services for funding through the Self-Help Land Aquisition Fund for purchase of certain wetland areas in the watershed

- .request for assistance to the Division of Water Pollution Control for match funding through the Clean Lakes Program for engineering and construction of structural wetland enhancement measures, flow calibration of the Lake's outlet structure, continued monitoring of algae and water quality, and monitoring of the effects of program implementation

.request for assistance to the Division of Water Pollution Control Construction Grants section for match funding for a Facilities Planning Study to include study of the recommended lake shoreline sewage disposal alternative, and to qualify the Town for engineering/construction funding

.retain a qualified consultant to monitor the municipal landfill in compliance with DEQE regulations; and develop a leachate collection and disposal plan, and a landfill closure plan.

2.0 PHYSICAL CHARACTERISTICS OF THE LAKE AND WATERSHED

2.1 Climate

Continuous on-site precipitation, temperature, and evaporation data is unavailable at Lake Massapoag. Instead, comparable data from climatically similar areas has been used to describe the Massapoag area. The 30-year monthly normals of precipitation and temperature at NOAA weather stations in Mansfield and Taunton are tabulated below. These norms were utilized instead of precipitation and temperature data collected during the study period because a 30-year average more accurately describes the long-term hydrologic characteristics of the Lake.

Monthly Climatic Normals (1941-1970)

Month	Precipitation (inches)	Temperature (^oF)
January	3.58	27.5
February	3.54	28.9
March	3.94	36.6
April	3.74	46.8
May	3.56	56.7
June	3.06	65.9
July	3.29	71.4
August	3.95	69.4
September	3.66	62.2
October	3.47	52.5
November	4.94	42.5
December	3.97	30.7
Mean Annual	3.73	49.3

As shown, precipitation is fairly evenly distributed throughout the normal year, though substantial departure from the normals may occur in any particular year. The monthly normals range from 3.06 inches in June to 4.94 inches in November. Snowfall is highly variable from year to year. Summer precipitation consists predominantly of thunderstorms. Runoff is usually highest in the late winter or early spring when snowmelt combined with rainfall flows over typically frozen soil surfaces.

The Atlantic Ocean and Narragansett Bay temper the month to month and diurnal variations of temperature although such variations may still be substantial. The range of normal monthly temperatures is from 27.5^oF in January to 71.4^oF in July. The average length of the growing season (frost free) at Taunton is 139 days, usually from mid May to the end of September.

Evaporation from Lake Massapoag is probably highest in the summer (normal peak = 5.6 inches in July, based upon a 16 year record [1952-67] from Rochester, Massachusetts) because of the high temperatures and long daylight hours. Evaporation values should be lowest during the shorter colder days of the winter months. Ice cover during this period further reduces evaporation from the Lake surface. There is no data concerning ice thickness and the extent of ice cover at Lake Massapoag. However, shoreline residents have observed that ice does not necessarily cover the lake continuously during the winter. Additionally, ice cover is often not continuous across the Lake surface and tends to freeze last at the mouth of the southernmost cove near Camp Gannet, the mouth of the southern cove on the western Lake shore, and near Piper and Stoddard Ledges. Freezing may be retarded in these zones because of possible increased water circulation and temperature resulting from groundwater inflow.

Wind direction is highly variable although southwest flow predominates in the summer and northwest flow predominates in the winter. The regular shape and substantial area of Lake Massapoag, which provide a long fetch, may result in significant wave heights during periods of sustained high winds. Waves from 2.5 to 3 feet high have been observed during a coastal hurricane which generated approximately 60 knot winds in Sharon. Waves one foot high are common during intense 'northeaster' storms.

2.2 Geology, Soils and Topography

The geology of the Lake Massapoag watershed was inventoried through a compilation of existing data and IEP field reconnaissance. Bedrock geology, surficial geology, soil properties and topography were examined to determine their influence on watershed hydrologic characteristics.

The bedrock geology of the watershed was mapped by Lyons (1969) and outcrops were observed during an IEP site visit. There are four bedrock units present in the watershed and all are medium to coarse-grained intrusive igneous rocks. Igneous rocks consist of minerals that crystallized directly from a liquid or molten state. The coarse-grained texture of the rock is due to the fact that the molten rock cooled slowly, allowing some of the individual crystals of the minerals to grow large enough to be seen with the naked eye.

The Barefoot Hill Quartz Monzonite and the Dedham Quartz Monzonite are believed to be Precambrian in age, forming approximately 600 million years before present. The principal mineral constituents of quartz monzonite are plagioclase, orthoclase and quartz, with minor amounts of biotite, hornblende and accessory minerals. The Barefoot Hill unit is a porphyritic variety of the Dedham Quartz Monzonite. Thus, both units probably had the same origin, however the Barefoot Hill Quartz Monzonite has a porphyritic texture that is not observed in the Dedham. A porphyritic texture is one in which the larger crystals in a rock are set in a finer-grained groundmass. These units occur in the southwest corner of the watershed. An outcrop of the Dedham Quartz Monzonite can be seen at the top of the hill between Lakeview Street and East Foxborough Street.

The Massapoag Lake Granite and an unnamed Diorite are believed to be Devonian in age, having formed about 375 million years before present. The Massapoag Lake Granite covers the eastern part of the watershed, with its contact running along the eastern shore of the Lake. Outcrops of this rock unit are numerous in the watershed and were observed during the IEP site visit and can be seen at the intersection of Massapoag Avenue and East Street and at the top of the hill on Mountain Street in the vicinity of the watershed boundary line. The coarse-grained granite has a saprolitic or rotten weathering look when seen in outcrop exposures. The principal mineral constituents are quartz and potassium and sodium feldspars. The dark minerals range from riebeckite (black amphibole) in the northern exposures to biotite in the southern section.

The unnamed Diorite was intruded into the surrounding rocks and is of local origin. It is composed of plagioclase, biotite, hornblende and quartz. Lyons (1969) suggests a ring dike origin for this unit due to its arcuate appearance. The Diorite occupies the northwestern corner of the watershed and forms the upland topography between Sharon Heights and the Sharon town center.

The surficial geology of the watershed was determined through IEP field reconnaissance. This was augmented by domestic well data and test well logs supplied by the United States Geological Survey, Water Resources Division, and test pit data from the Sharon Shire subdivision. There are two main surficial geologic types in the watershed; till and stratified drift. The distribution of these units can be seen in Figure 1, Surficial Geology.

New England was glaciated several times during the Pleistocene Epoch, the last time being between 26,000 years before present (YBP) and 13,000 YBP. This late Wisconsin glaciation extended southward to Long Island, Martha's Vineyard, Nantucket and Cape Cod. By 15,000 YBP the entire area from Canada south was covered by a continental ice sheet almost a mile thick. The till and stratified drift deposits in the watershed were deposited by this glaciation and subsequent deglaciation.

Material deposited directly from the ice with no influence of glacial meltwater is called glacial till. Till was the first unit to be deposited during glaciation and is usually found resting directly on the glacially modified bedrock topography. It is an unsorted, unstratified mixture of sediments that can range from boulders and cobbles down to gravel, sand and silt size particles. Till commonly occurs as a veneer on the bedrock surface, usually less than 10 feet in thickness. However, it may be thicker on the flanks of till covered streamlined hills. The hill between Lakeview Street and East Foxborough Street is a bedrock cored, till covered streamlined hill. The till area in the eastern part of the watershed is a fairly thin deposit and may be discontinuous in places.

Stratified drift deposits occur in the topographically lower portions of the watershed, filling in the low portions of the glacially scoured bedrock topography. These deposits of stratified sands and gravels were formed by meltwater streams flowing from the glacial ice into the low areas between bedrock highs. Due to the their deposition by water, which has a natural sorting process linked to velocity and corresponding sediment transport capacity, these sediments are well sorted and well stratified. The stratified drift deposits can be distinguished morphologically, i.e., according to their landform and topographic expression. The long sinuous ridge east of Massapoag Avenue is an esker, or an ice channel filling. This ridge indicates the position of a meltwater channel in the ice that was flowing prior to or during the retreat of the ice. The flat topped plain with steep sides on which the Sharon Community Center is located is called a kame plain. This landform was deposited by meltwater in an area surrounded by the ice. The steep sides are called ice contact faces and mark the place where the ice stood. When the ice melted away, the sand and gravel collapsed to their present topographic expression. The broad flat areas of stratified drift are outwash plains. Meltwater flowing away from the ice formed these flat, gently sloping plains. Lake Massapoag occupies an ice block depression. A stagnant ice block sat in the location of the lake while the ice around it melted away and deposited sand and gravel. When the ice block melted completely, a depression was left in its place to form the Lake Massapoag basin.

Swamp deposits are recent (last 10,000 years) deposits overlying the glacial units in areas where the water table is at or near the ground surface. They consist of fine sand, silt and clay with less than 50% organic matter. Such wetland areas cover approximately 35% of the Lake Massapoag watershed. They occupy areas northwest, east and south of the Lake and extend over parts of the southeastern portion of the watershed.

During the 1700's the swamp and lake bottom deposits in the Lake Massapoag watershed were mined for bog iron ore. The iron was formed by iron fixing bacteria augmented by naturally occurring iron in the hydrogeologic setting. At first this iron was used to make household and farming tools and later to make cannons and cannon balls during the American Revolution. The distribution of swamp deposits can be seen on Figure 1, Surficial Geology.

The soils of the Lake Massapoag watershed have been mapped by the USDA Soil Conservation Service. The soils present in the watershed were classed into hydrologic soils groups based on their hydrologic properties. This classification system was developed by the Soil Conservation Service and is summarized below (USDA Soil Conservation Service, 1982):

Property	Class A	Class B	Class C	Class D
Infiltration Rate (K)	High	Mod	Slow	Very Slow
Transmissivity	High	Mod	Slow	Very Slow
Runoff Potential	Low	Mod	High	Very High
Depth to Impermeable Layer(s)	-	40"	40"	-

The types of soils present in the watershed and their hydrologic soil classifications are listed in Table 1. The distribution of the four classes of soils can be seen on Figure 2, Hydrologic Soils Groups. The importance of this map is to identify areas of the watershed with regard to their infiltration capabilities. This in turn determines the surface water runoff potential of the area. Class A Soils have a low surface water runoff potential and the potential increases through Classes B, C and D. Thus, Class A is very well drained soil, Class B is moderately well drained, Class C is poorly drained and Class D is very poorly drained.

Hydrologic Soil Group A comprises 405 acres of the watershed, which is 18% of the watershed land area. Group B soils occur on 461 acres which is 21% of the watershed. Seventeen percent of the watershed area (378 acres) is occupied by Group C soils. Five hundred sixty-seven acres in the watershed, 26%, are covered by Group D soils. The Lake, which is 401 acres in size, occupies the remaining 18% of the watershed.

Much of the topography in the Massapoag watershed has been described in the geologic discussion. Summarizing then, the topography is indicative of southern New England glaciated terrain. The till and bedrock regions of the southwestern, southeastern, and eastern highlands of the watershed are composed of rounded hills with slopes ranging from 3 to 15%. Stratified drift and swamp deposits occupy lower elevations within the watershed. Swamps are generally flat-lying and abut streams, the Lake, and occupy minor topographic depressions. Stratified drift deposits are flat-topped with short, steep ice-contact slopes (up to 25%), gently undulating, or elongated and sinuous with ice-contact slopes (i.e., esker along the eastern lake

Table 1 .

Soils in the Lake Massapoag Watershed and Their Hydrologic Classifications

Soil Type	Hydrologic Class
Birdsall	D
Canton	B
Chatfield/Hollis/Rock outcrop	D
Freetown Muck	D
Hinckley	A
Merrimack	B
Montauk	C
Paxton	C
Ridgebury	C
Scarboro Muck	D
Scituate	C
Sudbury	B
Swansea Muck	D
Udorthents	B
Walpole	C
Whitman	D
Windsor	A
Woodbridge	C

shore). Stratified drift deposits surround the Lake and extend away from the Lake into the northwestern, eastern and southern reaches of the watershed.

2.3 Surface and Groundwater Hydrology

2.3.1 Surface Water Hydrology

The Lake Massapoag watershed is located in the Neponset River basin in southeastern Massachusetts. The Lake occupies eighteen percent of the 2212 acre watershed, and receives the majority of its surface water inflow from several tributaries draining the southern and eastern portions of the watershed.

The natural drainage system in the Massapoag watershed can be seen in Figure 3 of the Lake Massapoag Watershed. Sucker Brook is the only named tributary stream to Lake Massapoag. With a contributing area of 635 acres, the brook drains twenty-nine percent of the watershed of the Lake. The outlet of the stream is located along Massapoag Avenue near Camp Wonderland. Flow measurements taken throughout the study period (section 3.2) indicate that of the major inlets, Sucker Brook provides the most consistent flow into the Lake, and may be the major source of surface inflow during summer dry weather.

Two unnamed tributary streams enter Lake Massapoag at the cove on the Lake's southern shore. The larger of the two inlets has a watershed area of 615 acres located south of the Sucker Brook watershed; and reaches the Lake after flowing through a small pond dammed by a dike and weir. The other unnamed tributary enters the cove at Lakeview Street, and has a drainage area of approximately 60 acres. Other minor tributaries and storm drains in developed shoreline areas provide intermittent flow to the Lake. Storm drain locations and the areas contributing drainage to those drains are referenced in section 3.3. Surface water is contributed sporadically through storm drains, most often during and for a short period after storm events.

The outlet of Lake Massapoag is located at the northeastern end of the Lake at the intersection of Massapoag Avenue with Cedar, Pond and East Streets. The outlet consists of a control structure which releases water to Massapoag Brook. The structure has been used in recent years to control the water level of the Lake. The structure is maintained at a normal surveyed elevation of 252.56 feet, except for when the structure is depressed to 250.86 feet over the colder months in order to control vegetation growth.

The drainage divide that separates the Lake Massapoag watershed from other drainage systems can also be seen in Figure 3. This drainage divide was initially determined from the USGS 7.5' topographic map of the area. Revisions to this preliminary delineation were made on the basis of field

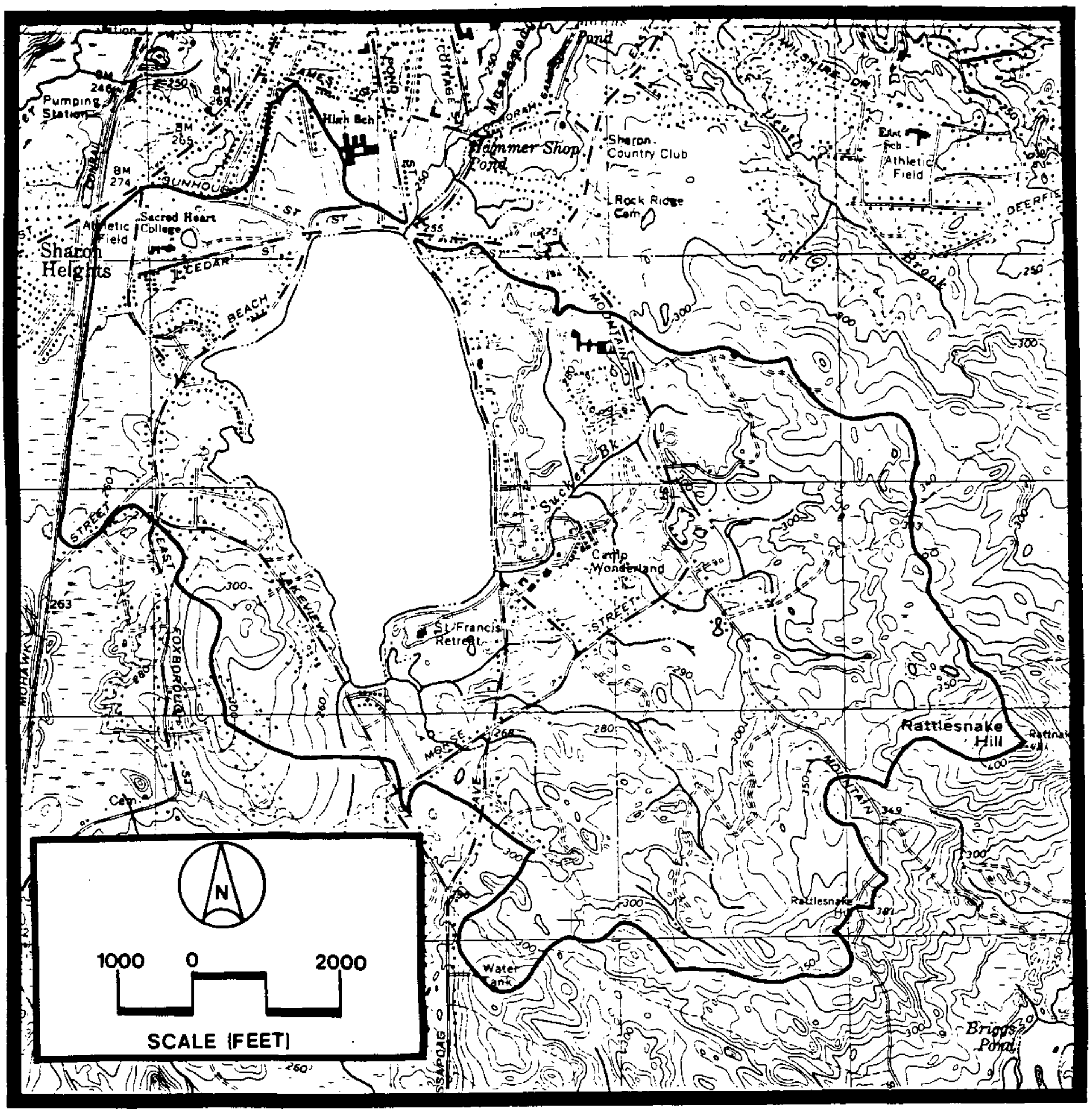

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FIGURE 3

LAKE MASSAPOAG WATERSHED

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surveys. In the region west of Lake Massapoag, four monitor wells were established and water table elevations were surveyed over a period of months in order to determine the direction of groundwater flow. On the basis of these data, the drainage divide was mapped east of the railroad tracks. Watershed boundaries in other areas of the drainage basin were checked and corrected by field inspection of surface drainage.

Monthly precipitation data used in this study is based on a 30 year norm. Further discussion about the precipitation and other climatic considerations influencing the surface hydrology is seen in section 2.1.

2.3.2 Groundwater Hydrology

The geologic deposits and the water table gradients within the moderately developed watershed of Lake Massapoag are the primary factors considered in determining groundwater flow rates and flow volumes. The more permeable stratified drift deposits occur throughout approximately 50% of the watershed. The northwest, southwest, and southeastern edges of the Lake are bordered by drift deposits. Water table gradients are inclined toward the Lake in stratified drift deposits, thus these areas are considered groundwater inflow zones (section 4.0). The northeastern section of the Lake is underlain by an accumulation of finer lake-bottom deposits, and because the groundwater table gradient appears to be inclined away from the Lake, this area is considered a groundwater outflow zone (section 4.0). Large areas of less permeable till make up the topographically high areas in the southeastern and southwestern sections of the watershed.

As indicated above, recharge to the groundwater supply contributing to the Lake occurs primarily through stratified drift deposits. This is due largely to the contrast in permeabilities and runoff characteristics (in addition to vegetation cover, depth to water table, etc.) associated with the different geologic regions in the Massapoag watershed. Areas underlain by till and bedrock generally have steeper land surface gradients and lower permeabilities, thus reducing the amount of infiltration and increasing surface water runoff. Stratified drift areas, however, are generally characterized by gentler topography and higher permeabilities, thus more infiltration and less runoff occur in these areas.

The regional groundwater movement in the Lake Massapoag watershed is from the southeast to the northwest. The water table gradient is steeper in areas of till than in stratified drift. Regionally, it appears that groundwater is entering the lake from all directions with the exception of the northeast.

The groundwater gradient is important in determining groundwater flow values. A modified Darcian equation, velocity of groundwater flow =

$$\frac{\text{(hydraulic gradient)(hydraulic conductivity)}}{\text{porosity}}$$

incorporates the water table gradient with geologic parameters to determine flow rates. Low porosity till deposits also exhibit low hydraulic conductivities. Till deposits will therefore contribute much less groundwater flow to the lake than the drift deposits. Because of this, the southeastern section of the Lake will contribute a larger percentage of surface water and a smaller percentage of groundwater to the Lake.

In order to monitor the water table elevation near the Lake, a dozen monitor wells were installed by IEP personnel. The wells are 1 1/4" diameter brass/stainless 30" well screens which allow groundwater to stabilize inside them at the natural piezometric surface. These wells were also used for conducting permeability tests and for the collection of water samples intended to be representative of background water quality. The permeability tests are called slug injection tests. They are useful in areas having conductivities too small to conduct a pump test or where pump testing is impractical. The test involves injecting a measured quantity of water into a well of known volume. The rate at which the water level decreases is controlled by the hydrogeologic characteristics of the materials in which the screen is located. Permeabilities were assigned to the geologic deposits surrounding Lake Massapoag based upon the slug injection test results, field observations and permeability values found in the literature. The stratified drift deposits were assigned a permeability of 500 gpd/ft^2. This means that in one day, 500 gallons of 60^{0}F water will flow through one square foot of this material under a hydraulic gradient of 1.00 (vertical). The finer lake bottom deposits were assigned a permeability of 10 gpd/ft^2 because of the much smaller pore spaces, reduced pore interconnection, and increased cohesion between groundwater and sand/silt particles. The permeability values will be applied to the groundwater component of the hydrologic budget in section 4.0.

2.4 Land Use and Development

Table 2 summarizes land use and land cover types found within the Lake Massapoag watershed. The distribution of land use and cover types was determined from areal photographs (Town of Sharon Department of Public Works) combined with field checking by IEP. A breakdown of total acreage and relative percent coverage of each type is also provided. This information is critical in assessing watershed nutrient sources and loadings and will be utilized in the development of a watershed nutrient budget. Figure 4 shows the distribution of these land use types.

Table 2. Land Use/Cover Types

Forest	1297 acres,	59%
Open Land	60 "	2%
Pasture	17 "	1%
Agricultural	21 "	1%
Residential	389 "	17%
Institutional	14 "	1%
Lake	401 "	18%
Landfill	24 "	1%
	2212 acres	

Despite its fairly intensive shoreline development, a large part of the Lake Massapoag watershed is forest cover. Residential uses, mostly occurring as scattered subdivision development across the watershed, comprise the second-most prominent cover type. The remaining open pasture, agricultural, institutional and other special land uses make up the balance of land cover within the watershed, and individually constitute 1 to 2% of the total watershed area.

Historically, land uses in the Massapoag watershed have taken two forms - those directly associated with the Lake and those independent of the Lake. As documented by the Sharon Bicentennial Committee (1976), iron ore was extracted from extensive bog iron deposits that were excavated from the Lake floor beginning around 1724. Lake ice was another resource in the late 1800's and provided a flourishing business through the early 20th century. Contemporaneously, mills were established downstream from the Lake on Massapoag Brook. The sole land use independent of the Lake was the cedar trees that were harvested from surrounding swamps for use as posts and rails in the early 1800's.

Development in Sharon and around Lake Massapoag took place without restriction until 1933. By this time the Town had recognized that in order to maintain their comfortable residential and aesthetic lakeside environment, a townwide zoning law assigning 10,000 ft^2 per residence had to be adopted. This zoning pattern was observed until post World War II at which time the Town established a 40,000; 20,000 and 10,000 ft^2 zoning pattern. Under this zoning, development in the downtown area was maintained at 10,000 ft^2 per residence; lakeside development was further restricted to 20,000 ft^2 extending out to South and North Main Streets and Walpole Street; and 40,000 ft^2 beyond this area to the Town line. In the late 70's, the Town recognized the need for more watershed resource protection and thereby restricted all development to 80,000 ft^2 per lot.

Development in the Massapoag watershed is of particular importance because it has a direct impact on the amount and quality of surface water and groundwater contributing to the Lake. Increased development is often directly correlated with an increase in poorer quality surface water runoff. Concurrent with an increase in surface water runoff, less water may infiltrate into the groundwater supply, thus potentially reducing groundwater inflow to the Lake. Groundwater quality, particularly along the Lake shore, will also degrade over time with the increased number of septic systems commensurate with increased development.

How the runoff and recharge characteristics of the Lake Massapoag watershed change with development is not only dependent upon how much area is covered over by impermeable surfaces, but also upon the character of the land developed in terms of the permeability of the geologic material, land surface slope and degree of vegetation. Generally, till and bedrock regions naturally create more runoff and less groundwater recharge, whereas stratified drift regions allow more infiltration and recharge to the groundwater supply. Thus, development of stratified drift regions not only increases runoff to the Lake but also reduces the major form of recharge to the groundwater supply. Development of till and bedrock regions increases runoff, but has less impact on the groundwater supply.

Heightened development within the Lake Massapoag watershed has also necessitated the installation of a storm drain network to facilitate drainage in the developed areas. The location of the drains and the areas that are serviced by them is referenced in section 3.2. Storm drains channel poorer quality surface water runoff from roofs and hard-tops directly into the Lake. Such drainage has two primary impacts: (1) surface water that may normally have infiltrated into the groundwater supply is maintained as surface water; and (2) a degree of natural filtration that occurs as water transmits through soil does not happen, thus further degrading the overall Lake water quality.

2.5 Morphometry, Bathymetry and Bottom Sediment Types

2.5.1 Morphometry

The morphometric data for Lake Massapoag is presented in Table 3. Lake Massapoag is a relatively large lake, comprised of one major basin with a surface area of 401 acres. It has a maximum depth of 45 feet and a mean depth of 14.59 feet. The Lake's axis trends north-south with a maximum length of 6831 feet (1.29 mi). The maximum length, similar to maximum width, is the maximum length between shorelines. In Lake Massapoag, the maximum width, 4068 feet (0.77 mi), is nearly two thirds the Lake's length. Because there are no topographical features such as islands or peninsulas extending into the Lake, the maximum length and maximum effective length, as well as maximum width and maximum effective width figures are equivalent. This

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TABLE 3

LAKE MASSAPOAG MORPHOMETRIC DATA

Drainage Area (including lake surface area), A = 2239.4 acres = 3.498 mi^2

Lake Area, A_0 = 397.0 acres = 17.29 x 10^6 ft^2

Maximum Depth, Z_{max} = 45 ft (WRRC, 1972)

Maximum Length, L_{max} = 6831 ft

Maximum Effective Length = 6831 ft

Maximum Width, W_{max} = 4068 ft

Maximum Effective Width = 4068 ft

Lake Volume, V = 252.34 x 10^6 ft^3

Mean Depth, $\bar{z} = V/A_0$ = 14.59 ft

Shoreline Perimeter, P = 20,700 ft

Mean Width, $\bar{w} = A_0/L_{max}$ = 2531 ft

Mean to Maximum Depth Ratio = 0.32

Development of Shoreline = 1.40

Development of Volume = 0.97

Flushing Rate ρ = 1.157/yr

Retention Time (turnover time), τ = 0.864 yr

Hypolimnion Volume = 14.104 x 10^6 ft^3

Depth to Hypolimnion = 27.9 ft

feature influences the effect of wind and wave action, and current and sedimentation patterns within the Lake.

The total volume of Lake Massapoag, being the sum of successive contour volumes, is 252.34 x 10^6 cubic feet. The development of volume is a ratio that compares the three-dimensional shape of a body of water to that of a cone (1.0). In Lake Massapoag, the development of volume is 0.97, thus it is very regular in form.

The length of shoreline is a measurement of the lake's perimeter, determined from the base map (Figure 1) with a rotometer. Its value is 20,700 feet (3.92 mi.) in Lake Massapoag. The development of shoreline is 1.40, indicating that the Lake has a slightly irregular shoreline in comparison to the circumference of a circle with an area equal to that of the Lake.

The drainage area of Lake Massapoag is relatively small (3.46 square miles), with a ratio of lake area to drainage area being 0.18. In general, the larger the drainage area is in relation to the size of the lake, the greater the contribution of nutrients. However, the flushing rate is also increased, therefore the productivity of the lake may not increase with a larger watershed.

Morphometrically, Lake Massapoag is a relatively uniform body of water, unique in its symmetry and homogeneity. In many of the values mentioned above, the Lake approximates that of a standard measurement. Due to the lack of extraordinary morphometric conditions, it appears that Lake Massapoag's physical properties do not uniquely affect water quality or trophic status or present special considerations for management.

2.5.2 Bathymetry

A bathymetric map depicting the bottom contours of Lake Massapoag is presented in Figure 5. The Massachusetts Division of Fisheries and Wildlife, as well as the Massachusetts Division of Water Pollution Control have produced bathymetry maps of Lake Massapoag; however, the map that is illustrated in this report has been prepared by IEP utilizing a base map with surveyed data points provided by the Town of Sharon. The exact date and origin of the base map are unknown, although Tim Walsh, a Town Engineer, feels that it may have been produced in the early 1960's due to the presence of the St. Francis Retreat Lodge which was acquired in 1957. This has been confirmed by a Sharon citizen who recalls a state agency performing depth soundings of Lake Massapoag in the early 1960's.

Lake Massapoag is composed of a single major basin with a gently sloping shoreline. Its shallow edges provide a large area within the littoral zone

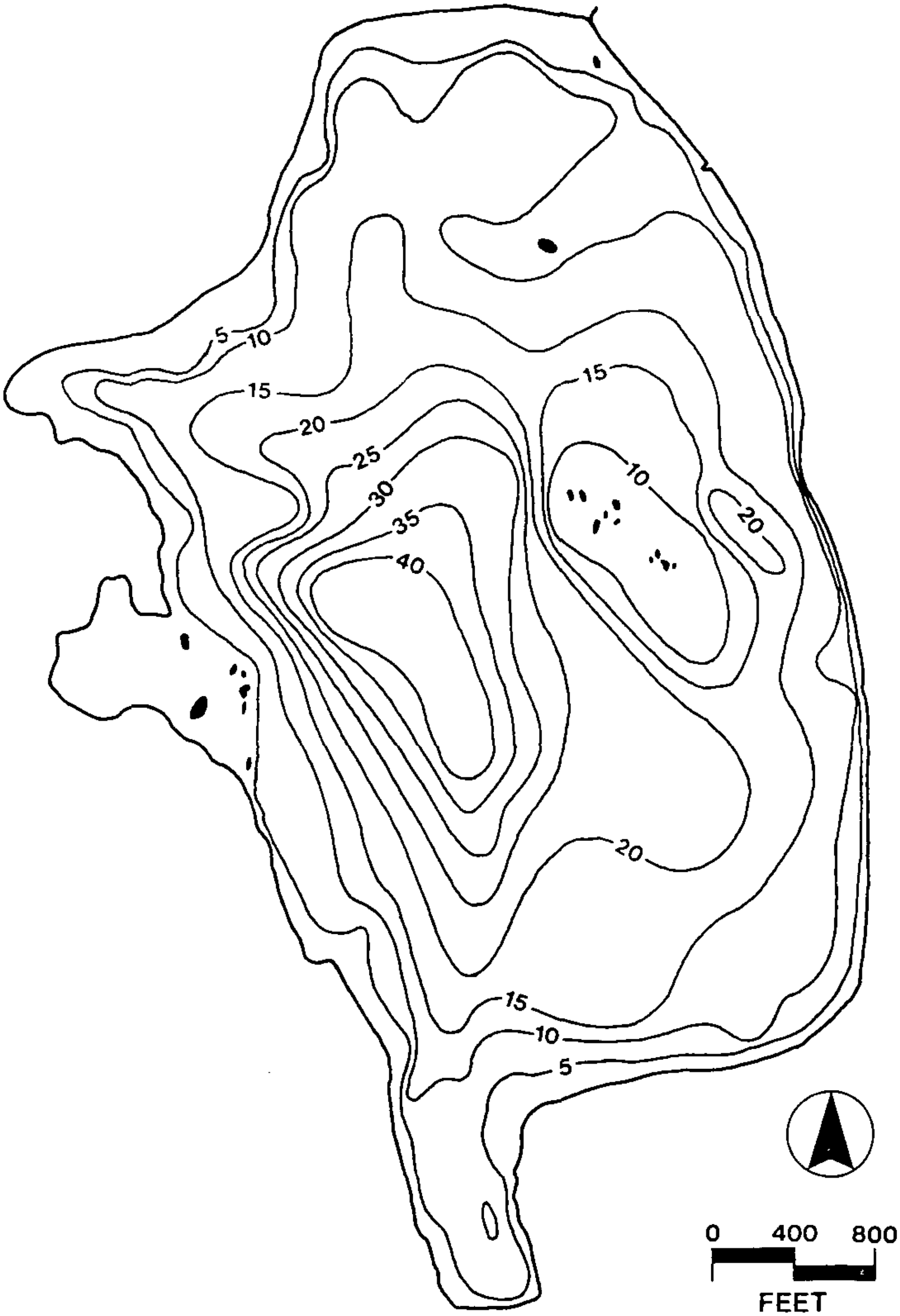

FIGURE 5
BATHYMETRIC MAP
WATER DEPTH IN FEET

LAKE MASSAPOAG DIAGNOSTIC / FEASIBILITY STUDY, IEP Inc.

allowing for the growth of rooted aquatic vegetation. The slope in the center of the Lake sharply descends to a maximum recorded depth of 45 feet.

Not illustrated on the bathymetric map are the areas where iron ore was mined from the Lake in the form of 'bog iron' during the Industrial Revolution (mid-1700's). Because of the mining, there may be isolated areas in Lake Massapoag that are deeper than the maximum recorded depth. However, they have not been surveyed or observed by divers (Gordon, personal commun.) and hence are excluded from the bathymetric map.

2.5.3 Bottom Sediment Types

The bottom substrate of Lake Massapoag was delineated by IEP personnel on September 24, 1981 (Figure 6). A total of 33 sampling stations were surveyed around the perimeter of the Lake, out to 60 feet from the shoreline. Utilizing a 1/2" stainless steel rod (peat probe) to determine the sediment composition, the four dominant substrate types were designated as sand, sand and gravel, silty organics, and rocks and boulders.

The most common substrate encountered was sand and gravel, extending from the western shore to the Town beach at the northern end, down to the beach at the southern shore. This substrate type, as well as fine to medium sand, is representative of areas with higher wave energy conditions whereby silty organics are usually flushed out. The most significant amount of vegetation occurs in areas dominated by a sand and gravel substrate. Pondweeds, brittleworts and milfoil inhabit the zones occupied by this sediment type. These aquatic plants are able to adapt to a variety of substrates and will proliferate where there is less competition with other species for available nutrients. Sand and gravel is not an ideal substrate for more particular species such as pickerelweed and cattail, thus they do not colonize these areas.

A silty organic substrate was encountered in substantial amounts along the southern cove and in front of the yacht club. In these areas, the sediments reached depths of 1-4 feet. Silty organics are representative of quiet, low energy sediment deposition. The region in front of the yacht club, characterized by up to 4 feet of organics, does not support rooted aquatic vegetation primarily due to the depth of the substrate which prevents the attachment of shallow root structures. Although this area is within the photic zone, there is probably some restriction on the amount of light available for vegetation due to the large number of boats moored throughout the growing season. Further documentation of the sediment types was supplied by Ron Gordon of the Lake Management Committee who completed an underwater survey of Lake Massapoag in 1969. He observed two other areas with substantial amounts of silty organics. On the eastern shore of the Lake, silty sediments occupied depths greater than 20 feet. On the western shore

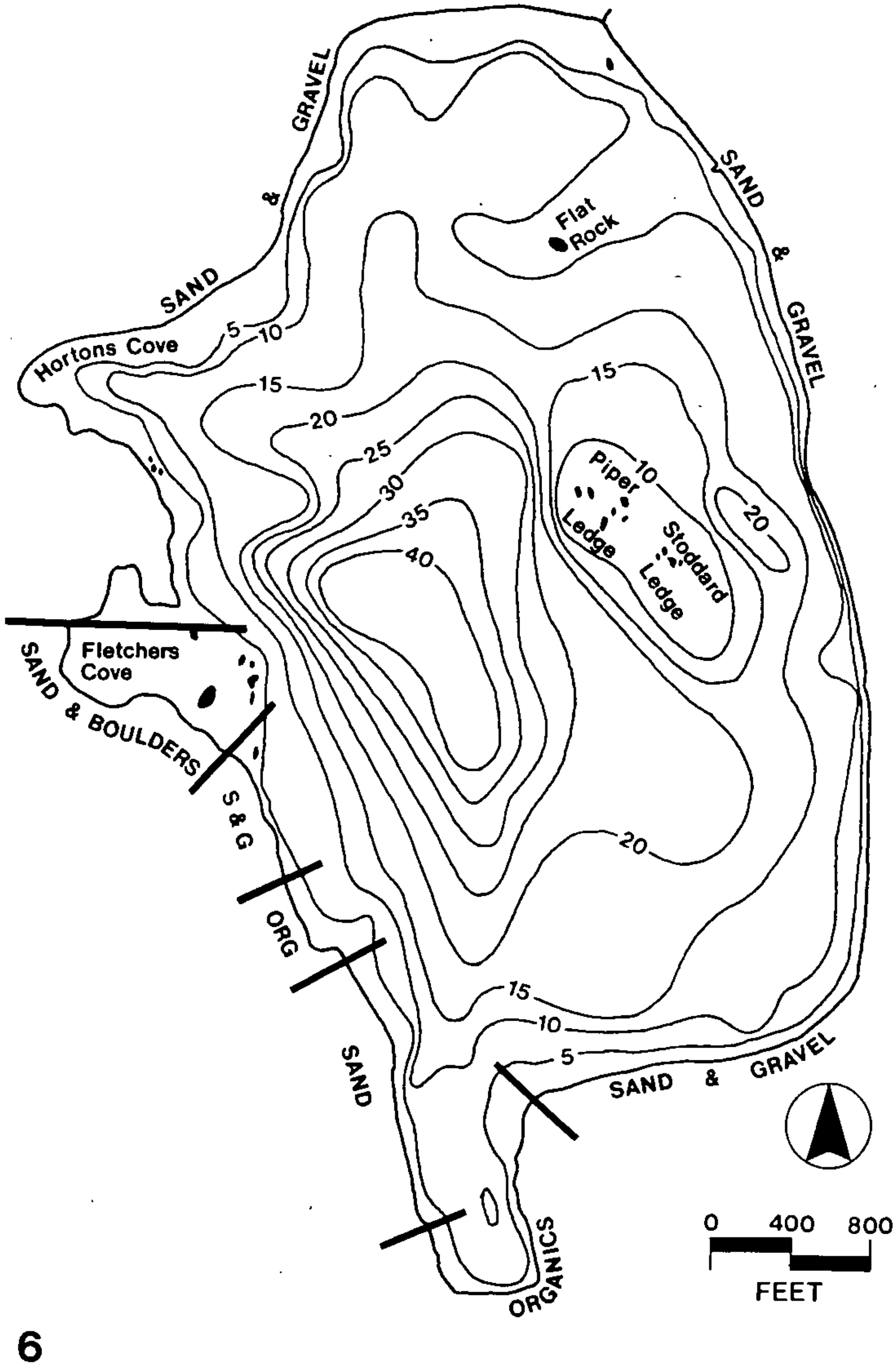

FIGURE 6
SUBSTRATE TYPE

LAKE MASSAPOAG DIAGNOSTIC / FEASIBILITY STUDY, IEP Inc.

near Horton's Cove, a small area having depths greater than 23 feet, was predominantly composed of silt. Other areas delineated by Ron Gordon are comparable to IEP's 1981 survey of the substrate types found within 60 feet of the Lake Massapoag shoreline.

Cobbles and boulders were surveyed by yacht club members and were found to occur in numerous isolated patches throughout Lake Massapoag, thereby dictating caution to boaters (Figure 7). Fletcher's Cove is a very shallow area with water depths of up to 6 feet. It has many cobbles scattered throughout that reach a depth to 13 inches below the normal high water level. A large exposed boulder also exists at the mouth of Fletcher's Cove. In the center of the Lake, Piper Ledge (also termed The Ledges) and Stoddard Ledge comprise a very rocky substrate in which several large boulders exist, from 6 to 52 inches below the Lake surface. Flat Rock occurs in the northern reaches of Lake Massapoag, 34 inches below normal high water.

In general, the shoreline of Lake Massapoag has a very uniform substrate, predominantly composed of sand and gravel. Silty organics occur in quiet areas which allow for settling and accumulation of sediments, however this substrate type makes up a small percentage of the overall sediment composition in the Lake.

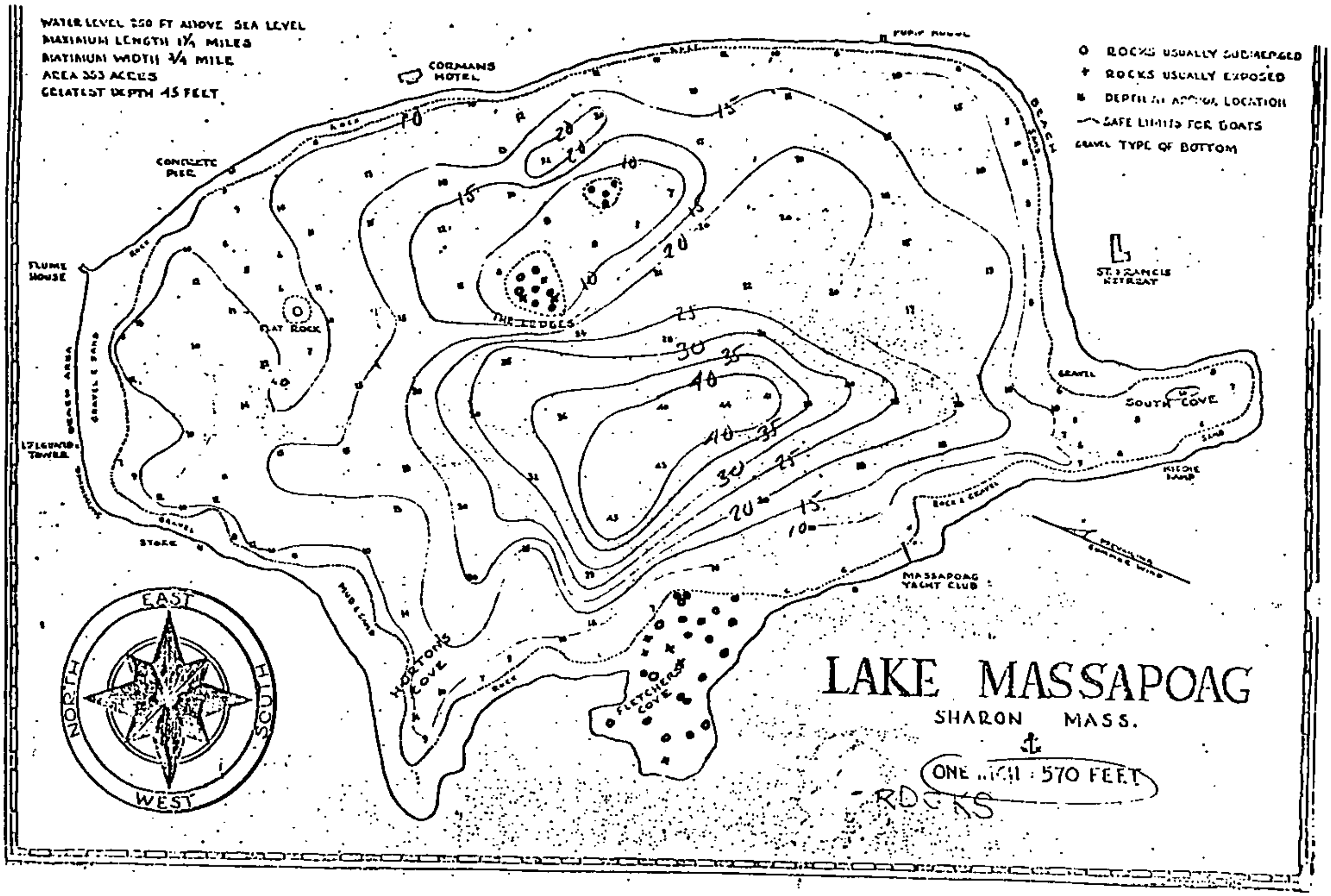

Figure 7. Boaters Map-based on a map from the Sharon Engineering Department
(Town of Sharon Engineering Dept.)

3.0 WATER QUALITY AND AQUATIC ECOLOGY

Fundamental to an understanding of the health of a waterbody is a knowledge of the quality of its water and of the vegetative life which grows there. Furthermore, the quality of incoming and outflowing waters can reveal much about sources, quantities and fates of nutrient inputs.

Prior to initiation of this study, USEPA, the Massachusetts Division of Water Pollution Control, the Town of Sharon and interested citizens had at various times conducted water quality and vegetative surveys of the Lake. In order to bring these data up to date, IEP and the MDWPC as part of this study conducted a year long sampling program designed to analyze inflowing waters (tributary streams, groundwater and storm water), and outflowing waters, as well as water in the Lake. It was determined that this information would be useful in assessing the existing condition of the Lake and any observable trends.

A similar approach was taken in the identification and mapping of aquatic vegetation within the Lake. During the summers of 1981 and 1982, IEP aquatic biologists conducted vegetation surveys of the Lake. These, in comparison to each other and other past surveys, were used to chart trends in rooted aquatic plant, as well as algal growth.

The following six sections present and discuss findings of surveys conducted as part of this study. This information is incorporated in section 5 which presents a nutrient budget for Lake Massapoag.

3.1 In-Lake

Eight rounds of in-lake samples were collected at Lake Massapoag between April of 1981 and March of 1982. The in-lake water quality sampling station (Station 1 in Figure 8) was located at the deepest portion of the Lake. During each round, samples were collected at depths of 0.5, 2.0, 3.5, 5.0, 6.5, 8.0, 9.5, 11.0 and 12.5 meters below the surface of the Lake. The Massachusetts Division of Water Pollution Control collected and analyzed the first four rounds of samples (April 16 to July 9, 1981), while IEP's aquatic biologists conducted the remaining four sample rounds. During each sample round, measurements were made for a temperature-dissolved oxygen profile between the Lake surface and bottom, using a YSI Model temperature-oxygen meter. Water samples collected in the field were kept on ice and delivered to Reitzel Associates in Boylston, Massachusetts for analysis. Parameters analyzed included total phosphorus, the inorganic and organic nitrogen series, pH, suspended and total solids, alkalinity, specific conductance, hardness, chloride, total and fecal coliform bacteria, and fecal streptococci bacteria. Results of the analyses are shown in Table 4.

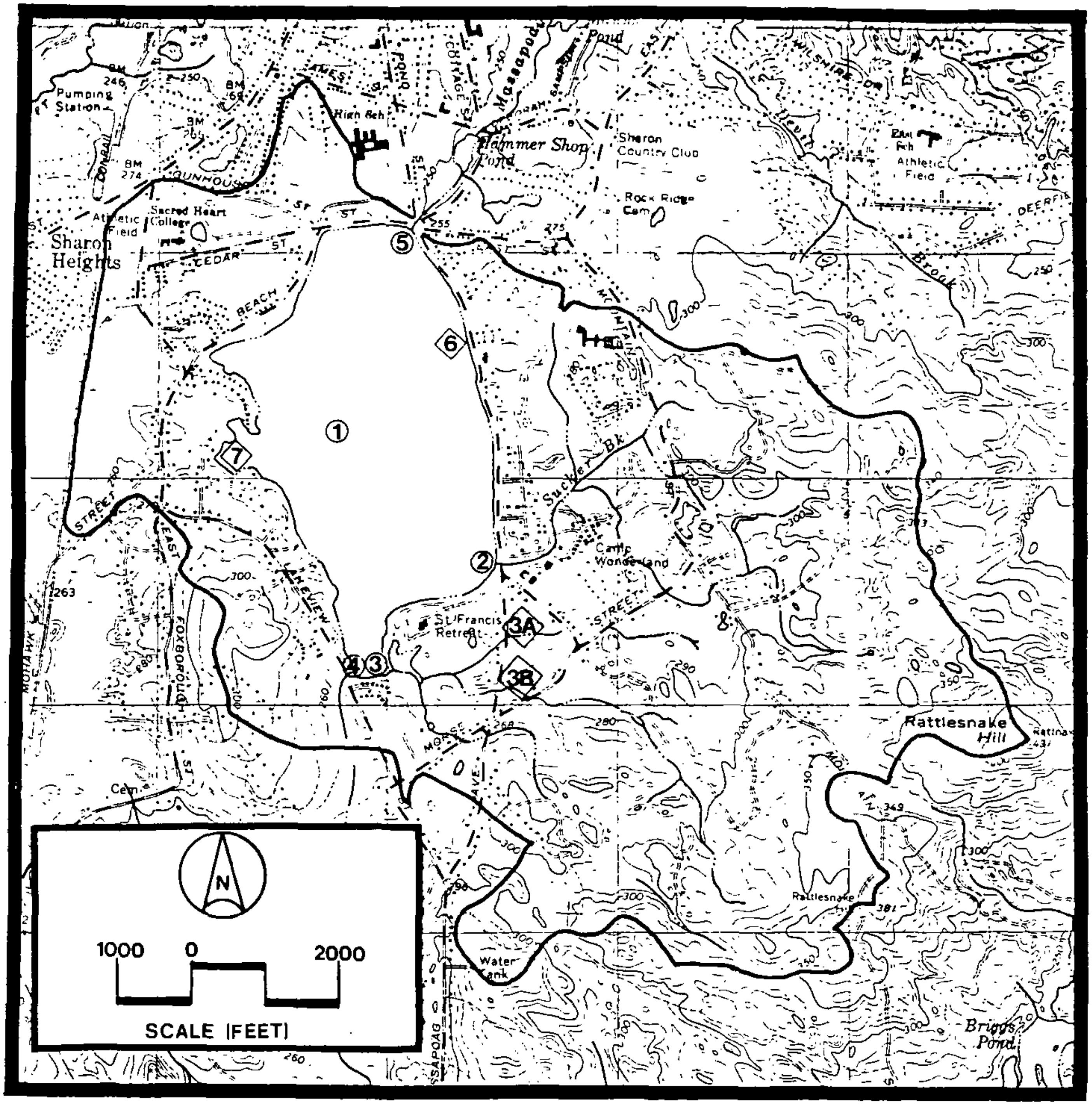

FIGURE 8

LAKE MASSAPOAG WATER QUALITY SAMPLING LOCATIONS

◇ DWPC STATION 1981

○ DWPC & IEP STATION 1981 - 1982

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LAKE MASSAPOAG DIAGNOSTIC/FEASIBILITY STUDY

RESULTS OF WATER QUALITY ANALYSES LAKE MASSAPOAG (SPRING 1981-SPRING 1982) DEEP HOLE, STATION 1

Depth		Date of Collection	pH	Alkalinity*	Bacteria - Total Coliform**	Bacteria - Fecal Coliform**	Bacteria - Fecal Streptococci**	Nitrogen - Ammonia*	Nitrogen - Kjeldahl*	Nitrogen - Nitrate*	Phosphorus Total*	Suspended Solids*	Chloride*	Iron*	Chlorophyll-a (mg/m³)	Transparency (ft)	Specific Conduc. (umho/cm)	Total Solids	Hardness	Manganese
0.5M	MDWPC	4/16/81	6.3	8.0	120	60	5	0.59	0.76	0.30	0.03	5.0	16.0	0.05	-	4.5	98	38	20.0	0.01
		4/29	6.2	6.0	<10	< 5	-	0.00	0.28	0.00	0.03	2.0	14.0	0.03	-	6.0	110	64	20.0	0.01
		6/11	6.5	4.0	20	< 5	-	0.04	0.82	0.00	0.05	4.0	11.0	0.19	-	3.0	98	82	22.0	0.08
		7/9	5.8	4.0	<10	<10	-	0.02	0.40	0.00	0.06	2.0	0.0	0.03	-	6.0	70	64	21.0	0.05
	IEP	8/31	5.6	8.8	-	21	0	0.17	0.30	<0.01	0.02	1.3	16.6	0.04	4.36	15.0	140	-	16.5	-
		10/15	-	6.9	-	-	2	0.04	0.59	<0.01	0.01	<2.0	16.2	0.05	2.20	11.2	-	-	-	-
		1/27/82	6.3	-	<10	<10	<10	0.08	0.80	0.33	0.03	-	-	-	1.51	-	-	-	19.9	-
		3/25	6.2	-	60	10	10	0.08	0.94	0.38	0.04	-	-	-	4.53	7.0	-	-	-	-
		x̄	6.1	6.3	38	17	5	0.13	0.61	0.13	0.03	2.7	12.3	0.07	3.15	7.5	103	62	19.9	0.04
2.0M	MDWPC	4/16/81	6.4	8.0				0.05	0.66	0.10	0.03	5.0	15.0	0.05			98	20	20.0	0.02
		4/29	6.4	7.0				0.01	0.37	0.00	0.02	2.0	14.0	0.02			110	54	19.0	0.00
		6/11	6.1	3.0				0.04	0.94	0.00	0.03	4.0	10.0	0.01			98	72	20.0	0.03
		7/9	7.3	9.0				0.04	0.48	0.00	0.03	3.0	11.0	0.03			70	68	21.0	0.05
	IEP	8/31	5.3	8.7				0.12	0.41	<0.01	0.05	1.2	16.3	0.04			150	-	18.1	-
		10/15	-	6.6				0.09	0.61	<0.01	<0.01	<2.0	16.2	0.07			-	-	17.3	-
		1/27/82	5.7	-				0.08	0.61	0.53	0.03	-	-	-			-	-	-	-
		3/25	6.1	-				0.09	2.58	0.32	<0.01	-	-	-			-	-	-	-
		x̄	6.2	7.1				0.07	0.83	0.12	0.03	2.9	13.8	0.04			105	53	19.2	0.03
3.5M	MDWPC	4/16/81	6.4	9.0				0.01	0.68	0.00	0.03	5.0	15.0	0.04			98	12	19.0	0.01
		4/29	6.5	8.0				0.02	0.78	0.00	0.04	2.0	15.0	0.05			110	66	20.0	0.01
		6/11	6.2	3.0				0.01	0.86	0.00	0.03	2.0	9.0	0.00			98	74	20.0	0.05
		7/9	5.8	5.0				0.02	0.33	0.00	0.02	4.0	10.0	0.03			70	54	21.0	0.06
	IEP	10/15	-	7.6				0.08	0.58	<0.01	0.01	<2.0	15.7	0.06			-	-	16.7	-
		1/27/82	5.7	-				0.20	0.65	0.16	0.02	-	-	-			-	-	-	-
		3/25	6.1	-				0.08	2.35	0.40	<0.01	-	-	-			-	-	-	-
		x̄	6.1	6.5				0.06	0.89	0.08	0.02	3.0	12.9	0.04			94	52	19.3	0.03
4.0M	IEP	8/31/81	6.2	9.3				0.15	0.24	<0.01	0.02	0.33	15.4	0.06			120	-	18.1	-
5.0M	MDWPC	4/16/81	6.5	9.0				0.13	0.61	0.00	0.03	4.0	14.0	0.05			98	14	19.0	0.01
		4/29	6.5	7.0				0.01	0.58	0.00	0.03	2.0	14.0	0.02			110	40	19.0	0.02
		6/11	6.1	5.0				0.44	0.92	0.10	0.02	3.0	18.0	0.00			98	78	20.0	0.03
		7/9	6.6	9.0				0.07	0.48	0.00	0.03	1.0	7.0	0.08			70	58	21.0	0.18
	IEP	8/31	6.3	8.6				1.24	1.37	<0.01	0.02	0.40	16.4	0.06			140	-	16.9	-
		x̄	6.4	7.7				0.38	0.79	0.02	0.03	2.0	13.9	0.04			103	48	19.1	0.06
6.5M	MDWPC	4/16/81	6.5	7.0				0.01	0.65	0.00	0.03	4.0	15.0	0.06			98	12	19.0	0.02
		4/29	6.5	7.0				0.01	0.49	0.00	0.02	3.0	14.0	0.04			110	40	19.0	0.01
		6/11	6.0	7.0				0.02	0.71	0.10	0.02	4.0	12.0	0.00			96	76	20.0	0.02
		7/9	5.6	11.0				0.28	0.46	0.00	0.01	1.0	6.0	0.20			80	70	22.0	0.59
	IEP	10/15	-	7.2				0.08	0.63	<0.01	0.02	<2.0	16.1	0.06			-	-	18.1	-
		1/27/82	5.4	-				0.10	0.69	0.16	0.03	-	-	-			-	-	-	-
		3/25	6.0	-				0.12	0.72	0.40	<0.01	-	-	-			-	-	-	-
		x̄	6.0	7.8				0.09	0.62	0.10	0.02	2.8	12.6	0.07			96	50	19.6	0.16
8.0M	MDWPC	4/16/81	6.4	7.0				0.27	0.81	0.90	0.04	4.0	14.0	0.07			98	14	20.0	0.02
		4/29	6.4	7.0				0.00	0.54	0.00	0.03	2.0	14.0	0.05			110	36	19.0	0.00
		6/11	5.9	6.0				0.02	0.44	0.00	0.03	2.0	11.0	0.05			98	76	20.0	0.41
		7/9	6.7	13.0				0.10	0.34	0.00	0.02	1.0	8.0	0.14			70	78	22.0	2.40
		x̄	6.4	8.3				0.10	0.53	0.20	0.03	2.3	11.8	0.08			94	51	20.3	0.71
8.5M	IEP	8/31/81	6.3	-				-	-	-	-	-	-	-			150	-	-	-
9.5M	MDWPC	4/16/81	6.4	8.0				0.01	0.67	0.10	0.03	6.0	14.0	0.05			98	16	19.0	0.01
		4/29	6.3	8.0				0.01	0.62	0.00	0.03	2.0	14.0	0.04			110	44	19.0	0.01
		6/11	5.9	10.0				0.15	0.47	0.00	0.01	1.0	13.0	0.06			98	86	20.0	0.62
		7/9	5.8	12.0				0.20	0.47	0.20	0.03	5.0	13.0	0.94			90	70	22.0	4.00
	IEP	8/31	6.1	32.6				1.30	1.84	0.01	0.19	0.5	15.9	5.80			180	-	28.9	-
		10/15	-	6.8				0.06	0.63	0.01	0.01	<2.0	16.6	0.06			-	-	17.3	-
		1/27/82	5.3	-				0.13	0.68	0.22	0.03	-	-	-			-	-	-	-
		3/25	6.0	-				0.07	0.44	0.39	<0.01	-	-	-			-	-	-	-
		x̄	6.1	12.9				0.26	0.73	0.10	0.04	2.8	14.4	1.16			115	54	21.0	1.16
11.0M	MDWPC	4/16/81	6.5	9.0				0.03	0.75	0.10	0.03	5.0	14.0	0.07			98	16	19.0	0.00
		4/29	6.3	6.0				0.03	0.49	0.00	0.03	3.0	14.0	0.05			110	46	18.0	0.01
		6/11	6.0	10.0				0.03	0.80	0.00	0.04	3.0	11.0	0.12			98	74	20.0	1.10
		7/9	6.8	14.0				0.24	0.64	0.00	0.04	6.0	12.0	2.00			95	78	23.0	4.00
		x̄	6.4	9.8				0.08	0.67	0.03	0.04	4.3	12.8	0.56			100	54	20.0	1.27
12.0M	MDWPC	6/11/81	6.0	10.0				0.24	0.70	0.00	0.03	2.0	10.0	0.30			105	86	20.0	2.4
		7/9	5.8	19.0				0.30	0.71	0.00	0.04	6.0	15.0	2.50			90	88	23.0	4.2
		x̄	5.9	14.5				0.27	0.71	0.00	0.04	4.0	12.5	1.40			98	87	21.5	3.3
12.5M	IEP	8/31/81	6.3	34.7				1.13	1.68	<0.01	0.29	3.0	15.1	7.60			150	-	31.8	-
		10/15	-	7.7				0.08	<0.01	-	0.03	3.0	16.7	0.09			-	-	16.2	-
		1/27/82	5.3	-				0.16	0.72	0.21	0.03	-	-	-			-	-	-	-
		3/25	6.0	-				0.07	0.20	0.25	<0.01	-	-	-			-	-	-	-
		x̄	5.9	21.2				0.36	0.65	0.16	0.09	3.0	15.9	3.80			150	-	24.0	-

- No Data Reported
* mg/l
** colonies/100 ml. sample (mf)

The temperature and dissolved oxygen profiles for Lake Massapoag are shown graphically in Figures 9 and 10. The Lake was found to be thermally stratified on August 31, with a 10°C temperature difference between the surface and bottom (12.5m). A thermocline had developed at a depth of around 8 meters. The temperature profiles for June and July indicate the development of stratification through the early summer period. Clinograde dissolved oxygen profiles for June, July and August all indicate a lack of mixing during the summer months, and the development of an anoxic hypolimnion. At the Lake surface, the dissolved oxygen concentration remained near 8.0 mg/l, with a sharp decline (approaching 0 mg/l) between 5 and 10 meters. The clinograde oxygen profiles recorded at Lake Massapoag during the 1981 water quality surveys are characteristic of a highly productive or eutrophic waterbody.

Total phosphorus exhibited an increase from the Lake surface to bottom during the August 31 survey of 0.02 to 0.29, respectively. Based on the Massachusetts Division of Water Pollution Control's Lake Classification System (January, 1980), epilimnetic phosphorus concentrations in this range are considered to be potentially degrading. Inorganic nitrogen (ammonia plus nitrate) levels were moderate at the surface through the 4.0 meter depth in August (0.24 to 0.41 mg/l), but increased at depth to values between 1.37 and 1.84 mg/l. The dramatic increase of total phosphorus, ammonia and Kjeldahl nitrogen observed in the hypolimnion of Lake Massapoag reflects reducing conditions and release of these constituents from the bottom sediments (Figure 11).

Theoretically, hypolimnetic phosphorus could circulate throughout the Lake during fall turnover. However, the October round of samples, taken after turnover as indicated by the temperature and dissolved oxygen profiles, do not show increases in epilimnetic phosphorus. Reintroduction of oxygen to the hypolimnion apparently results in reprecipitation of phosphorus. The pattern of iron and manganese concentrations substantiate this hypothesis of nutrient release and removal. Iron and manganese concentrations increase sharply at depth during stratification, with levels decreasing after fall turnover.

Alkalinity and pH of the in-lake samples were also analyzed. Alkalinity increased somewhat with depth during the period of stratification, but was generally very low at both the surface and bottom. The range of alkalinity values was 3.0 to 34.7 mg/l, indicating soft or weakly buffered waters. The pH of the Lake averaged 6.1 at the surface and 5.9 at the bottom.

Total and suspended solids, specific conductance, hardness, and chlorides of the in-lake samples were also analyzed. Suspended solid concentrations were somewhat higher during spring runoff (April), and decreased through the summer. Total solid concentrations were generally low throughout the water

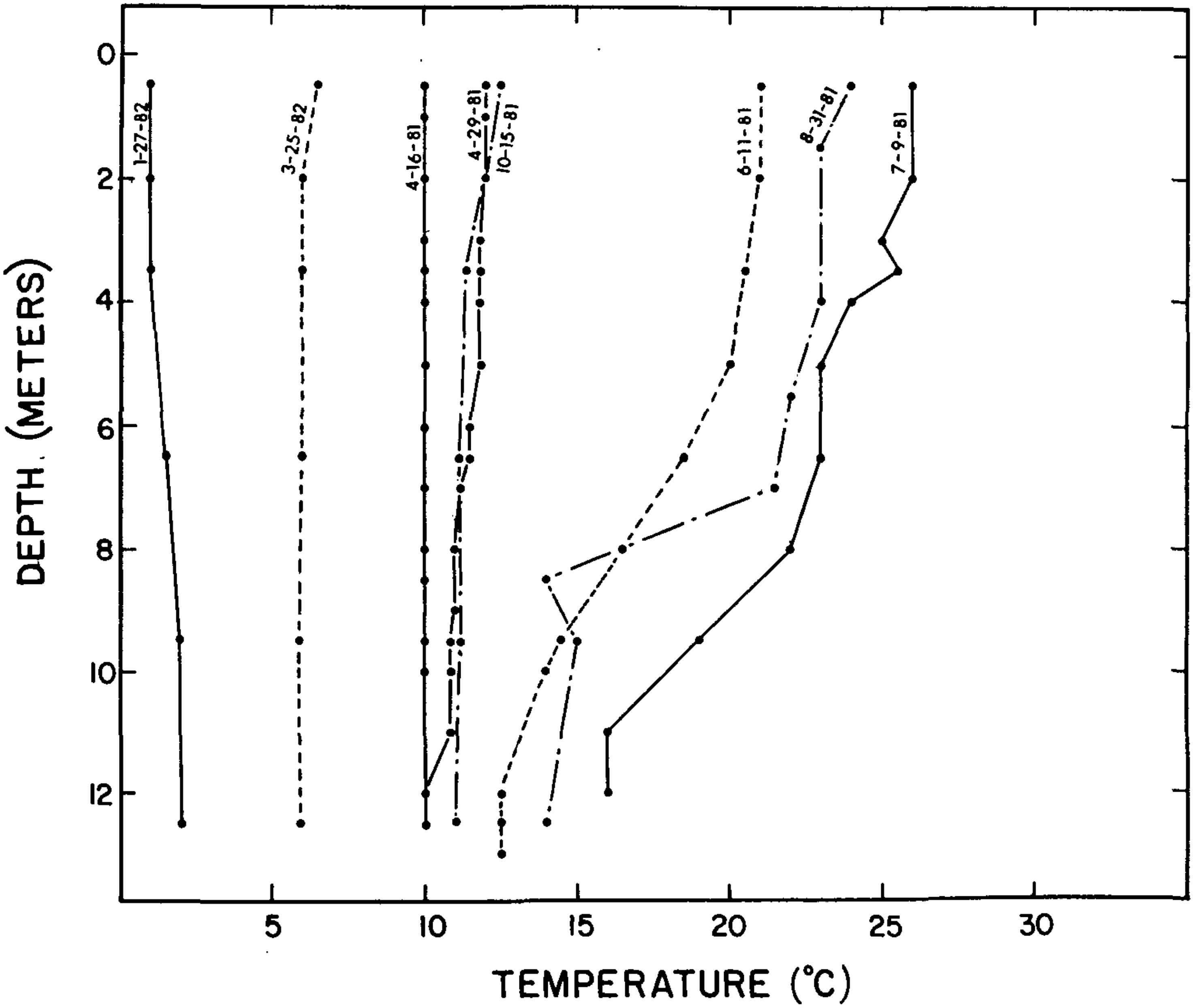


FIGURE 9 . TEMPERATURE PROFILE

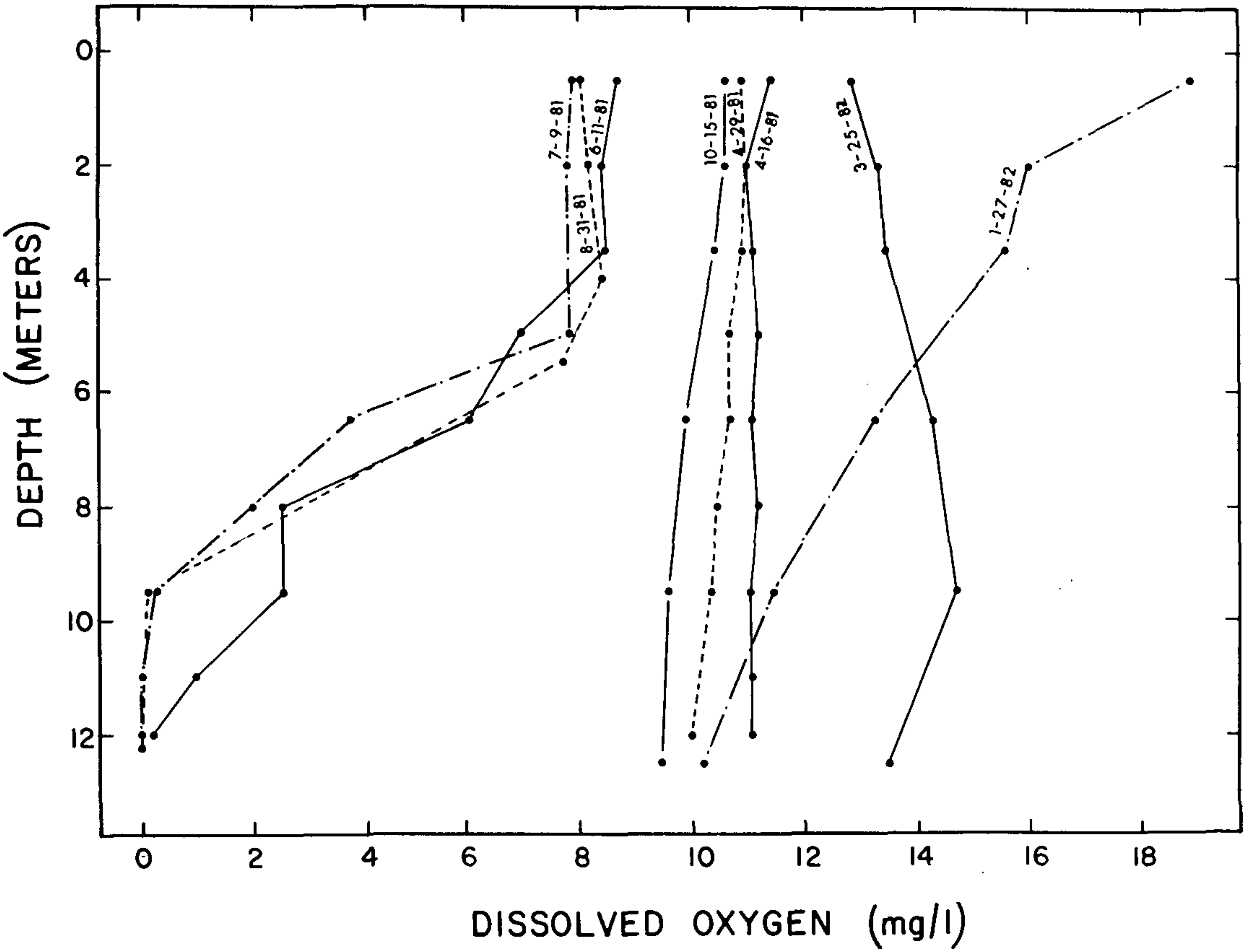
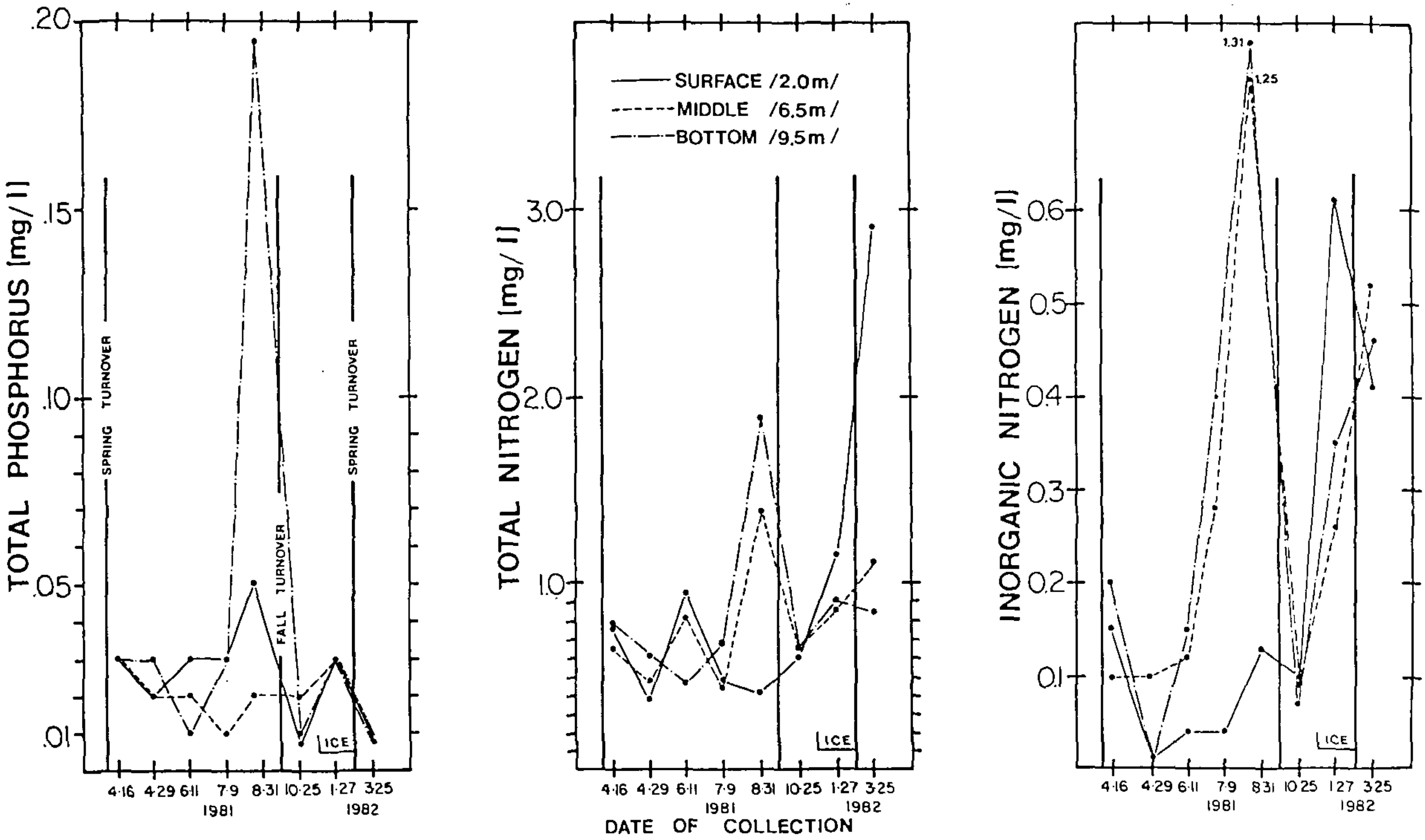


FIGURE 10 . DISSOLVED OXYGEN PROFILE

FIGURE 11

SEASONAL AND DEPTH VARIATIONS OF TOTAL PHOSPHORUS, TOTAL NITROGEN, AND INORGANIC NITROGEN — LAKE MASSAPOAG (APRIL 1981 — MARCH 1982)



DATES FOR SPRING AND FALL TURNOVER WERE ESTIMATED FROM TEMPERATURE-DISSOLVED OXYGEN DATA.

column (48 - 87 mg/l average), but showed an increasing trend through early summer. Values of specific conductance ranged from 70 to 150 umho/cm, and did not vary significantly through the water column. This level of specific conductance is indicative of low dissolved mineral content. Hardness and chloride values were relatively low, and in line with the values reported for related parameters such as conductance and alkalinity.

Total and fecal coliform bacteria and fecal streptococci were analyzed at the surface sampling depth throughout the period of study. All values for total and fecal coliform were well below the Commonwealth's Class B criteria for swimmable/fishable surface water. The low densities of coliform bacteria found at station 1 may not be representative of bacterial counts found in near-shore areas because this midlake station is removed from the potential sources of coliform, thus initial concentrations are subject to lake water dilution and subsequent reduced concentrations.

Prior to the year-round water quality sampling program carried out as part of the Lake Massapoag diagnostic/feasibility study, other studies of limited extent and duration were conducted. In 1970, temperature profiles were measured on July 25 and August 3 by R.D. Gordon of the Lake Management Committee. These surveys indicated a fairly uniform temperature throughout the upper 10-15 feet of the lake, with a gradient of approximately .6°F per foot in the deeper portions. An intensive water quality survey was conducted by the EPA New England Basins Office later in 1970. Sampling over a three day period, September 29 to October 1, included seven in-lake stations, nine inlet stations and the outlet. The in-lake stations included sampling near the lake surface and bottom for a complete spectrum of physical, chemical and biological parameters. Photosynthesis data was also collected at four locations. The temperature profile at a deep station established for the study (similar location to IEP Deep Hole station 1) indicated that the lake was weakly stratified, with a bottom dissolved oxygen concentration of 3.5 mg/l. Considering the R.D. Gordon data, it is possible that Lake Massapoag did not completely stratify in the summer of 1970, or that stratification occurred after August 3rd, with the effects of Fall turnover evident by the late September - early October survey.

A survey of Lake Massapoag was conducted by the Massachusetts Division of Water Pollution Control on August 11, 1977. One in-lake station, two inlets, and the outlet were sampled for physical, chemical and biological parameters. The in-lake station was sampled at three depths for chemical analysis, and ten depths for dissolved oxygen and temperature. The lake appeared to be stratified on this occasion, with a minimum dissolved oxygen concentration less than one mg/l. Total phosphorus concentration did not vary significantly with depth; however, iron and manganese concentrations increased by two orders of magnitude throughout the water column, indicative of the development of reducing conditions. Chemical characteristics of the

Lake appeared fairly consistent among the three surveys, with the exception of the hypolimnion samples during late summer of 1977, as a result of the development of anoxic conditions and a stratified water column. Conductance, a measure of dissolved solids, showed an increasing trend, with values of 75 and 100 umho/cm, in 1970 and 1977, respectively. Values from the 1981-1982 surveys range from 70 to 180, with an average near-surface value of 105 umho/cm.

3.2 Tributary Water Quality

In order to characterize the quality of surface water entering Lake Massapoag, a comprehensive tributary sampling program was developed. Sampling stations were established to monitor the major tributaries to the Lake (stations 2, 3 and 4), and the outlet stream, Massapoag Brook (station 5). Water quality samples were taken by personnel from the Massachusetts Division of Water Pollution Control and IEP, Inc. on a monthly or bimonthly basis during the period of study (March 1981 through March 1982). Figure 8 shows the locations of the sampling stations.

Water quality samples were analyzed for a wide range of physical, chemical and biological parameters, including bacteria, nutrients, solids, iron, manganese, pH, alkalinity and occasionally, dissolved oxygen. Results of the water quality analyses are listed in Table 5. Flow measurements were made in conjunction with water quality sampling at the monitoring points. Results of the flow measurements, as well as the drainage areas above each station, are given in Table 6.

Sampling station 2 was located at the mouth of Sucker Brook, on the southeastern shore of the Lake. Sucker Brook has the largest drainage area of the inlet streams and contributes a major portion of the surface water inflow to the Lake. Water quality analyses indicated elevated nitrogen concentrations, particularly ammonia-nitrogen (average concentration 0.38 mg/l). Total Kjeldahl nitrogen ranged between 0.25 and 1.60 mg/l. The average phosphorus concentration in Sucker Brook water samples was 0.04 mg/l.

The values in Table 5 represent only the instantaneous concentrations of nutrients in the stream at the time the samples were taken. In order to estimate the total contribution of nutrients to the Lake from the Sucker Brook inlet, the concentrations of each parameter must be weighted by the water discharge from the stream at the time of sampling. Multiplying nutrient concentration by stream flow leads to an estimate of nutrient loading in pounds per day. Figure 12 shows the variation in nutrient loading to Lake Massapoag from Sucker Brook throughout the study period.

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TABLE 5. RESULTS OF WATER QUALITY ANALYSES (SPING 1981-1982) LAKE MASSAPOAG TRIBUTARIES; STATIONS 2-7

Station and Description		Date of Collection	Temperature (°C)	Dissolved Oxygen*	pH	(mg/l as $CaCO_3$) Alkalinity	Bacteria - Total Coliform**	Bacteria - Fecal Coliform**	Bacteria - Fecal Streptocci**	Nitrogen - Ammonia*	Nitrogen-Nitrite*
Station 2 Sucker Brook Inlet	MDWPC	3/3/81	4.0	10.8	6.5	7.0	< 5	< 5	< 5	0.33	-
		4/16	9.0	-	7.3	21.0	10	< 5	< 5	0.45	-
		4/30	14.0	-	7.5	18.0	20	5	-	0.39	-
		6/11	19.0	-	7.5	23.0	500	375	-	0.22	-
		7/9	-	-	7.8	20.0	40	10	-	0.04	-
	IEP	9/14	-	-	6.6	20.3	-	10	160	0.15	-
		11/20	-	-	5.8	14.2	-	<10	200	0.38	-
		1/27/82	0.0	-	5.8	31.0	-	<10	10	0.92	<0.01
		3/25	10.0	10.8	6.2	18.7	-	<10	<10	0.55	-
		x̄	9.3	10.8	6.8	19.3	115	49	65	0.38	0.01
Station 3 Inlet at Dike	MDWPC	4/16/81	10.0	-	6.5	4.0	<10	< 5	5	0.13	-
		4/30	12.0	-	8.0	2.0	<10	< 5	-	0.05	-
	IEP	9/14	-	-	6.0	5.7		<10	70	0.25	-
		11/20	-	-	4.7	1.1		<10	<10	0.12	-
		1/27/82	-	-	4.7.	1.7		<10	10	0.16	<0.01
		x̄	11.0		6.0	2.9	10	8	24	0.14	0.01
Station 3A Unnamed Tributary Massapoag A	MDWPC	3/3/81	5.0	12.3	6.0	2.0	10	< 5	< 5	0.14	-
Station 3B Unnamed Tributary Massapoag A	MDWPC	3/3/81	5.0	12.1	5.0	-	10	< 5	<5	0.09	-
Station 4 Inlet on Lakeview Street	MDWPC	3/3/81	4.0	6.5	5.0	-	< 5	< 5	< 5	0.08	-
		4/16	7.0	-	5.5	3.0	10	< 5	< 5	0.07	-
		4/30	13.5	-	5.5	-	30	20	-	0.12	-
		6/11	19.0	7.2	5.0	-	850	10	-	0.14	-
		7/9	-	7.3		-	-	-	-	-	-
		11/20	-	-	3.9	0.0	-	<10	<10	0.25	-
		1/27/82	1.0	-	3.8	0.0	<10	-	40	0.16	<0.01
		x̄	8.9	7.0	4.8	1.0	181	10	15	0.14	0.01
Station 5 Massapoag Brook Outlet	IEP	11/20	-	-	5.8	6.5	-	20	20	0.09	-
		1/27/82	-	-	5.5	6.8	-	<10	<10	0.08	<0.01
		3/25	9.0	12.6	6.1	6.9	-	<10	<10	0.09	-
		x̄	9.0	12.6	5.8	6.7	-	13.3	13.3	0.09	0.01
Station 6 Street Drain Massapoag A	MDWPC	3/3/81	6.5	10.8	6.0	11	< 5	< 5	< 5	0.19	-
Station 7 Center of Cove	MDWPC	7/9/81	-	-	-	400	110	-	-	-	-

Station and Description		Date of Collection	Total Solids	Nitrogen-Kjeldahl*	Nitrogen-Nitrate*	Phosphorus Total*	Suspended Solids*	Chloride*	Iron*	Manganese	Hardness	(umho/cm) Specific Conduc.	Acidity Total
Station 2 Sucker Brook Inlet	MDWPC	3/3/81	48	0.50	0.70	0.06	0	13.0	0.50	0.1	28.0	120	-
		4/16	52	0.97	0.30	0.03	2	16.0	0.65	0.06	31.0	130	-
		4/30	32	0.78	0.20	0.02	2	16.0	0.74	0.05	33.0	150	-
		6/11	114	0.94	0.00	0.01	2	16.0	0.65	0.03	37.0	145	-
		7/9	108	0.25	0.40	0.03	7	4.0	0.78	0.07	27.0	90	-
	IEP	9/14	-	0.41	<0.01	0.02	<2	24.6	0.12	-	48.7	199	-
		11/20	-	0.62	0.66	0.02	<2	20.1	0.75	-	-	176	-
		1/27/82	-	1.60	0.47	0.12	<5	22.0	1.50	-	-	153	-
		3/25	-	0.77	0.46	0.01	5	16.0	1.54	-	-	146	-
		x̄	71	0.76	0.36	0.04	3	16.4	0.80	0.06	34.1	145	-
Station 3 Inlet at Dike	MDWPC	4/16/81	20	0.63	0.30	0.03	1	10.0	0.26	0.11	16.0	86	-
		4/30	38	0.48	0.10	0.04	3	10.0	0.36	0.11	17.0	90	-
	IEP	9/14	-	0.76	0.10	0.03	11	14.2	0.32	-	19.3	95	-
		11/20	-	0.32	0.57	0.08	2	14.2	0.34	-	-	106	-
		1/27/82	-	0.63	0.57	0.03	<5	22.0	0.26	-	-	89	-
		x̄	29	0.56	0.33	0.04	4	14.1	0.31	0.11	17.4	93	-
Station 3A Unnamed Tributary Massapoag A	MDWPC	3/3/81	40	0.45	0.00	0.04	2	21.0	0.03	0.12	21.0	125	-
Station 3B Unnamed Tributary Massapoag A	MDWPC	3/3/81	24	0.40	0.3	0.04	1	6.0	0.17	0.18	13	70	2.0
Station 4 Inlet on Lakeview Street	MDWPC	3/3/81	48	0.52	0.9	0.05	1	12.0	0.14	0.09	22	120	2.0
		4/16	20	0.94	0.3	0.02	0	11.0	0.24	0.05	15	98	-
		4/30	66	0.60	0.2	0.04	2	10.0	0.31	0.04	15	110	2.0
		6/11	138	1.4	0.1	0.07	3	8.0	1.5	0.70	9	80	3.0
		7/9	-	-	-	-	-	-	-	-	-	-	-
		11/20	-	0.65	0.50	0.02	2	17.6	0.41	-	-	142	-
		1/27/82	-	0.85	0.56	0.02	< 5	37.0	0.42	-	-	165	-
		x̄	68	0.82	0.42	0.04	2	15.9	0.50	0.22	15	119	2.3
Station 5 Massapoag Brook Outlet	IEP	11/20	-	0.39	0.36	0.02	< 2	21.6	0.20	-	-	106	-
		1/27/82	-	0.80	0.18	0.03	< 5	17.0	0.10	-	-	102	-
		3/25	-	0.43	0.45	<0.01	13	16.5	0.26	-	-	123	-
		x̄	-	0.54	0.33	0.02	6.7	18.4	0.19	-	110.3	164	-
Station 6 Street Drain Massapoag A	MDWPC	3/3/81	196	0.54	0.70	0.13	0	57	0.52	0.15	12	160	-
Station 7 Center of Cove	MDWPC	7/9/81	-	-	-	-	-	-	-	-	-	-	-

- No Data Reported
* mg/l
** org/100 ml

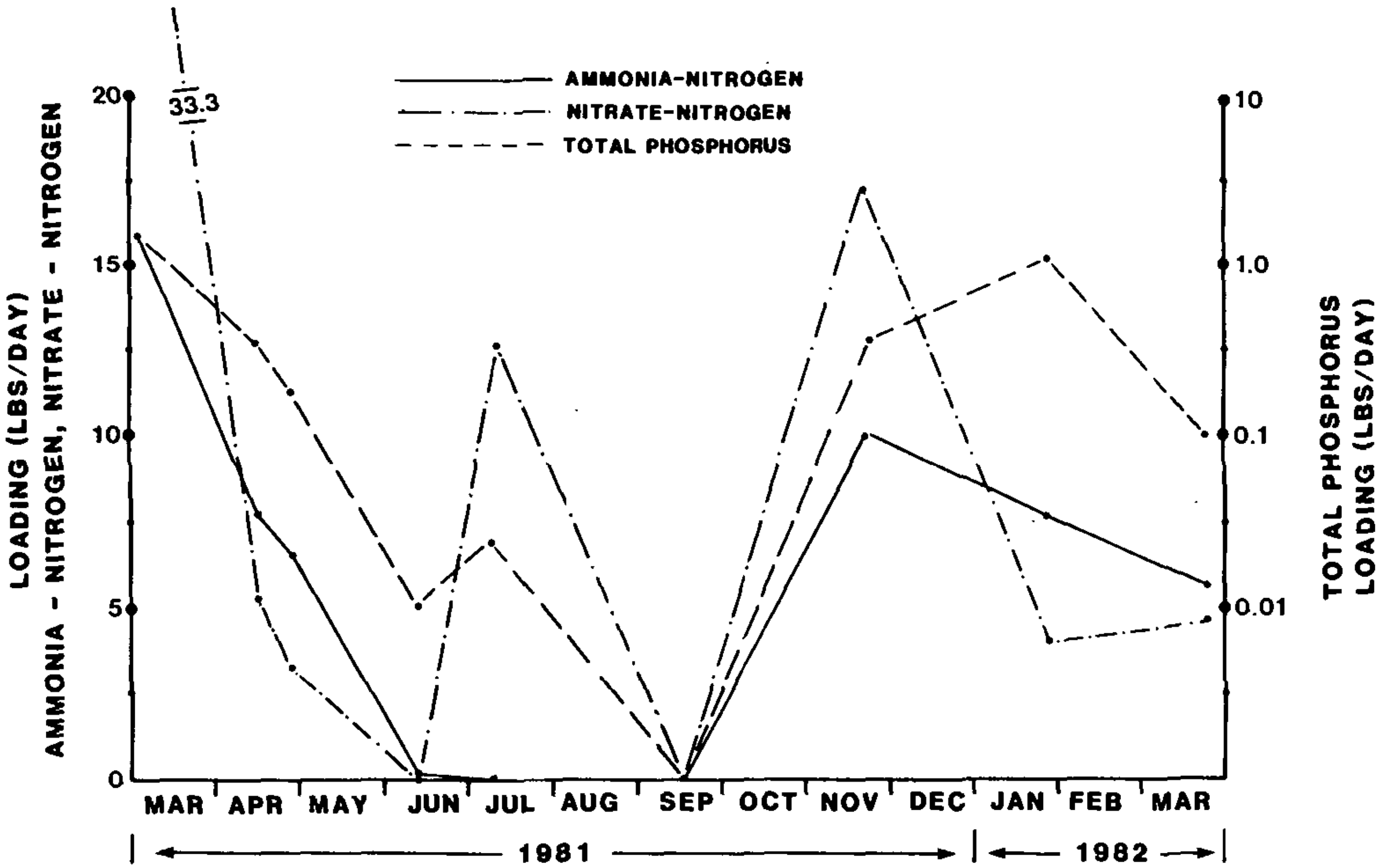
TABLE 6 . INLET AND OUTLET FLOW MEASUREMENT (cfs) LAKE MASSAPOAG

Date	Station 2 Sucker Brook Inlet	Station 3 Inlet at Dike*	Station 4 Inlet on Lakeview Street	Station 5 Massapoag Brook Outlet
3/3/81	8.82	9.65	2.59	no flow
4/16/81	3.24	11.78	0.43	no flow
4/30/81	3.07	no flow	0.69	no flow
6/11/81	0.24	no flow	0.13	no flow
7/9/81	0.24	no flow	no flow	no flow
9/14/81	no flow	no flow	no flow	no flow
11/20/81	4.88	no flow	0.33	0.81
1/27/82	1.58	1.60	0.80	4.00
3/25/82	1.87	2.13	0.26	6.70
Drainage Area (acres)	635	615	60	2212

*When flow measurement was not possible at dike, flow measurements of upstream tributaries were totalled to estimate flow at Station 3.

FIGURE 12

VARIATION IN NUTRIENT LOADING TO LAKE MASSAPOAG FROM SUCKER BROOK (1981 - 1982)



The other inlet samples (stations 3 and 4), both unnamed streams entering the Lake at its southern extremity, showed nutrient concentrations generally within the same range of values as those found in Sucker Brook. Ammonia-nitrogen concentrations were, on the average (0.14 mg/l), lower at stations 3 and 4 than at Sucker Brook.

Bacteria counts showed low levels of coliform organisms in all tributary stations for dry weather sampling dates. One sample in violation of the water quality criterion of 200 organisms per 100 ml was taken at Sucker Brook. This sample and other samples with elevated coliform counts (total, fecal or fecal strep), were taken shortly after, or during, a precipitation event.

The monitoring program revealed a marked variation in pH, alkalinity, and hardness among tributary sampling stations. Sucker Brook had the highest pH, with circumneutral values (5.8 to 7.8). Alkalinity and hardness values were also the highest of the three tributary stations sampled, averaging 19.3 mg/l and 34.1 mg/l, respectively. Although these values are well within the expected range for natural waters, the pH and alkalinity of Sucker Brook water are well above the values for the other tributaries, and the Lake outlet. Stormwater sampling in the upper reaches of Sucker Brook indicated possible leaching from the landfill area, which is likely to account for elevated levels of ammonia-nitrogen and alkalinity, and the higher pH at its mouth. Table 7 lists representative ranges for some inorganic constituents in leachate from sanitary landfills. Leachate entering Sucker Brook would be diluted by inflow from other areas of the watershed. However, elevated levels of some or all of these constituents would be expected to occur in Sucker Brook downstream of the landfill, if leachate is entering the Brook. Visual inspection of Sucker Brook during the summer of 1983, indicated that leachate does contaminate the northern tributary of Sucker Brook. East of Mountain Street, the landfill lies adjacent to the stream bed. The tributary was highly colored, and iron precipitate was visible in the water and on the stream bed. The visual effects of the leachate in the tributary extended at least to its confluence with the southern branch of Sucker Brook. West of its crossing under Mountain Street, the tributary remains channelized for several hundred feet, before flow disperses in a hummocky wetland (wooded swamp). This wetland apparently allows settling and infiltration of the contaminated water; and is presumed to provide pollution attenuation through physical, chemical and biological means.

See section 3.3 for a discussion of water quality sampling in the upper reaches of Sucker Brook, conducted during storm flow.

Station 4 was located at the mouth of a small tributary draining a wetland area. The water in this stream has a low pH (ranging between 3.8 and 5.5), very low alkalinity, and an average hardness of 15 mg/l. The difference in

TABLE 7

Representative Ranges for Various Inorganic Constituents in Leachate From Sanitary Landfills (Freeze and Cherry, 1979)

PARAMETER	REPRESENTATIVE RANGE (mg/l)
K^+	200-1000
Na^+	200-1200
Ca^{2+}	100-3000
Mg^+	100-1500
Cl^-	300-3000
SO_4^{2-}	10-1000
Alkalinity	500-10,000
Fe (total)	1-1000
Mn	0.01-100
Cu	< 10
Ni	0.01-1
Zn	0.1-100
Pb	< 5
Hg	< 0.2
NO_3^-	0.1-10
NH_4^+	10-1000
P as PO_4	1-100
Organic nitrogen	10-1000
Total dissolved organic carbon	200-30,000
COD (Chemical oxidation demand)	1000-90,000
Total dissolved solids	5000-40,000
pH	4-8

water quality characteristics between stations 4 and 2 may be due, in part, to the influence of wetlands surrounding the smaller tributary.

Water quality samples at twelve stations located in the Lake Massapoag watershed were collected over a fifteen year period by the Town of Sharon for total and fecal bacteria analysis. Figure 13 shows the locations of the Town's sampling sites, which are further described in Table 8. Water samples were collected on a sporadic basis, and were obtained primarily between the months of May and September when the Lake is commonly used for primary-contact recreational activities.

Figure 14 presents the results of the Town's sampling program in terms of the percent of samples at each station which exceeded state water quality criteria of 1000 organisms per 100 ml for total coliform, or 200 organisms per 100 ml for fecal coliform. Six of the twelve stations violated either the total or fecal coliform criteria, or both, on more than twenty percent of the sampling dates. Violations of the fecal coliform criteria occurred at the Town Beach (station 1) in twenty-two percent of the samples. Total coliform violations occurred almost fifty percent of the time at the public right of way at Sturges/Livingston Road Cove (station 9). Both total and fecal coliform violations occurred frequently at the Sucker Book (station 5). The frequency of violations in coliform criteria at other (stations 3, 10, 11, 12) may be biased, since these stations are located at storm drains or intermittent streams. In the case of these stations, samples were not taken during dry weather, that is, when there was no flow at the site. The age and siting of cesspools in the area of station 10 are most likely accountable for the coliform violation at this station. Cesspools for homes in the area of this storm drain are estimated to be over 50 years old. In addition, the groundwater table is sufficiently high sometimes at the ground surface - to inhibit the proper functioning of most types of subsurface sewage disposal systems.

Coliform problems in Sucker Brook have, in the past, been blamed on landfill leachate entering the Brook and institutional septic systems located along the downstream reaches of the Brook. However, sampling in the upper reaches of Sucker Brook revealed the lowest coliform counts of all samples collected on that date (August 25, 1982). Data from a municipal landfill in Fitchburg, Ma. indicated minimal counts of total and fecal coliform in leachate effluent. On the basis of this information, it is considered that the landfill is not a major source of coliform problems at the mouth of Sucker Brook.

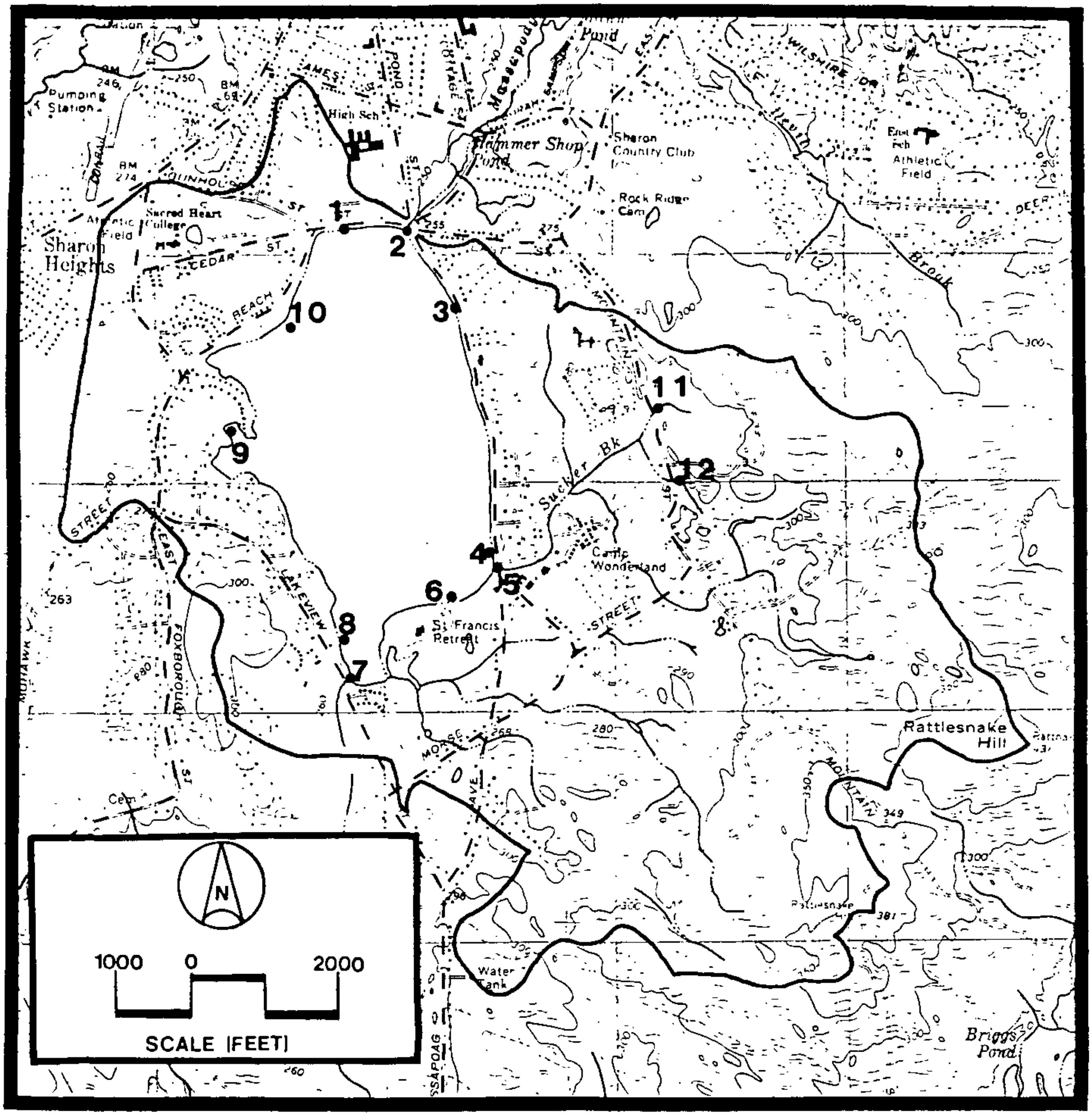


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FIGURE 13
SURFACE WATER QUALITY SAMPLING LOCATIONS TOWN OF SHARON

LAKE MASSAPOAG DIAGNOSTIC/FEASIBILITY STUDY

iEP Inc.

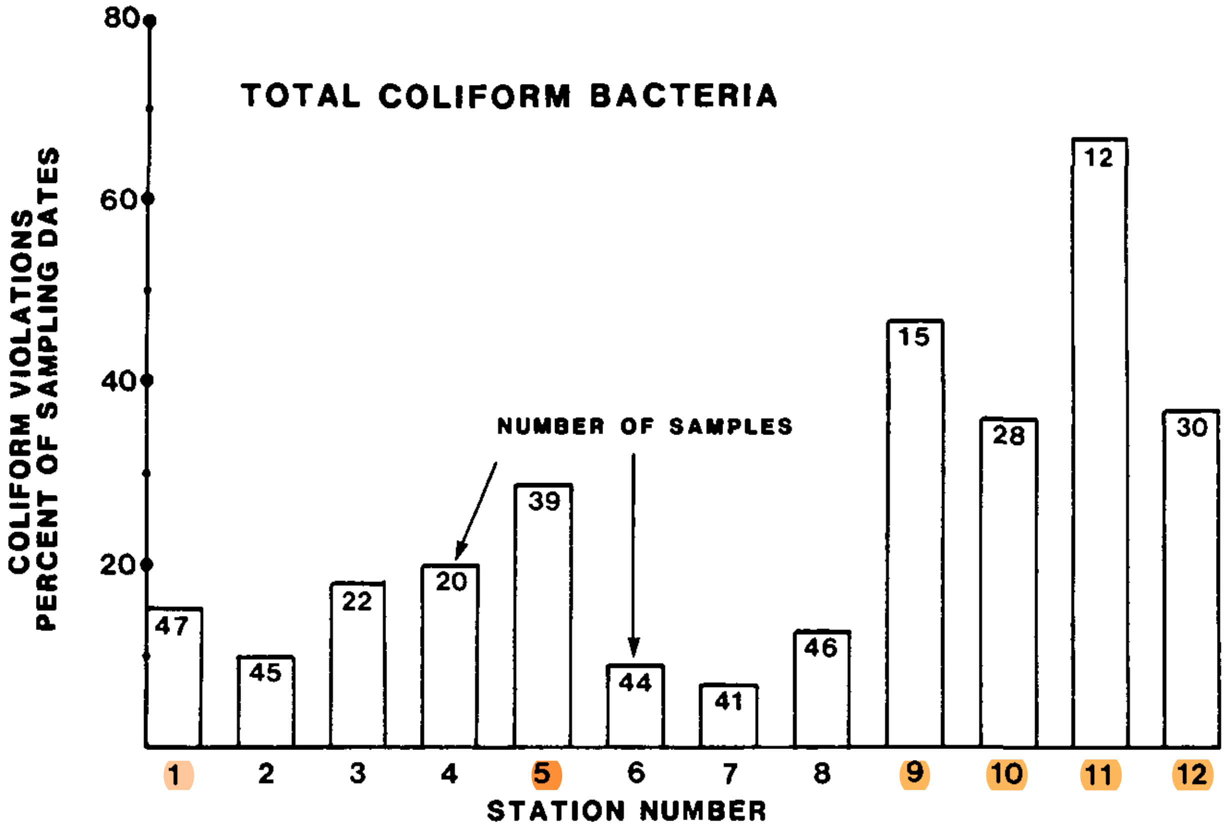
TABLE 8 LAKE MASSAPOAG

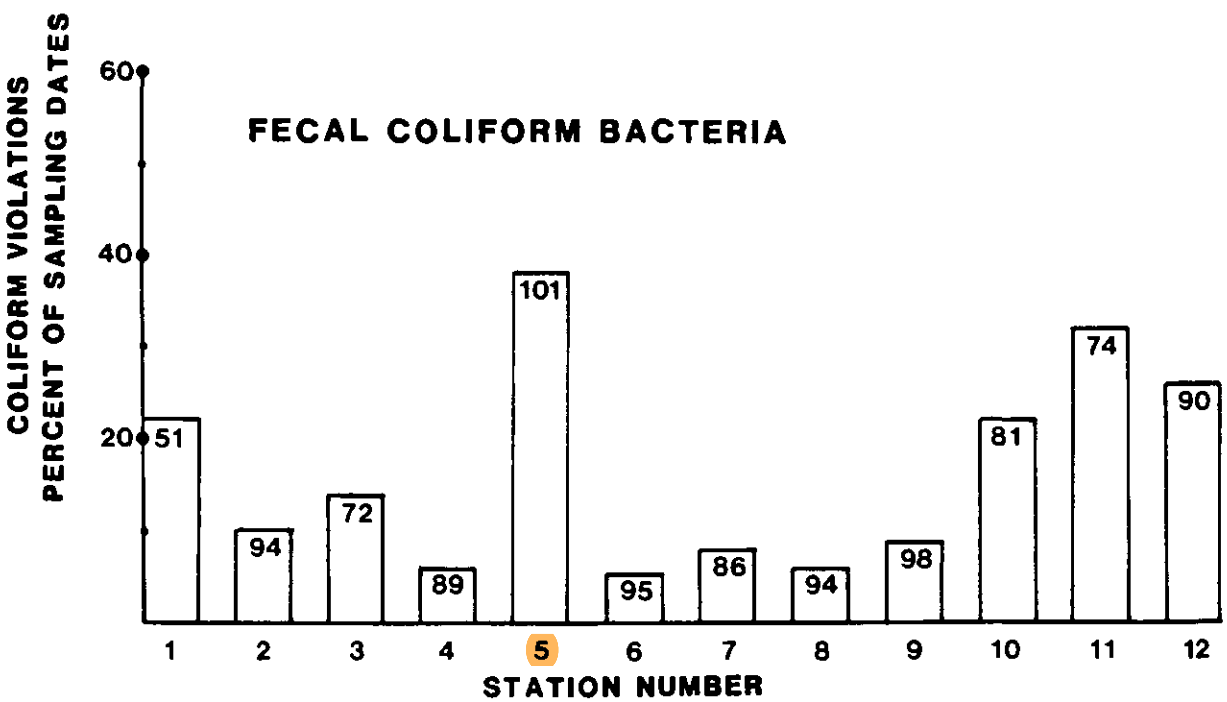
Descriptions of Sampling Stations
Town of Sharon

Station No.	Location	Description
1	Town Beach	Sample taken within swimming area enclosed by docks (about four feet water depth area).
2	Boat Landing area	Sample taken at end of dock near launching ramp.
3	Arboro Drive Drain	Sample taken of discharge from drain. If dry, do not sample.
4	Camp Wonderland Beach	Sample taken within swimming area enclosed by docks.
5	Sucker Brook	Sample taken in brook on side of Massapoag Avenue away from lake (easterly side).
6	Community Center Beach	Sample taken opposite life guard tower in swimming area.
7	Camp Gannett Beach	Sample taken in swimming area enclosed by docks.
8	Kiddie Camp Beach	Sample taken in swimming area enclosed by docks.
9	Sturges/Livingston Road Cove	Sample taken in lake at end of public right of way.
10	Drain opposite 123 Beach St.	Sample taken of water discharging from drain. If dry, do not sample.
11	Sanitary Landfill Drainage-North	Sample taken on upstream side of drain passing under Mountain Street. If dry, do not sample.
12	Sanitary Landfill Drainage-South	Sample taken on upstream side of drain passing under Mountain Street. If dry, do not sample.

FIGURE 14 RESULTS OF SURFACE WATER QUALITY SAMPLING: LAKE MASSAPOAG

TOWN OF SHARON





3.3 Stormwater Quality

In addition to tributary sampling at regular intervals, water quality sampling of various inlets to Lake Massapoag was conducted during storm events. Stormwater sampling is important to the study since many areas of the watershed contribute surface inflow to the Lake only during, or immediately following, a storm event. Also, water quality of perennially flowing tributary streams is likely to change significantly in response to storm runoff. In planning the stormwater sampling program, a delineation was made of the subdrainage areas within the Lake Massapoag watershed (Figure 15). The areas of the storm-drain and tributary watersheds are presented in Table 9.

Stormwater sampling was conducted for two precipitation events: a three-day intermittent rainstorm on August 24 through 26, 1982, following 5 days of dry weather, which yielded a total of 0.40 inches; and a half-day storm on December 16, 1982, following three days without significant precipitation, with a total rainfall of 0.46 inches.

Sampling during the August event took place over a six hour period on August 25. Field observations at the sampling sites indicated that precipitation occurred approximately between the hours of 9:10 a.m. and 11.35 a.m., with the heaviest rainfall occurring about 10:00 a.m. Grab samples were collected at stations 1, 5, 7A, 7B, 8, 10, and 11. Flow proportional composite samples were taken at stations 7, 13 and 14 with time-variable sampling (grab samples taken at intervals during the course of the storm) at station 9.

No flow was observed at the other proposed sampling locations (stations 2, 3, 4, 6, 12, and 15). All samples were analyzed for bacteria (total and fecal coliform, and fecal strep), nutrients (ammonia-nitrogen, nitrate nitrogen, total Kjeldahl nitrogen and total phosphorus) and solids (suspended solids and specific conductance), and flow measurements were made at the sampling sites. The results of the water quality analyses are presented in Tables 10, and 11.

Due to the intermittent, low intensity pattern of the August event, prediction of the time of concentration was difficult. Stormwater sampling began within an hour of the start of precipitation on August 25, and continued an hour or more after rainfall had stopped. Flow measurements show that runoff remained steady or gradually increased during the sampling period. Pollutographs (Figure 16) developed from the time-variable grab samples taken at station 9 show a general increase in fecal coliform, suspended solid concentrations, and nutrient concentrations. Conductivity measurements show a peak about 2 1/2 hours after the start of the storm event.

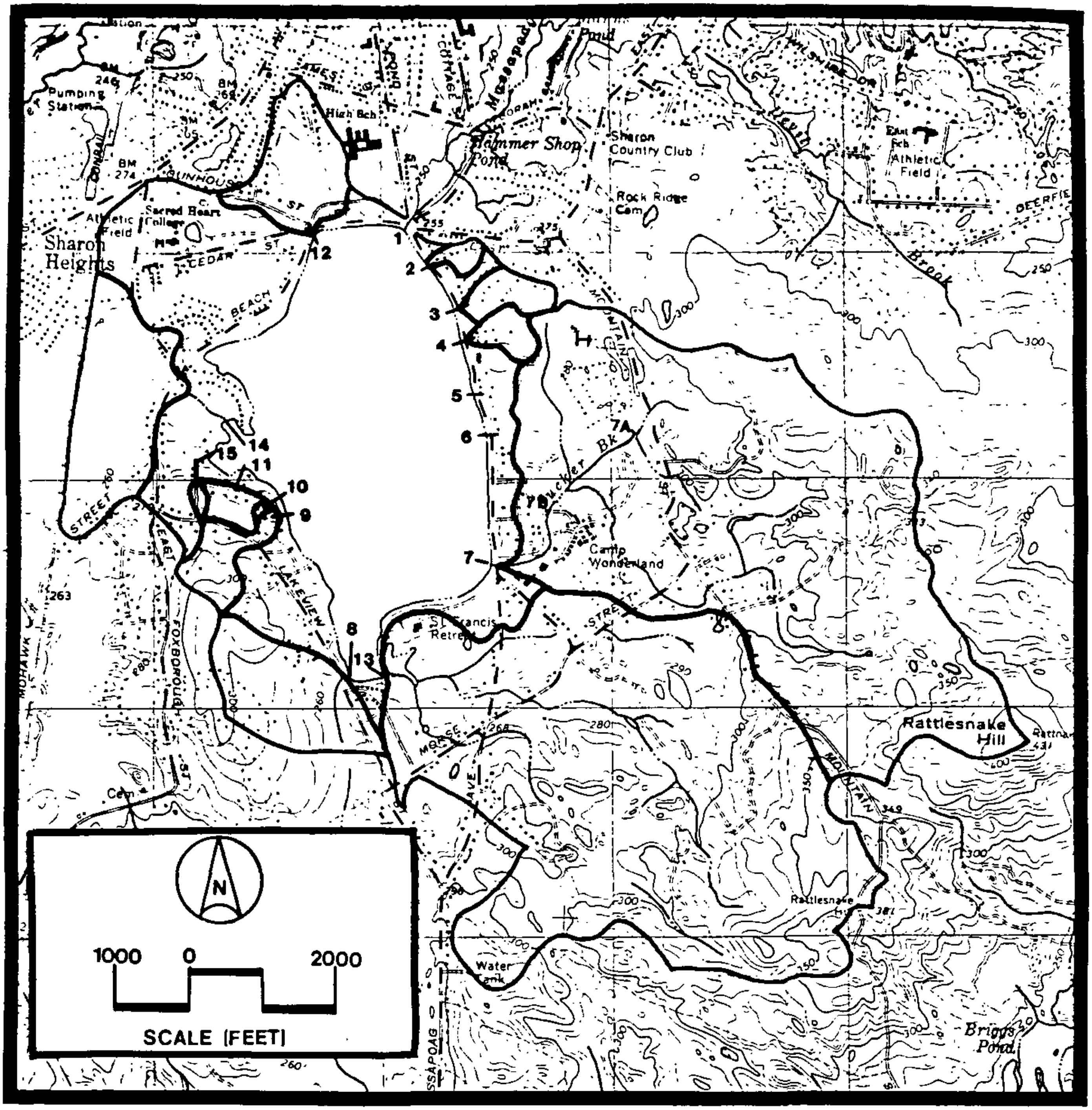


FIGURE 15

SUBDRAINAGE AREAS

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LAKE MASSAPOAG DIAGNOSTIC/FEASIBILITY STUDY

TABLE 9. STORMWATER SAMPLING STATIONS - LAKE MASSAPOAG

Station Number	Description	Area (Acres)	Percent of Total Area
1	Lake Massapoag outlet	2212	100
2	Storm drain - Massapoag Avenue at Massapoag Lane	5	< 1
3	Storm drain - Massapoag Avenue at Arboro Drive	15	< 1
4	Storm drain - Massapoag Avenue at Franklin Avenue	10	< 1
5	Storm drain - Massapoag Avenue	-	-
6	Storm drain - Massapoag Avenue	-	-
7	Sucker Brook - mouth	635	29
7A	Sucker Brook - downstream of landfill	-	-
7B	Sucker Brook - downstream of Sucker Brook tributaries	-	-
8	Unnamed tributary to Lake Massapoag	60	3
9	Storm drain - Livingston Road area	20	1
10	Storm drain - Livingston Road area	1	< 1
11	Storm drain - Livingston Road area	10	< 1
12	Unnamed tributary to Lake Massapoag	50	2
13	Unnamed tributary to Lake Massapoag	615	29
14	Unnamed tributary to Lake Massapoag	88	4
15	Storm drain - Livingston Road area	2	< 1
-	Areas draining to Stations 5 and 6; and all areas with direct drainage to Lake	300	13

TABLE 11 RESULTS OF STORM SAMPLING STATIONS

GRAB SAMPLES

AUGUST 25, 1982

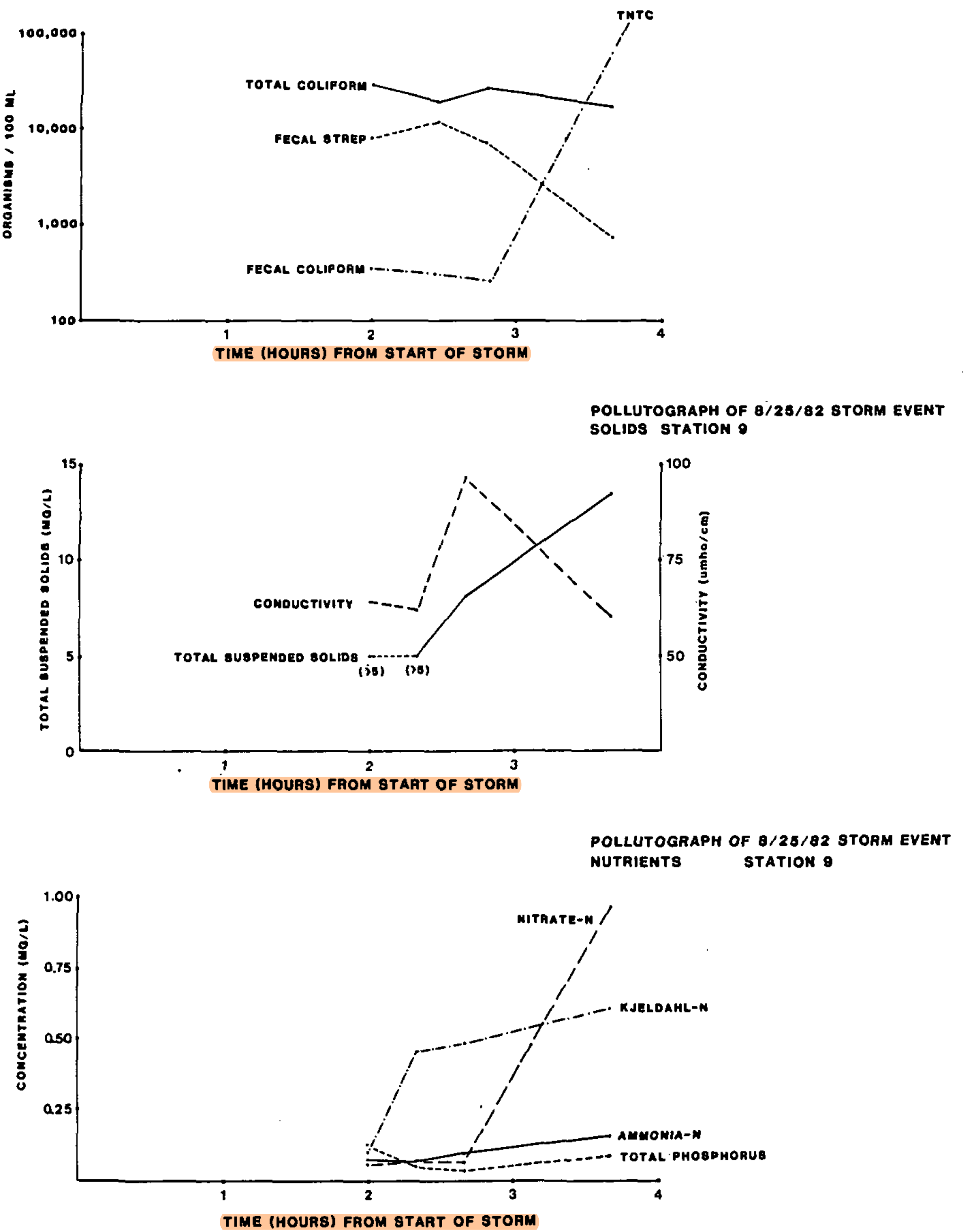
Station	Time	Total Coliform org/100ml	Fecal Coliform org/100ml	Fecal Strep. org/100ml	Conductivity umho/cm	Total Suspended solids mg/l	Ammonia-N mg/l	Nitrate-N mg/l	Kjeldahl-N mg/l	Total Phosphorus mg/l
1		100	10	710	116	6	0.12	0.11	0.39	0.02
5	1048	16,000	2,480	1,170	88	14	0.05	0.93	0.79	0.13
7A	*0945	-	-	-	780	5	3.58	0.14	3.72	0.01
7A	0945	300	110	240	775	8	3.57	0.16	4.38	0.01
7B	0955	800	30	290	170	5	1.09	0.50	1.52	0.03
8	1050	2,900	230	70	93	5	0.34	0.10	1.43	0.10
10	1240	15,000	6,300	6,188	70	8	0.54	1.80	1.14	0.12
11	1235	69,000	26,700	4,522	74	12	0.41	1.50	1.17	0.13

*Dry weather sample

TABLE 10 RESULTS OF STORM SAMPLING STATIONS - LAKE MASSAPOAG
COMPOSITE AND TIME-VARIABLE SAMPLES
AUGUST 25, 1982

Station	Time	Total Coliform org/100ml	Fecal Coliform org/100ml	Fecal Strep. org/100ml	Conductivity umho/cm	Suspended Solids mg/l	Ammonia-N mg/l	Nitrate-N mg/l	Kjeldahl-N mg/l	Total Phosphorous mg/l	Flow cfs
7	1010	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.29
7	1040	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.24
7	1110	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.47
7	1145	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.94
7	Composite	9700	890	1650	165	7	0.45	0.85	0.95	0.03	
9	1112	31000	360	8700	64	5	0.07	0.06	0.11	0.14	0.03
9	1135	21000	320	12900	62	5	0.06	0.06	0.46	0.05	0.03
9	1200	27000	290	7600	94	8	0.11	0.07	0.47	0.03	0.03
9	1250	19000	TNTC	750	61	12	0.14	0.92	0.59	0.08	0.033
13	1030	↓	↓	↓	↓	↓	↓	↓	↓	↓	3.05
13	1100	↓	↓	↓	↓	↓	↓	↓	↓	↓	
13	1130	↓	↓	↓	↓	↓	↓	↓	↓	↓	5.40
13	1200	↓	↓	↓	↓	↓	↓	↓	↓	↓	2.82
13	Composite	1200	50	80	107	5	0.10	0.13	0.68	0.03	
14	1400	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.03
14	1420	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.03
14	1437	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.03
14	Composite	3000	120	20	17	5	1.25	0.09	2.81	0.21	

Figure 16. Pollutographs from storm sampling results: Lake Massapoag 8/25/82 storm event, station 9



A graphical presentation of the stormwater quality data allowing visual comparison of storm drain and tributary samples is shown in Figure 17. Storm drains are generally expected to show higher concentrations of many pollutants than natural streams, because there is less dilution from base flow in the stormwater drainage; and because pollutants often build up in the drains between storm events. Land use impacts may also be reflected in the differentiation between storm drains and tributaries. Generally, storm drains serve residential and institutional land uses, while unserviced areas are those with less development. Examination of the Lake Massapoag stormwater data shows that with respect to bacteria and suspended solids, water quality from storm drains is poorer than that entering the Lake from natural tributaries. Generally, nutrient concentrations are somewhat higher in samples collected from storm drains than in tributary samples. High concentrations of ammonia in samples from the upstream portions of Sucker Brook (station 7A, downstream of the landfill) result in a higher input of nitrogen to the Lake from this inlet. Nutrient concentrations were also relatively high at station 14, an inlet tributary which drains extensive wetlands in the western portion of the watershed. Conductivity measurements, used to indicate total dissolved solids, indicated higher concentrations in the tributaries than in storm drains, probably due to the base flow component of tributary streams. Tributary samples were within the range of specific conductance values encountered during dry weather sampling, with the exception of station 7A. Elevated dissolved solid levels in this upstream reach of Sucker Brook are indicative of landfill leachate contamination.

Appendix D summarizes sample results from a landfill leachate study conducted by the Division of Water Pollution Control in Fitchburg. The data shows leachate values for numerous parameters as well as comparison of the effects of the leachate on stream water quality.

Sampling during the December 16 storm took place over a two hour period. Precipitation started at 11:45 a.m. and sampling began one-half hour to forty-five minutes later. Flow proportional composite samples were collected at stations 7, 13 and 14; and time variable grab samples were taken at station 9. Flow measurements were made at all four stations. All samples were analyzed for bacteria (fecal coliform and fecal strep) and nutrients (ammonia nitrogen, nitrate-nitrogen, total Kjeldahl nitrogen and total phosphorus). The results of the water quality analyses are presented in Table 12. Flow measurements at station 9 are presented as a runoff hydrograph in Figure 18; and show a rise to a peak flow occurring one hour after the start of the storm, with a second, lower peak occurring approximately one-half hour after the first. Pollutographs for bacteria and nutrients at Station 9 are also presented in Figure 18. Fecal coliform counts decreased over the period of the storm. Fecal strep counts increased

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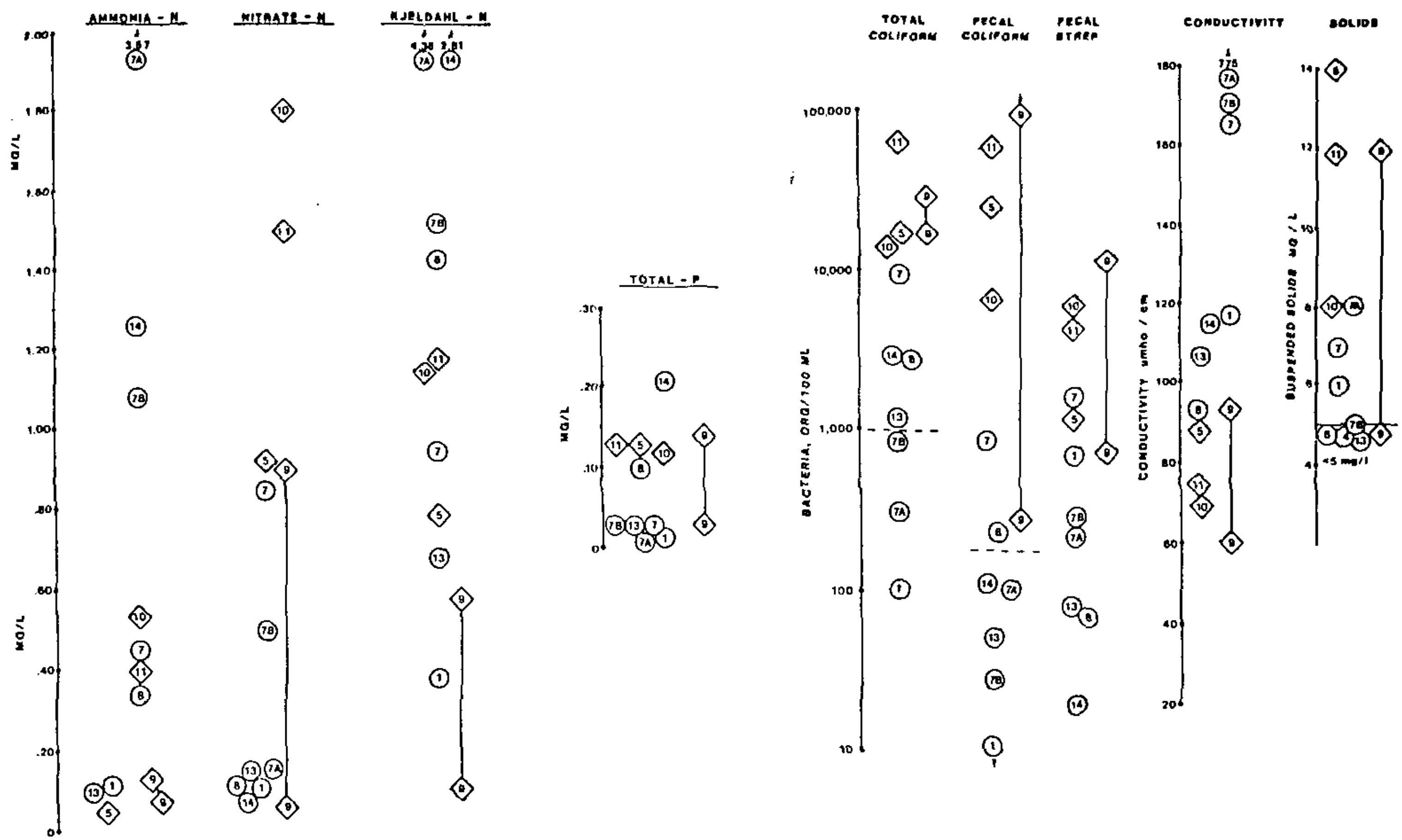

Figure 17 Results of stormwater sampling
8/25/82 storm event Lake Massapoag.
Comparison of tributary and storm drain sampling results.

KEY: storm drain stations ◇5
tributary stations ⑧

TABLE 12 RESULTS OF SELECTED STORM SAMPLING STATIONS ON LAKE MASSAPOAG
COMPOSITE AND TIME VARIABLE SAMPLES
DECEMBER 16, 1982

Station	Time	Fecal Coliform org/100ml	Fecal Strep org/100ml	Ammonia-N mg/l	Nitrate-N mg/l	Kjeldahl-N mg/l	Total Phosphorus mg/l	Flow cfs
7	1225	↓	↓	↓	↓	↓	↓	0.134
7	1243	↓	↓	↓	↓	↓	↓	0.134
7	1300	↓	↓	↓	↓	↓	↓	0.134
7	1316	↓	↓	↓	↓	↓	↓	0.134
7	1334	↓	↓	↓	↓	↓	↓	0.134
7	1349	↓	↓	↓	↓	↓	↓	0.134
7	Composite	80	270	0.48	0.45	0.84	0.04	
9	1225	670	3,100	0.27	0.55	2.00	0.06	0.067
9	1243	480	3,200	0.18	0.62	1.48	0.10	0.084
9	1255	390	10,000	0.14	0.43	1.90	0.18	0.179
9	1313	310	24,700	0.13	0.26	0.46	0.03	0.107
9	1329	300	10,400	0.08	0.15	0.37	0.15	0.134
9	1345	330	8,300	0.05	0.23	0.34	0.10	0.134
13	1214	↓	↓	↓	↓	↓	↓	0.017
13	1236	↓	↓	↓	↓	↓	↓	0.050
13	1253	↓	↓	↓	↓	↓	↓	0.008
13	1310	↓	↓	↓	↓	↓	↓	0.022
13	1325	↓	↓	↓	↓	↓	↓	0.011
13	1342	↓	↓	↓	↓	↓	↓	0.625
13	Composite	10	130.	0.34	0.30	0.61	0.03	
14	1215	↓	↓	↓	↓	↓	↓	0.038
14	1235	↓	↓	↓	↓	↓	↓	0.041
14	1247	↓	↓	↓	↓	↓	↓	0.064
14	1305	↓	↓	↓	↓	↓	↓	0.051
14	1320	↓	↓	↓	↓	↓	↓	0.064
14	1336	↓	↓	↓	↓	↓	↓	0.029
14	Composite	110	730	0.43	0.24	2.34	0.06	

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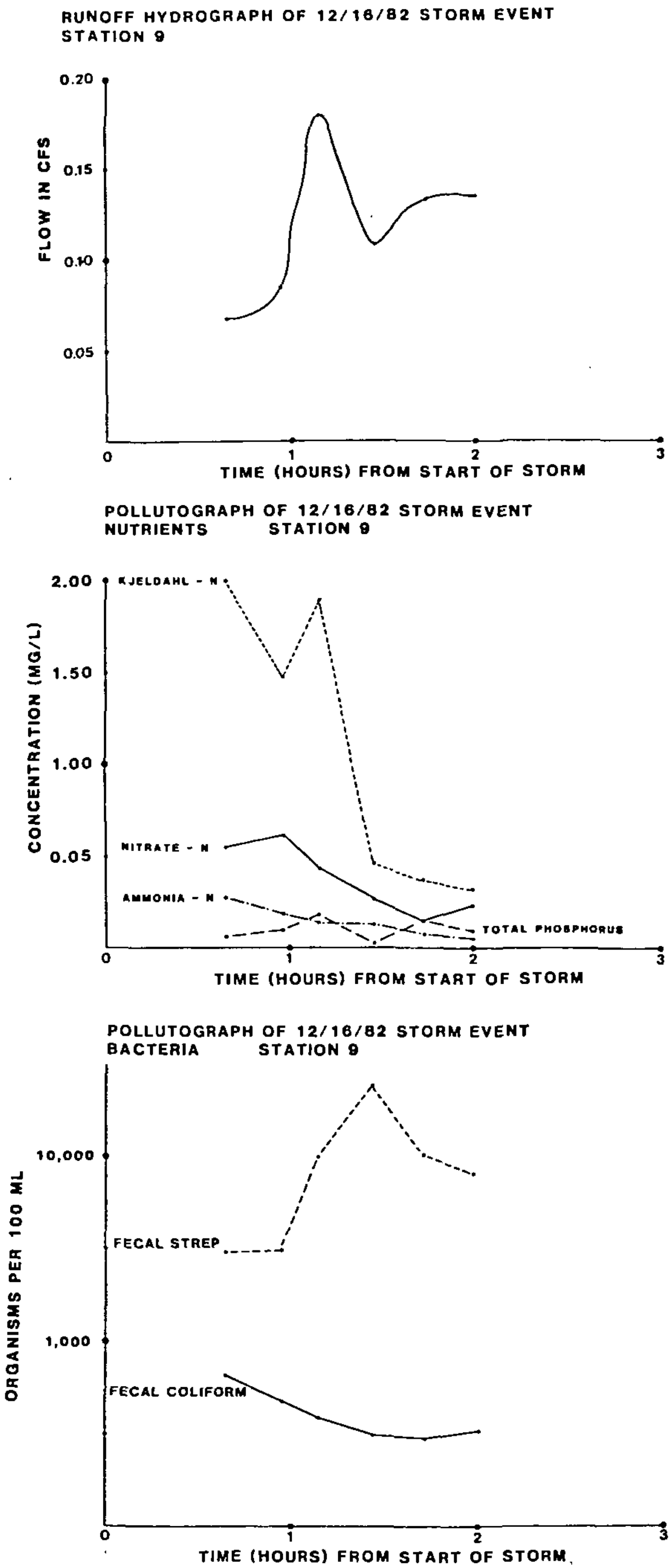


Figure 18. Pollutographs from storm sampling results: Lake Massapoag 12/16/82 storm event, station 9.

over the remainder of the storm. Nutrient concentrations peaked prior to or concurrently with peak runoff.

3.4 Groundwater Quality

The quality of groundwater entering Lake Massapoag is related to the geologic deposits through which it flows, the distance it travels and the proximity to potential contaminant sources such as subsurface sewage disposal systems.

To determine the nutrient concentrations of groundwater entering Lake Massapoag, two rounds of groundwater samples were collected on July 8, and October 1, 1982 from seven monitor wells placed in strategic locations around the Lake. With the exception of one site, two wells were located at each station; one shallow well two feet below the water table and one deep well, four to six feet below the water table (Figure 19). Wells A1 and A2 were driven at the southeastern end of the Lake in the shoreline fronting the St. Francis Retreat. Site B was located approximately 1500' north of the mouth of Sucker Brook. Site C was approximately 2000' south of the Lake's outlet, Massapoag Brook. Site D was on the western side of the Lake at the southern extreme of the southernmost cove. Only one monitor well was located at Site D because of difficulty encountered when driving the well points.

Water samples were collected using either a pitcher pump or when necessary, a hand powered suction-lift, boat-type pump. The pitcher pump was utilized when the subsurface materials were permeable enough to pump freely. The hand pump was used when sampling wells whose screens were in relatively impermeable material. Several liters of water were evacuated from the test well before a sample was taken to ensure a fresh groundwater sample. All samples collected were stored in ice-filled coolers prior to being delivered to the laboratory for analysis and were filtered before being analyzed. The parameters tested for included total phosphorus, nitrate nitrogen, ammonia nitrogen, Kjeldahl nitrogen and conductivity.

The groundwater samples analyzed were intended to be indicative of background groundwater quality (Table 13). Therefore, the monitor wells were located in varying hydrogeologic and land development conditions where a septic leachate detector survey (section 3.5) indicated there were no potential leachate plumes entering the Lake. However, two groundwater samples proved to have high phosphorus readings (on 7/9/82 well #B2 and on 10/1/82 well #C2), that suggested sewage contamination. These values were not used in groundwater loading calculations. Figure 20 shows the well locations and graphically depicts the relative concentrations of conductance, total phosphorus and total nitrogen for all samples.

The total phosphorus levels in all the groundwater samples were below the average "deep hole" surface sample level and comparable to the background

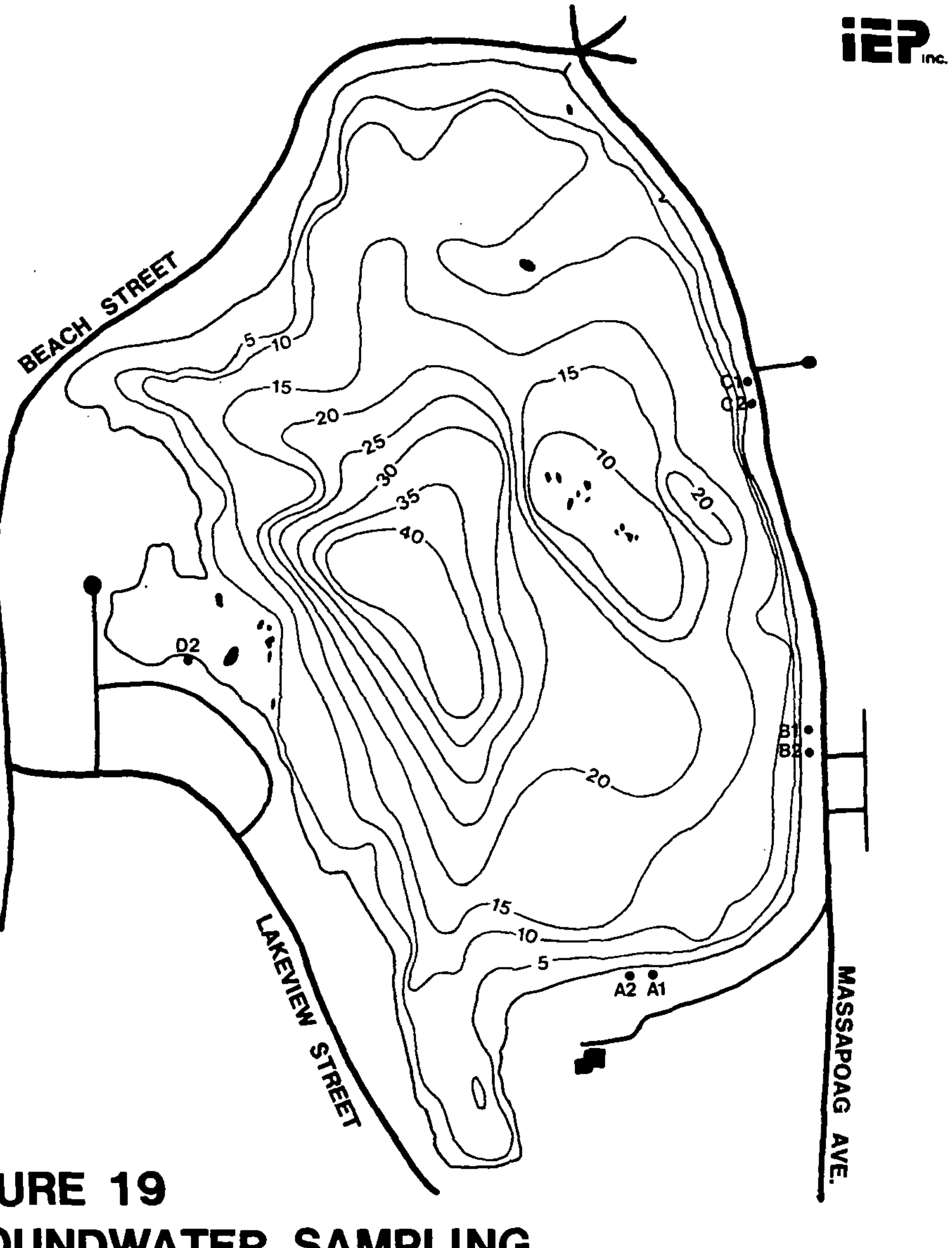


FIGURE 19
GROUNDWATER SAMPLING LOCATIONS

LAKE MASSAPOAG DIAGNOSTIC / FEASIBILITY STUDY, IEP Inc.

TABLE 13 GROUNDWATER QUALITY SAMPLING RESULTS, LAKE MASSAPOAG

Sampling Station	Date	Total Phosphorus mg/l	Nitrate-N mg/l	Ammonia-N mg/l	Kjeldahl-N mg/l	Conductance mmho/cm	Total Coliform Bacteria org./100ml	Fecal Coliform Bacteria org./100ml
A1	7/8/82	0.01	0.24	0.07	0.12	85		
	10/1/82	0.02	0.32	0.02	0.25	85	<100	<100
	Average	0.015	0.28	0.045	0.19	85		
A2	7/8/82	0.01	0.10	0.06	0.09	175		
	10/1/82	0.01	0.25	0.10	0.13	157	<100	<100
	Average	0.01	0.175	0.08	0.11	166		
B1	7/8/82	0.01	1.25	0.09	0.15	180		
	10/1/82	0.01	0.96	0.02	0.13	127	<100	<100
	Average	0.01	1.11	0.055	0.14	153.5		
B2	7/8/82	0.07	1.05	0.25	0.76	930		
	10/1/82	0.01	0.51	<0.01	<0.01	126	<100	<100
	Average	0.04	0.78	0.25	0.76	528		
C1	7/8/82	0.01	0.09	0.49	1.37	135		
	10/1/82	0.02	0.11	0.02	0.21	118	<100	<100
	Average	0.015	0.10	0.26	0.79	126.5		
C2	7/8/82	0.01	0.18	0.07	0.27	130		
	10/1/82	0.08	0.09	0.15	0.36	111	<100	<100
	Average	0.045	0.135	0.11	0.315	120.5		
D2	7/8/82	0.01	0.50	0.11	0.13	157		
	10/1/82	0.01	2.27	0.04	0.40	143	300	<100
	Average	0.01	1.385	0.075	0.265	150		
	Average	0.021	0.566	0.107	0.313	189.93	128	<100

samples taken during the septic leachate survey (see Tables 4 and 14). Phosphorus does not move freely in groundwater, but is removed in the soil by chemical and biological mechanisms. Phosphorus forms precipitate in combination with iron, calcium and aluminum compounds in the soil. It can be adsorbed by soil particles and held by electrostatic bonds with the individual sand grains. The organic constituents of the soil may be replaced by the inorganic fossilization of the phosphorus. The sands and gravels which compose the stratified drift deposits surrounding Lake Massapoag have a finite capacity to attenuate phosphorus. Sand and gravel outwash soils have been estimated to have phosphorus sorption capacities ranging from 9 to 20 mg P/100g soil (Sawhney and Hill, 1975; Tofflemire and Chen, 1977).

The water samples collected at station B exhibited levels of ammonia (NH_3) and nitrate (NO_3) that greatly exceeded background surface water levels, and conductivity readings that were the highest of all the groundwater samples. These higher levels were not verified by the septic snooper survey because the snooper survey did not extend to this part of the shoreline. Station B is located at the water's edge, less than one hundred feet from a residential dwelling. It appears likely that the dwelling located upgradient of station B is contributing to levels encountered at this station.

Sample sites C and D exhibited low levels for all parameters with the exception of ammonia-N and Kjeldahl-N. There is not enough support from the levels of the other parameters to assume that leachate contaminated groundwater is entering the Lake at these points. Often times water samples obtained in muck or highly organic sediments show higher Kjeldahl-N and ammonia-N concentrations than samples in sand and gravel deposits. Nitrification, or the conversion of nitrogen containing compounds (in the form of organic and ammonia-nitrogen) to nitrate is inhibited in soils which contain an abundance of oxidizable organics. Sites C and D are both overlain by shallow organic layers and were probably sampled when a portion of the well screen was exposed to these organic sediments, thus elevating the ammonia and Kjeldahl levels. Site D was located several feet downgradient of a street runoff pipe. It is likely therefore, that nitrate levels exceeding background quality found at Site D were also enhanced by lawn or plant fertilizers from the residential area drained by this street pipe. The hydrologic budget (section 4), in conjunction with groundwater sample quality, enables determination of the quantity of nutrients entering the Lake via the groundwater system.

3.5 Lake Shoreline Sanitary Survey

A shoreline sanitary survey of Lake Massapoag was conducted on August 24 and 26, 1982. The purpose of the shoreline survey was to locate plumes of poorly treated domestic effluent entering the Lake via the groundwater flow system. The need for such a survey results from the fact

Table 14 Results of Septic Leachate Detector Survey
Lake Massapoag, Sharon, MA

Plume #	Total Coliform Bacteria org/100 ml	Fecal Coliform Bacteria org/100 ml	Ammonia-N mg/l	Nitrate-N mg/l	$NH_3 + NO_3$-N	Total Phosphorus mg/l
1	140	4	0.03	0.06	0.09	0.01
2	20	<10	0.04	0.06	0.10	0.02
3	140	<10	0.04	0.03	0.07	0.03
4	80	13	0.03	0.02	0.05	0.01
5	<10	<10	0.02	0.09	0.11	0.03
6	40	7	0.04	0.05	0.09	0.01
7	10	10	0.04	0.08	0.12	0.02
8	--	--	0.10	0.08	0.18	0.04
9	80	20	0.03	0.03	0.06	0.02
10	60	3	0.08	0.06	0.14	0.02
11	200	42	0.08	0.06	0.14	0.04
12	1900	57	0.17	0.42	0.59	0.04
13	10	12	0.11	0.36	0.47	0.02
mean	223.75	15.25	0.06	0.17	0.23	0.024
Background A	80	3	0.07	0.07	0.14	0.02
Background B	10	7	0.07	0.06	0.13	0.02
Background C	<10	4	0.08	0.06	0.14	0.02
mean	31.6	4.6	0.07	0.06	0.13	0.02
Grab 1	1100	16	0.34	0.05	0.39	0.10
DWPC Class B Criteria or Eutrophication Guideline	1000	200	--	--	0.30	0.05

that all the homes surrounding Lake Massapoag utilize on-site subsurface sewage disposal methods, many of which have been in place for over a decade, thus increasing the possibility of septic system failure.

Background and Methodology

In unsewered suburban areas, shoreline waste disposal systems, despite the requirements of the Massachusetts State Environmental Code, are often a major contributor of nutrients to groundwater and subsequently to lake water. Title V of the State Environmental Code is designed to protect surface waters and groundwaters from contamination by pathogenic organisms, but fails to adequately protect against nutrient leaching in certain situations.

Lakefront development is particularly inclined to add to lake nutrient loadings for a number of reasons. This is because many of the lot sizes predate zoning and are small in order to maximize frontage and access to the waterbody. Many seasonal dwellings have been and will be converted to year-round homes, thus placing greater stress on sewage disposal facilities. Lakefront deposits tend to be fairly coarse, often composed of sand and gravel, with little pollutant/nutrient attenuation capability. Water table elevations are high relative to septic system placement, thus further encouraging pollutant/nutrient loading to the waterbody.The northwest, northeast and southeastern reaches of the Lake Massapoag shoreline are composed of stratified drift. The characteristic sorting of this deposit allows it to have good porosity and permeability. The remaining quarter of the shoreline is underlain by glacial till-derived soils that may be overlain by stratified drift deposits. Till deposits are characteristically unstratified and unsorted. They are a conglomeration of grain sizes ranging from boulders to silts and clays. Because of this range in grain sizes, most void spaces which potentially could be occupied by water molecules are filled by finer grained materials. These qualities make till relatively impermeable.

In the porous stratified deposits surrounding much of Lake Massapoag, over-burdened or failing septic systems will probably not show surface signs of failure (i.e., overland flow, soggy upper soils), but will allow untreated wastewater to percolate down to the groundwater interface and flow with the groundwater system into the Lake. This will cause the appearance of an effluent plume in the Lake. Plume concentrations and sizes vary depending upon the characteristic permeabilities of the two types of glacial deposits. Plumes in stratified drift deposits are usually broad and of less concentration than those sharper more confined plumes found in till deposits.

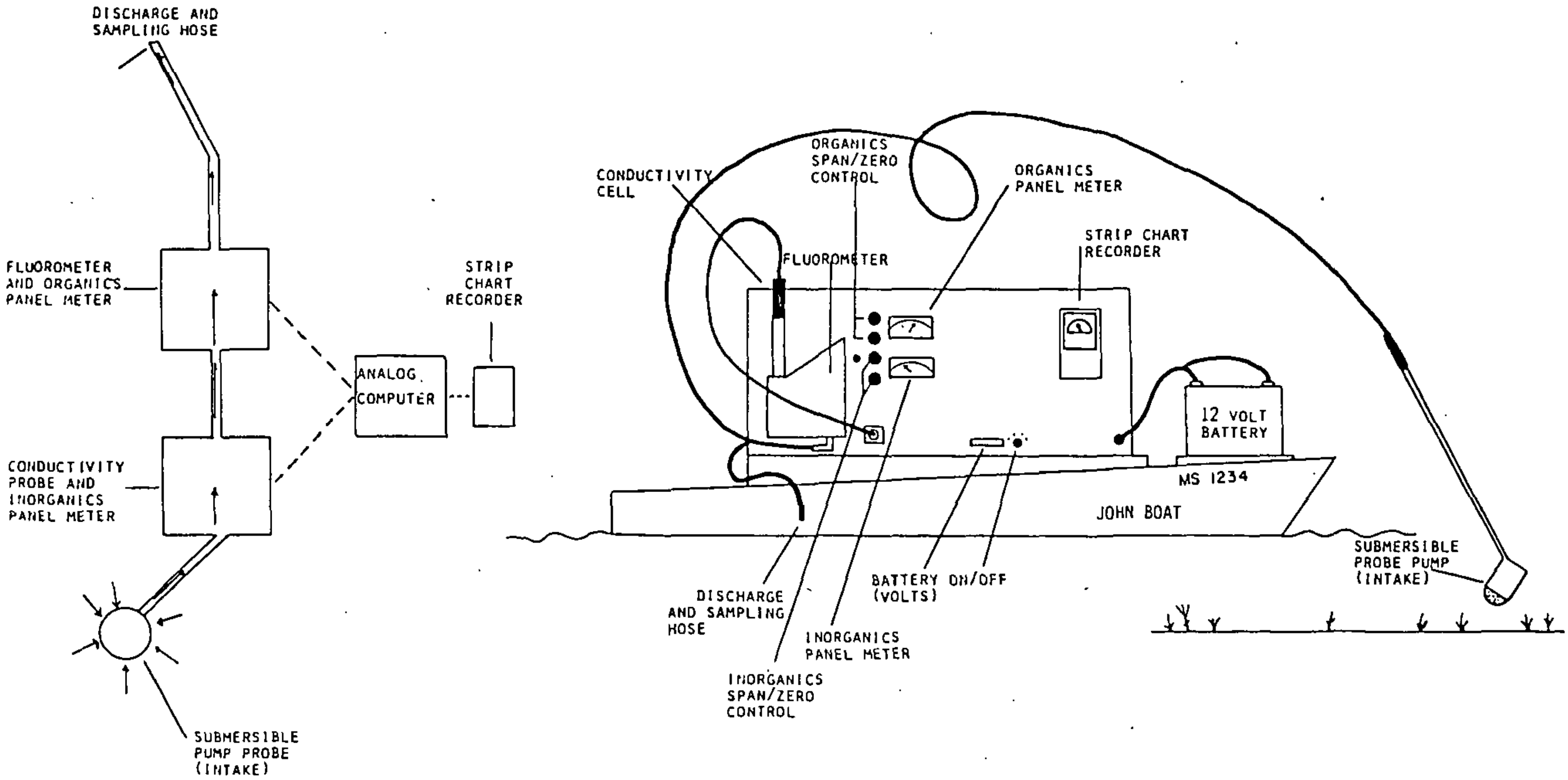
Normally, oxidizable nitrogen-containing compounds entering the soil in septic tank effluent are converted to nitrate by Nitrosomas bacteria and from nitrate to nitrite by Nitrobacter spp. In order for these conversions to take place, the soils must have favorable moisture, temperature, and oxygen content. Nitrification will not take place if the soil is so waterlogged that reducing (anaerobic) conditions result. Overloading the soils with oxidizable organics will also inhibit nitrification. Once reducing conditions develop as the result of overloading, both nitrogen and phosphorus compounds can move significant horizontal distances, eventually discharging into the pond, and encouraging microscopic algae blooms and dense growth of aquatic vascular plants.

In order to locate these septic plumes, IEP employed a device called a septic leachate detector system. The septic leachate detector is a portable field unit consisting of a subsurface probe, a water intake system, an analyzer control unit and a graphic recorder (Figure 21). The septic leachate detector system monitors two parameters, fluorescence (organic channel) and conductivity (inorganic channel). The system functions on the theory that a stable ratio exists between fluorescence and conductivity in typical septic leachate. Readings for each channel appear visually on a panel meter while individual channels or a combined signal are measured and reported on a self-contained strip chart recorder. The submersible pump unit in the subsurface sensor assembly continuously draws in lake water that is passed through the conductivity probe and the fluorometer unit. The probe is held slightly off the lake bottom where groundwater seeps or springs normally enter the lake. The water passing through the instrument first encounters the conductivity probe. The probe is a graphite electrode-type conductivity cell that is sensitive to inorganic ionic components of leachate such as chloride (Cl^-) and sodium (Na^+). If there is a rise in the incoming water conductivity, it will appear on the inorganics channel panel meter. Water then enters the fluorometer unit which is sensitive to fluorescing organic molecules typical of laundry whiteners and organic residuals of septic leachate discharges. The incoming water is passed by an ultraviolet light. If a molecule is fluorescent it will absorb the light and emit light at a different wavelength, which registers on the flurometer (organics channel) panel meter. Fluorescence and conductivity signals are generated and sent to an analog computer circuit that compares the signals against the background to which the instrument was calibrated. The resultant output is expressed as a percentage of the background and is continuously documented on the strip chart recorder. Full scale recorder output is provided for less than 1% septic leachate concentration.

A 2% solution of secondarily treated effluent was obtained from the municipal wastewater treatment plant in Marlborough, Massachusetts for use in the fixed calibration of the Septic Leachate Detector System. A 300 scale (1"=300') assessors map of the Lake area was used to plot the locations of suspected plumes (Figure 22). Written descriptions of each plume location were recorded in a field notebook and appear in Appendix C. Should any

Figure 21

SEPTIC LEACHATE DETECTOR SYSTEM



discrepancy arise between the map plotted plume location and the description provided, the written description should be considered more accurate.

The IEP field crew consisted of two individuals. One IEP employee walked parallel along the lake shoreline, holding the submersible pump slightly off the bottom, ahead of the John Boat which contained the Detector's deck unit. The second crew member observed the instrument panels and the recorder/strip chart noting and recording any indication of leachate plumes and rezeroing the organics and inorganics channels when a change in background water quality appeared evident. The second member of the survey team also plotted plume locations on the base map, collected water samples and recorded all pertinent information. The water samples were taken directly from a discharge hose located at the end point of the Leachate's circulatory system. This enabled the IEP crew to take a direct sample of a plume located under the submersible pump, a practice that would be impossible without the Septic Leachate Detector System. The water samples were kept in an ice-filled cooler at all times. The field crew also monitored the performance of the Detector System by conducting a calibration check 3 to 4 times daily. Upon completion of the field survey the water samples were taken directly to Reitzel Associates of Boylston for analysis. Reitzel Laboratories are certified by both the EPA and the state for water quality analysis.

Results and Discussion

The Septic Leachate Detector Survey was conducted continuously along the shoreline, omitting the western shoreline from the intersection of Massapoag Avenue southward to north of Porter Avenue. This shoreline was omitted because septic systems are generally set back far enough from the shoreline to reduce the potential for lake water contamination from septic leachate. Table 14 displays the test results of 13 plumes, 3 background samples and one grab sample taken at Lake Massapoag as part of the Leachate Detector Survey. Figure 22 shows the plume locations and graphically depicts the relative concentrations of bacteria and nutrients for all samples. Factors that determine when and where septic leachate will contaminate the Lake include soil type, septic system age, set back distance from the shoreline, depth to the water table, and the number and frequency of people using the system. Soil types attenuate phosphorus at different rates for different amounts of time depending generally upon their infiltration characteristics and the chemistry and mineralogy of the soil environment (see section 5.1.1). Greater volumes of soil which are determined by set back distance and the depth to the water table, offer more potential for phosphorus attenuation. More people using the septic system more frequently produce more leachate to attenuate.

Based upon the majority of samples taken with the Septic Leachate Detector System, it appears that overall, groundwater quality is quite good. An apparent source of nutrients and elevated bacteria counts are the two inlet tributaries, sampled (Plumes 11 and 12) by the Septic Leachate System, and the stream sampled as Grab Sample No. 1. Groundwater samples were collected through 1 1/4" monitor wells by IEP in this general area. The water quality results of these samples suggest that the quality of groundwater feeding the lake is comparable in nutrient levels to plume samples 12 and 13 and grab sample 1.

Two weeks preceding the Septic Leachate Detector Survey, there had been very little rain. In previous similar surveys performed by IEP, runoff from storm drains has registered consistently as effluent plumes and therefore have been sampled. At Lake Massapoag there were no samples taken at storm drains because none exhibited flow and there were no deflections in either of the two panel meters (conductance or fluorescence) of the survey instrument.

Comparing groundwater sampling results with the septic leachate detector survey samples and stormwater samples indicates that domestic subsurface waste disposal systems currently play a minor role in contributing nutrients to Lake Massapoag. They were also apparently not the cause of any elevated bacteria counts at the time this survey was taken. Over time, however, nutrient contributions from these and other areas will increase as the soil attenuation capabilities of septic systems are depleted.

Results of this survey will be incorporated as one component in the nutrient budget for Lake Massapoag. Loadings from septic systems will also be estimated utilizing a model developed by the Center for the Environment and Man (CEM, 1976) in order to provide a range of the likely septic system nutrient contribution. Future septic loadings will also be estimated using the CEM model.

3.6 Aquatic Vegetation and Plankton

3.6.1 Aquatic Vegetation

The history of aquatic weeds in Lake Massapoag is relatively recent. In the early 1950's the Massachusetts Division of Fisheries and Game (MDF&G) reported the scarcity of all types of aquatic vegetation. However, by 1969 weed growth had increased enough that the Sharon Planning Board recognized the need for a lake management program. R. D. Gordon of the Lake Management Study Committee in 1969 conducted an underwater survey of the Lake and determined that the dominant plant growth at that time was watermilfoil and bladderwort.

The early to mid-1970's brought about heavy infestations of watermilfoil which accumulated at the northern end of the Lake along Memorial Beach. It was observed that summer storms, particularly those from a southerly direction, would break the milfoil stems. The resulting weed fragments would be deposited along the shoreline and the Town would then collect the deposits. It was noted that the weed accumulation reached a peak in mid-July, but by the latter portion of the month, vegetation densities decreased to insubstantial amounts.

The year 1972 exhibited a longer duration of maximum vegetative growth, beginning in June and extending into early August. In 1976, a Massachusetts Division of Water Pollution Control (MDWPC) survey found 13 plant species to be infesting the shoreline and shallow coves of Lake Massapoag. Watermilfoil was the dominant plant species found.

Vascular aquatic plants were identified and their distribution throughout Lake Massapoag was mapped, during a survey by IEP biologists on September 24, 1981 (Figure 23). In addition to those species noted by the MDWPC in their 1976 autumn survey, golden-pert (Gratiola aurea), American elodea (Elodea canadensis), pondweed (Potamogeton sp.) and bulrush (Scirpus sp.) were new macrophytes observed in IEP's 1981 survey.

It appears that the present trend in Lake Massapoag is an acceleration of the natural lake aging process known as eutrophication. Due to man's intervention, the accumulation of nutrients, organic sediments, and aquatic vegetative growth, which normally occurs over many thousands of years, has proceeded at a rapid rate. This often results in an increased growth of macrophytes, often to nuisance proportions. In Lake Massapoag, the increased vegetation concentration has interfered with boating (clogging outboard motors), swimming and has caused premature vegetative succession. The MDWPC has assigned a trophic status of mesotrophic, or intermediate, to Lake Massapoag. Aquatic vegetation is incorporated into the lake trophic classification system with five other physical and chemical parameters. These are assigned severity points relative to other lake classifications and current literature resulting in the determination of a trophic level.

In looking at Figure 23, it can be seen that aquatic vegetation proliferates along the entire shoreline, to a maximum depth of 12 feet (at the time of the survey), with the exception of the beach areas at the northern and southern portions of the Lake. This may be due to the addition of beach sand which is deposited every few years, as well as the raking of the Town beaches by lifeguards during the recreational season. Thus, swimming and boating activities in the vicinity of the Town beaches are not affected by macrophytes. However, recreational activities along many privately owned beaches and docks are hampered by nuisance aquatic vegetation. The vegetation was not surveyed along the western shoreline at the yacht club due to the number of moored boats, which made the area unnavigable. According to Ron Gordon of the Lake Management Committee (personal commun., April 17, 1982), the high level of silty organics that comprise the bottom substrate

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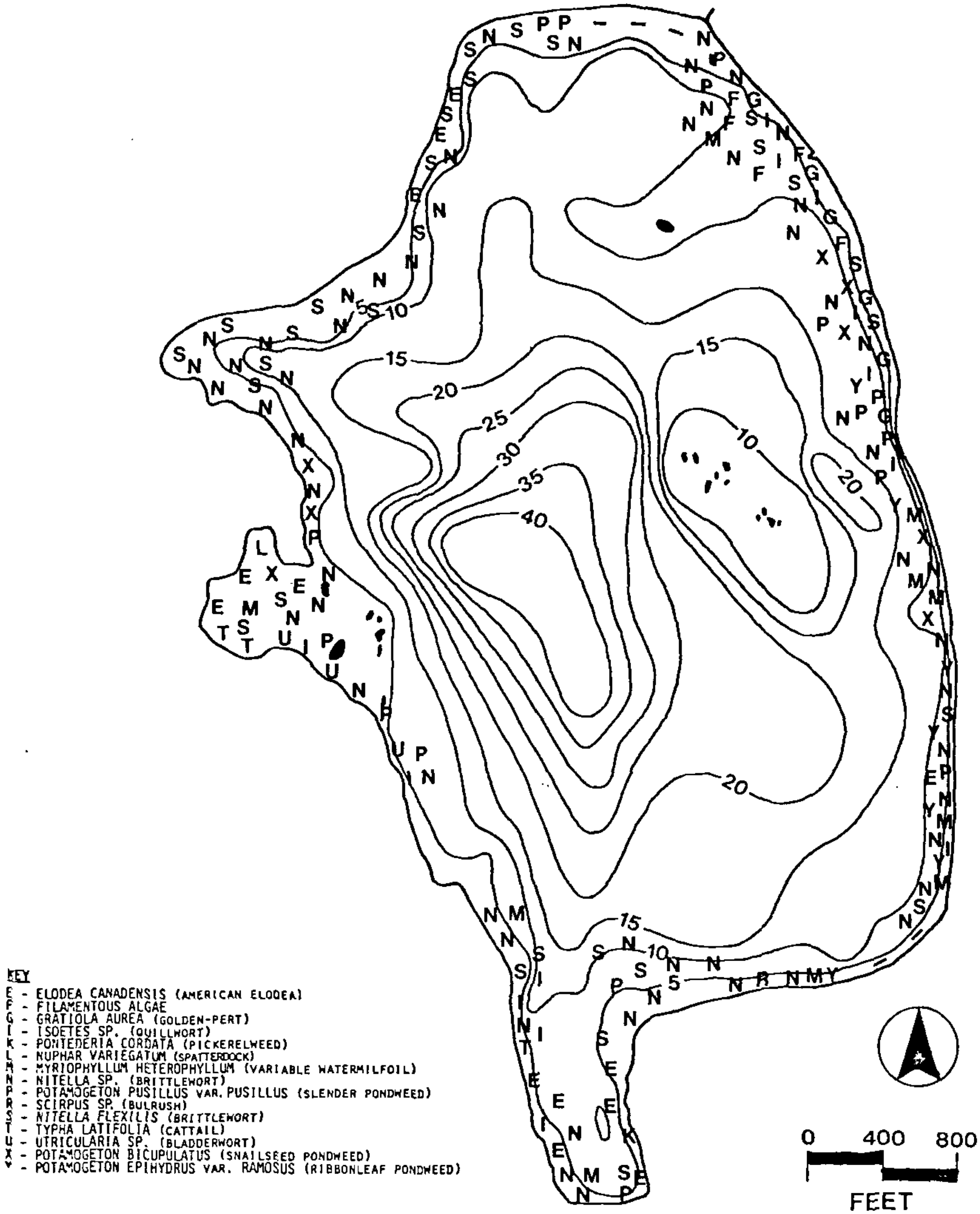

FIGURE 23
AQUATIC VEGETATION, 1981 SURVEY

LAKE MASSAPOAG DIAGNOSTIC / FEASIBILITY STUDY, IEP Inc.

allow no appreciable rooted vegetative growth to inhabit the area of the yacht club.

Watermilfoil appears to be the dominant macrophyte in the MDWPC survey, but has since been drastically reduced, most notably along the western shore (Figure 23). Sediment sampling revealed that watermilfoil inhabits primarily sand and gravel substrates such as found along the eastern shoreline. However, due to its adaptability, it was also surveyed in areas of one to two feet of silty organics, as in the southern cove. Watermilfoil is capable of colonizing a variety of organic and inorganic bottom types and may assimilate nutrients directly from the water column in order to maintain growth. This is particularly true of sand and gravel substrates which are often low in available nitrogen and phosphorus. A source of watermilfoil to the Lake may be from broken fragments or seeds originating in the wetland adjacent to the southern cove, behind the community center. This deep marsh was observed to have a significant population of watermilfoil which may produce fragments that float through its outlet to the Lake.

Brittlewort (Nitella sp., Nitella flexilis), a macroscopic algae, presently appears to be the dominant plant type in Lake Massapoag. It characteristically grows close to the bottom substrate of lakes and ponds, thus restricting the growth of the taller plant species. Because it is a low growing species that normally does not impede recreational activities Nitella is regarded as one of the most advantageous and valuable aquatic plants to inhabit New England waters and should not be discouraged in Lake Massapoag.

The three species of pondweeds (Potamogeton bicupulatus, P. epihydrus var. ramosus, and P. pusillus var. pussilus) all occur in sparse to moderate densities. Ribbonleaf pondweed inhabits only the eastern edge of the lake whereas slender and snailseed pondweeds occur throughout Lake Massapoag largely on sand and gravel substrates.

The distribution of spatterdock (Nuphar varilegatum) and bladderwort (Utricularia sp.) has not change appreciably since the 1976 MDWPC survey. Bladderwort was a dominant specie in Lake Massapoag during the 1969 study completed by R. D. Gordon but decreased by 1976 and has remained sparsely populated along the western shore. Pickerelweed (Pontederia cordata) has decreased since 1976, and is presently found only in the southern cove.

Quillwort (Isoetes sp.) has increased in distribution from its original colonization of the southern beach and cove to the eastern and western shoreline. Cattail (Typha latifolia) has increased slightly, and has been surveyed in the southern and western coves. Both quillwort and cattail are found only in sparse densities and are not considered to be nuisance species.

American elodea (Elodea canadensis), bulrush (Scirpus sp.) and golden-pert (Gratiola aurea) are three new inhabitants of Lake Massapoag. Golden-pert is a low growing macrophyte, found only along the eastern shore and is not considered a nuisance specie. Bulrush was surveyed in one area along the southern beach in very sparse densities, thus is not considered significant. American elodea is scattered throughout the perimeter of the lake in sparse to moderate densities and may be of some concern if it exhibits an increase over time.

Since the initiation of the annual fall/winter drawdown program in 1976, the vegetative composition has been appreciably altered. Overall, the density of vegetation appears to have decreased since the last completed survey in 1976, although IEP surveys indicate a shift towards a greater abundance of brittlewort, pondweeds and American elodea.

On August 4, 1982, IEP conducted a mid-summer aquatic vegetation survey in Lake Massapoag. The annual fall/winter drawdown was not carried out the previous winter (1981-82) thus, there was much interest in any notable changes of vegetative composition and distribution. The survey revealed that the absence of drawdown did not significantly alter the overall density and distribution of macrophytes. However, a few particular species did exhibit an observable change as shown in Figure 24.

The overall trend within Lake Massapoag appears to be a decrease in densities of aquatic vegetation. However, certain species, most notably slender pondweed and American elodea on the eastern shore occupy areas which were dominated by variable watermilfoil. Watermilfoil continues to decrease and presently has been reduced to sparsely inhabit the western and southern shorelines. It appears that regular overwinter drawdown of the Lake has helped to control the expansion of this species. Light, space and nutrients that have become available as a result of the reduction of watermilfoil are being utilized by newer macrophytic and algal growth, most notably along the eastern shore.

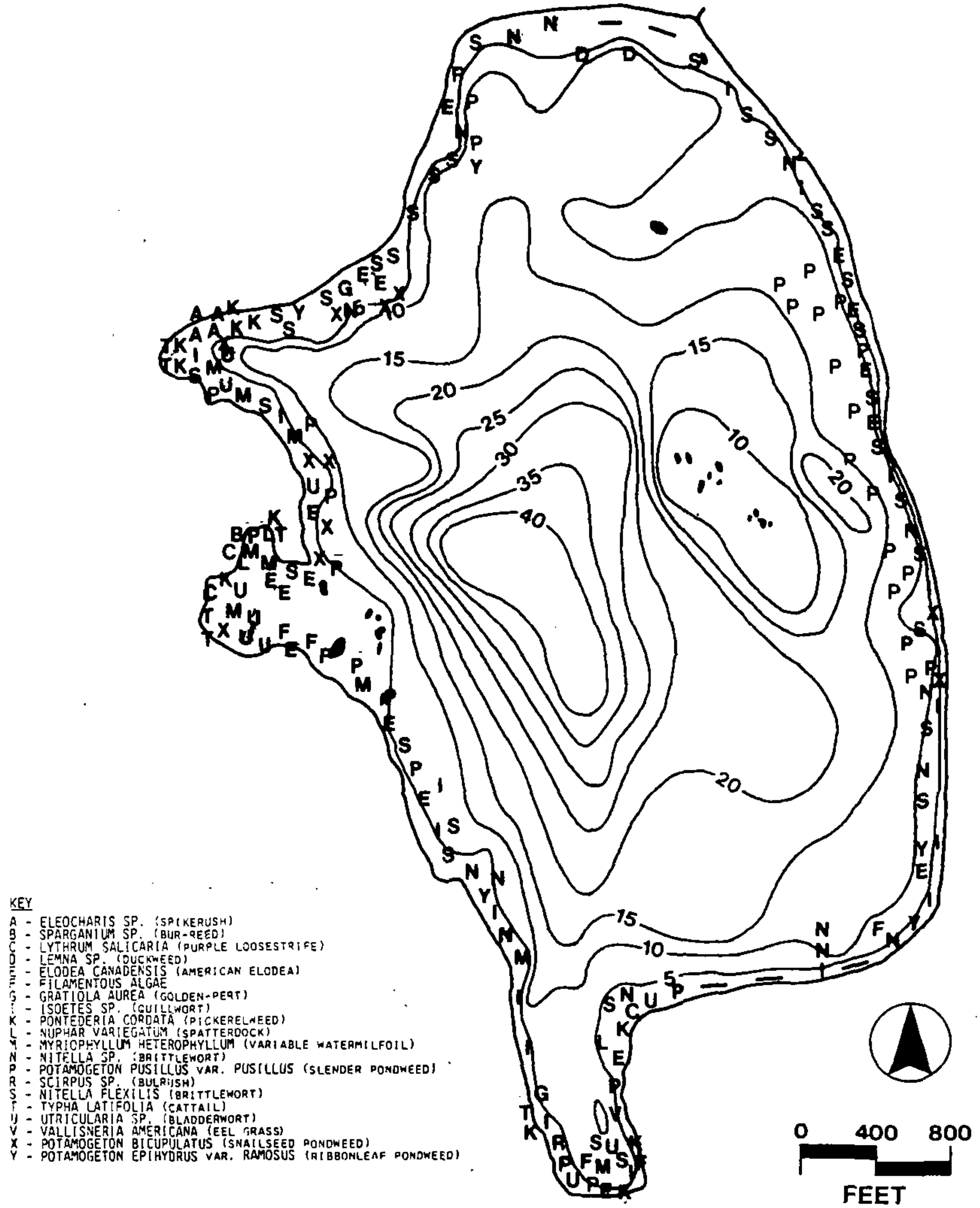

FIGURE 24

AQUATIC VEGETATION, 1982 SURVEY

LAKE MASSAPOAG DIAGNOSTIC / FEASIBILITY STUDY, IEP Inc.

Several shallow water inhabitants such as spikerush, bur-reed and purple loosestrife are prevalent along the shoreline, however, due to their inability to normally grow in water greater than three feet, these emergent species would not become a nuisance throughout the Lake. Other species such as the brittleworts and golden-pert are normally low-growing submergents which do not restrict recreational activities, thus they are not considered a nuisance in the Lake. Those species which do not inhibit recreation in Lake Massapoag should be encouraged to grow, thereby competing for available space, light and nutrients.

3.6.2 Phytoplankton, Transparency and Chlorophyll a

Throughout the monitoring period (4/16/81 - 5/4/82), water samples were collected for microscopic examination at the deep hole, station 1, by MDWPC and IEP personnel. Two types of samples for plankton analyses were collected during seven of the eight regularly scheduled rounds of baseline water quality surveys. One sample type was an integrated column sample and the other was a surface grab sample. Additional samples were taken in conjunction with other sampling activities. The samples were enumerated utilizing the strip method with a Sedgewick-Rafter counting chamber as outlined in Standard Methods (APHA, 1973). The results of the phytoplankton analyses are presented in Table 15, and a comparison of total phytoplankton, chlorophyll a and transparency analyses are presented in Figure 25.

The phytoplankton data in Table 15 reveal a wide diversity of genera throughout the sampling period. However, the total densities of algae that were in bloom conditions at the onset of the study (spring and early summer) sharply decreased in late June 1981 and stayed relatively low throughout the remainder of the sampling program. One might hypothesize that the high densities of algae observed during late spring/early summer may have been linked to the influx of nutrients resulting from decaying vegetation following an over-winter drawdown of 2 to 3 feet in the winter of 1980-1981. However, in 1981-1982 an overwinter drawdown was not carried out by the Town of Sharon. Algal densities remained low at the termination of the IEP-MDWPC water quality sampling program in March 1982.

Transparency data, taken at corresponding sampling intervals also illustrates trends in algal productivity. Transparency and phytoplankton densities generally are inversely proportional. As the density of an algal population increases, secchi disk readings decrease. This is due to the amount of suspended particulate matter in the water column. Thus, in a generalized fashion, the secchi disk is often utilized to estimate the approximate density of phytoplankton populations (Wetzel, 1975). For example, in looking at Figure 25, it is apparent that the lowest transparency reading of 3.0 feet on June 11, 1981 corresponds with a bloom of Chrysochromulina with

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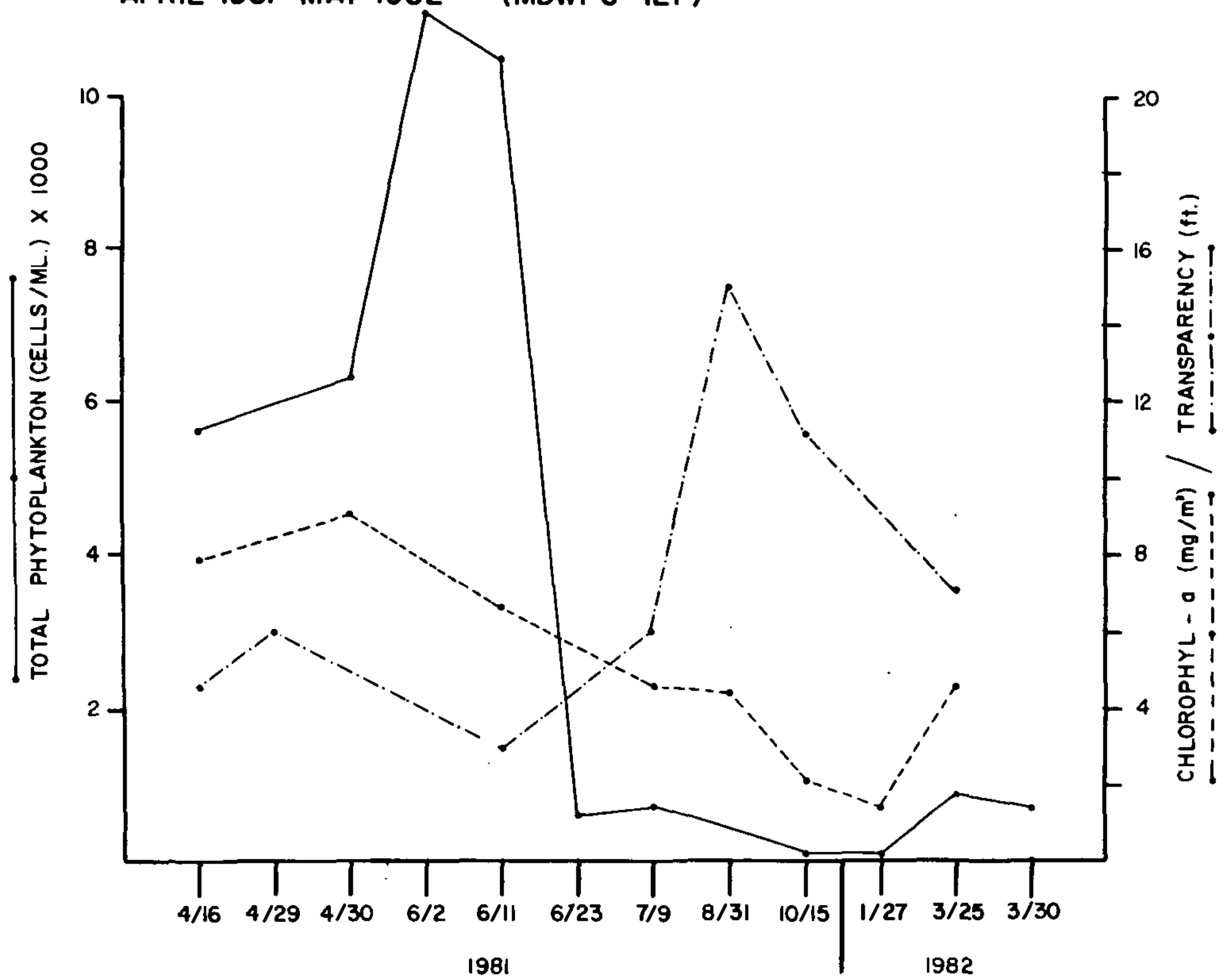
Table 15. Summary of Plankton Analyses - Lake Massapoag
MDWPC and IEP (April 1981-May 1982)

	4/16/81	4/30	6/2	6/11	6/23	7/9	10/15	1/27/82	3/25	3/30	5/4
Green Algae											
Ankistrodesmus	-	-	-	-	-	-	-	-	7	-	-
Arthrodesmus	-	-	-	28	-	-	-	-	-	-	-
Chlorella	-	-	-	-	-	322	-	-	-	101	-
Closteridium	-	-	-	-	-	-	-	7	7	-	-
Closteriopsis	-	-	-	225	-	-	-	-	43	14	-
Closterium	-	-	-	-	-	-	-	-	14	29	-
Cosmarium	-	-	-	-	-	140	-	-	-	-	-
Gloeocystis	-	-	-	-	-	-	-	-	-	-	48
Mougeotia	-	-	-	-	-	-	43	-	-	-	-
Oedogonium	-	-	-	-	-	-	-	-	14	-	-
Oocystis	-	-	-	56	-	42	-	-	-	-	-
Pediastrum	-	-	-	-	-	14	22	-	-	-	-
Phytoconis	-	-	-	-	-	-	-	-	14	-	-
Scenedesmus	-	-	28	281	-	14	-	-	-	-	646
Schroederia	-	-	-	56	-	-	-	-	-	-	-
Sphaerocystis	28	-	-	-	-	-	-	-	-	-	-
Staurastrum	-	-	-	-	-	14	-	-	22	-	-
Stichococcus	-	-	-	-	-	-	-	-	-	-	145
Tribonema	-	-	-	-	-	14	-	-	-	-	-
Ulothrix	-	-	-	-	-	-	-	-	-	14	-
Unidentified	-	-	28	-	-	70	-	-	-	14	48
Total	28	-	56	646	-	630	65	7	121	172	887
Green Flagellates											
Chlamydomonas	-	-	-	-	-	14	-	-	7	-	-
Chroomonas	-	28	-	-	28	-	-	-	-	-	-
Cryptomonas	-	-	-	28	-	-	-	-	-	-	-
Trachelomonas	28	56	-	-	-	-	-	-	-	-	-
Unidentified	-	-	28	56	112	-	-	50	14	-	-
Total	28	84	28	84	140	14	-	50	21	-	-
Blue Green Algae											
Anabaena	-	-	-	-	-	-	-	-	-	-	-
Anacystis	-	-	-	-	28	-	14	-	101	-	190
Total	-	-	-	-	28	-	14	-	101	-	190
Dinoflagellates, Golden Brown Algae and Protozoans											
Chrysochromulina	1405	3232	10173	6940	253	-	-	-	-	-	-
Dinobryon	-	-	-	-	-	-	-	-	374	331	238
Gymnodinium	-	-	-	-	28	-	-	-	-	-	-
Hemidinium	-	-	-	56	-	-	-	-	-	-	-
Mallomonas	-	-	-	-	28	-	-	-	-	-	-
Peridinium	-	-	84	393	-	-	-	-	-	-	-
Synura	-	-	-	-	-	-	-	-	7	-	-
Unidentified	-	-	-	28	-	-	-	7	22	-	-
Total	1405	3232	10257	7417	309	-	-	7	403	331	238
Diatoms											
Asterionella	197	534	253	28	-	-	-	-	7	-	38
Cocconeis	-	-	-	-	-	-	-	-	7	-	-
Cyclotella	56	84	28	-	-	-	-	-	-	14	-
Cymbella	-	-	-	-	-	14	-	-	-	-	-
Diatoma	-	-	-	-	-	-	-	-	22	-	-
Fragilaria	-	-	84	-	-	28	-	-	14	-	-
Gyrosigma	-	-	-	-	-	-	-	-	7	-	-
Meridion	28	-	-	-	-	-	-	-	7	-	-
Navicula	-	534	-	56	-	-	-	7	7	14	124
Nitzschia	-	-	-	-	-	-	-	7	22	58	-
Pinnularia	-	-	-	-	-	-	-	-	7	-	-
Stauroneis	-	-	-	-	-	14	-	-	-	-	-
Synedra	3906	1855	562	2051	112	42	-	-	101	29	304
Tabellaria	-	-	-	-	-	-	-	-	14	43	19
Unidentified	-	-	-	-	-	-	-	-	22	29	76
Total	4187	3007	927	2135	112	98	-	14	237	187	561
Total Organisms (cells)/ml	5648	6323	11268	10282	589	742	79	78	883	690	1876

FIGURE 25
LAKE MASSAPOAG, SHARON, MA.
DISTRIBUTION OF PHYTOPLANKTON, CHLOROPHYLL a CONCENTRATIONS, AND TRANSPARENCY

APRIL 1981 - MAY 1982 (MDWPC - IEP)



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densities reaching 10173 and 6940 cells/ml on June 2 and June 11, 1981, respectively.

Chlorophyll a is another parameter utilized as a general indicator of phytoplankton biomass/productivity in lentic waters. All algae contain chlorophyll a thus, measurement of this pigment may give an indication of the relative amount of algal standing crop (Weber, 1973). At Lake Massapoag, chlorophyll a samples were analyzed for the months of April 1981 through March 1982. Chlorophyll a has a close relationship with phytoplankton densities, thus a plot of the chlorophyll a measurements for the sampling duration follows the general curve of the natural trend in algal fluctuations.

Although the plankton analyses reveal a great diversity of phytoplankton taxa, there were few prevalent genera throughout most of the sampling program. The dominant alga that accounted for the bloom conditions in April to mid-June 1981 was the golden brown alga, Chrysochromulina. This species caused a 'rotten cabbage' odor in the winter of 1981 and has produced similar odors in New Hampshire and Ontario freshwater lakes (Nicholls, et. al., unpublished). Chrysochromulina rapidly declined by late June 1981 and was not present in further sampling and analyses. It is interesting to note that the chlorophyll a measurements taken during the bloom of Chrysochromulina (Class Chrysophyceae) did not reflect the high algal densities. The apparent divergence between chlorophyll a concentrations and this may be because the abundance of pigments such as B-carotene and xanthophylls, common in the golden brown algae, tend to mask the chlorophyll pigments in most species in this group (Bold, 1973). Thus, the chlorophyll a pigments are not as prevalent in Chrysochromulina as in other algae and the chlorophyll a measurement is generally not a good indicator of relative biomass of this algae.

Another prevalent algal group in Lake Massapoag was the diatoms. Of fourteen identified genera, two were predominant. Asterionella, which produces a fish odor when present in large numbers (Palmer, 1977), was at its peak from April to mid-June 1981. It then declined and was not observed again until March 1982, in very low densities. Synedra followed a similar trend. This diatom usually produces an earthy to musty odor when found in high densities, which was noted by various lake residents. Other diatoms such as Navicula and Fragilaria were found in lesser densities at various intervals throughout the monitoring period.

Summer Distribution of Phytoplankton and Transparency

An additional summer algal monitoring program was initiated following the observance of bloom conditions of a colonial blue-green alga, Anacystis by the MDWPC in mid-June, 1982. Weekly sampling was performed during the months of July-October. Sampling of phytoplankton, chlorophyll a and transparency at the deep hole (station 1) was conducted by IEP personnel. An integrated column sample was taken for algal identification and algal counts. The results of this analysis are presented in Table 16. Surface grab samples were also obtained at the deep hole on a weekly basis and at the two westerly coves during two of the sampling rounds to supplement the data obtained from the integrated column samples. The results of this analysis are presented in Table 16, 17 and 18.

Results of column algae sampling show that densities remained low throughout the summer with the highest densities reaching 590 cells/ml on July 26th. According to the lake classification system set forth by MDWPC (1980), 0-500 natural cells/ml represent clean water quality with no associated problems. Algae counts between 500-1000 cells/ml represent a slight problem that may be potentially degrading. In six of the eight integrated column sampling rounds, algae densities remained well within the lowest category for degree of severity. However, moderate to high densities of colonial blue-green algae were observed throughout the summer on the surface of the water, creating at times a thick greenish cast. The column algae counts do not reveal the bloom conditions that existed, thus the surface grab sample analyses are of primary importance for discussion purposes.

The two codominant algae groups present in Lake Massapoag during the summer were the diatoms and blue-green algae. Asterionella was the predominant diatom genera, with densities to a maximum of 209 cells/ml on September 5th. Most prevalent in the surface grab sample analyses was the colonial blue-green genera, Anacystis, which was present at the onset of the sampling program, however this algae did not reach bloom conditions within the integrated column samples. Surface grab samples identified Anacystis to be the predominant organism at the deep hole, station one, as well as in the two westerly coves (Table 18). During one sampling round (August 4), clouds of Anacystis were observed on the surface of the lake at station one. On August 26, a very thick greenish cast in the northwestern cove revealed extremely dense concentrations of Anacystis whereas the center of the lake and the southwestern cove exhibited only moderate amounts of this colonial algae. It appears that a surface algae problem may exist in the northwestern cove, possibly contributing to occasional in-lake surface algal blooms during the summer months.

Prior to the initial observation of an algal bloom by MDWPC, heavy rains occurred in early June throughout eastern Massachusetts. Hypothetically speaking, this may have resulted in an influx of nutrients from the surrounding watershed thereby resulting in an algal bloom. At this time however, there is not sufficient data to make a determination as to the cause of the surface algal blooms within the lake or in the two westerly coves. It

Table 16. Summary of Plankton Analysis, Column Sample Lake Massapoag (IEP - July 1982 - October 1982)

	7/8	7/26	8/4	8/14	8/20	8/26	9/5	10/1
Green Algae								
Ankistrodesmus	-	-	-	-	-	-	-	-
Arthrodesmus	-	-	-	-	-	-	-	-
Chlorella	-	-	57	-	57	29	10	-
Closteridium	-	-	19	-	-	-	-	19
Closteriopsis	-	-	-	-	-	-	-	-
Closterium	-	19	-	-	-	10	-	-
Cosmarium	-	-	-	-	-	-	-	-
Gloeocystis	-	-	48	38	133	19	57	-
Mougeotia	-	-	-	-	-	-	-	10
Oedogonium	-	-	-	-	-	-	-	10
Oocystis	-	-	-	10	38	-	-	-
Pediastrum	-	-	-	-	-	-	-	-
Phytoconis	-	-	-	29	-	-	-	-
Scenedesmus	29	-	48	-	-	-	-	10
Schroederia	-	-	-	-	-	-	-	-
Sphaerocystis	-	-	-	-	-	-	-	10
Staurastrum	-	-	-	-	-	-	10	38
Stichococcus	-	-	-	-	-	-	-	-
Tribonema	-	-	-	-	-	-	-	-
Ulothrix	-	-	-	-	-	-	-	-
Unidentified	-	-	10	-	-	-	-	-
Total	29	19	182	77	228	58	77	97
Green Flagellates								
Chlamydomonas	29	-	-	-	-	-	-	-
Chroomonas	-	-	-	-	-	-	-	-
Cryptomonas	-	-	-	-	-	-	-	-
Trachelomonas	19	-	-	-	-	-	-	-
Unidentified	-	10	10	-	-	-	-	10
Total	48	10	10	-	-	-	-	10
Blue Green Algae								
Anabaena	-	19	-	-	-	-	10	29
Anacystis	238	494	162	171	114	105	48	77
Oscillatoria	-	-	-	-	-	-	-	10
Total	238	513	162	171	114	105	58	116
Dinoflagellates, Golden Brown Algae and Protozoans								
Chrysochromulina	-	-	-	-	-	-	-	-
Dinobryon	10	-	-	-	-	-	-	-
Gymnodinium	-	-	-	-	-	-	-	-
Hemidinium	-	-	-	-	-	-	-	-
Mallomonas	-	-	-	-	-	-	-	-
Peridinium	-	-	-	-	-	-	-	-
Synura	-	-	-	-	-	-	-	-
Unidentified	-	-	-	-	-	-	-	10
Total	10	-	-	-	-	-	-	10
Diatoms								
Asterionella	200	48	10	-	19	124	209	57
Cocconeis	-	-	-	-	-	-	-	-
Cyclotella	19	-	-	-	-	-	-	29
Cymbella	-	-	10	-	-	-	-	-
Diatoma	-	-	-	-	-	-	-	-
Fragilaria	-	-	-	-	-	-	-	10
Gyrosigma	-	-	-	-	-	-	-	-
Meridion	-	-	-	-	-	-	-	-
Navicula	10	-	19	-	-	38	-	76
Nitzschia	-	-	-	19	-	-	-	29
Pinnularia	-	-	-	-	-	-	-	-
Stauroneis	-	-	-	-	-	-	-	-
Synedra	-	-	10	10	19	48	19	-
Tabellaria	-	-	10	-	-	-	-	48
Unidentified	-	-	-	-	-	-	-	-
Total	229	48	59	29	38	210	228	249
Total Organisms (cells)/ml	554	590	413	277	380	373	363	482

Table 17. Station One - Surface Grab Sample Results,
Summer Algal Monitoring Program 1982
Lake Massapoag

	7/26	8/4	8/14	8/20	8/26	9/5	10/1
Green Algae							
Chlorella			C				S
Gloeocapsa	C						
Gloeocystis			C	C	C		S
Oedegonium		C					S
Coelastrum			C	S			
Arthrodesmus					S		
Scenedesmus							S
Blue Green Algae							
Anabaena	C	D				C	
Anacystis	D	D	D	D	D	C	S
Chroococcus						C	
Dinoflagellates, Golden Brown Algae and Protozoans							
Euglena					S		S
Rotifers		S					
Ciliates			S				
Diatoms							
Asterionella					C	C	D
Navicula		C					
Synedra		S				S	S
Tabellaria		C					S
Diatoma							S
Comments:	Very low densities overall	Very dense cloudy masses on surface of water	Very low densities overall	Moderate densities overall	Moderate densities overall	Moderate densities overall	Very low densities overall

Key:
S - sparse
C - common
D - dense

Table 18. Westerly Coves - Surface Grab Sample Results, Lake Massapoag Summer Algal Monitoring Program

	8/14 Northwestern Cove	8/14 Southwestern Cove	8/26 Northwestern Cove	8/26 Southwestern Cove
Green Algae				
Chlorella	S	S		
Coelastrum	S			
Gloeocystis	C	S		S
Blue Green Algae				
Anacystis	D	D	D	D
Dinoflagellates, Golden Brown Algae and Protozoans				
Euglena	S	S		S
Tibonema				S
Diatoms				
Tabellaria		S		
Asterionella				C
Comments:	Very low densities overall	Very sparse densities overall	Very dense, greenish cast on water, cloudy masses on surface of water.	Moderate densities overall

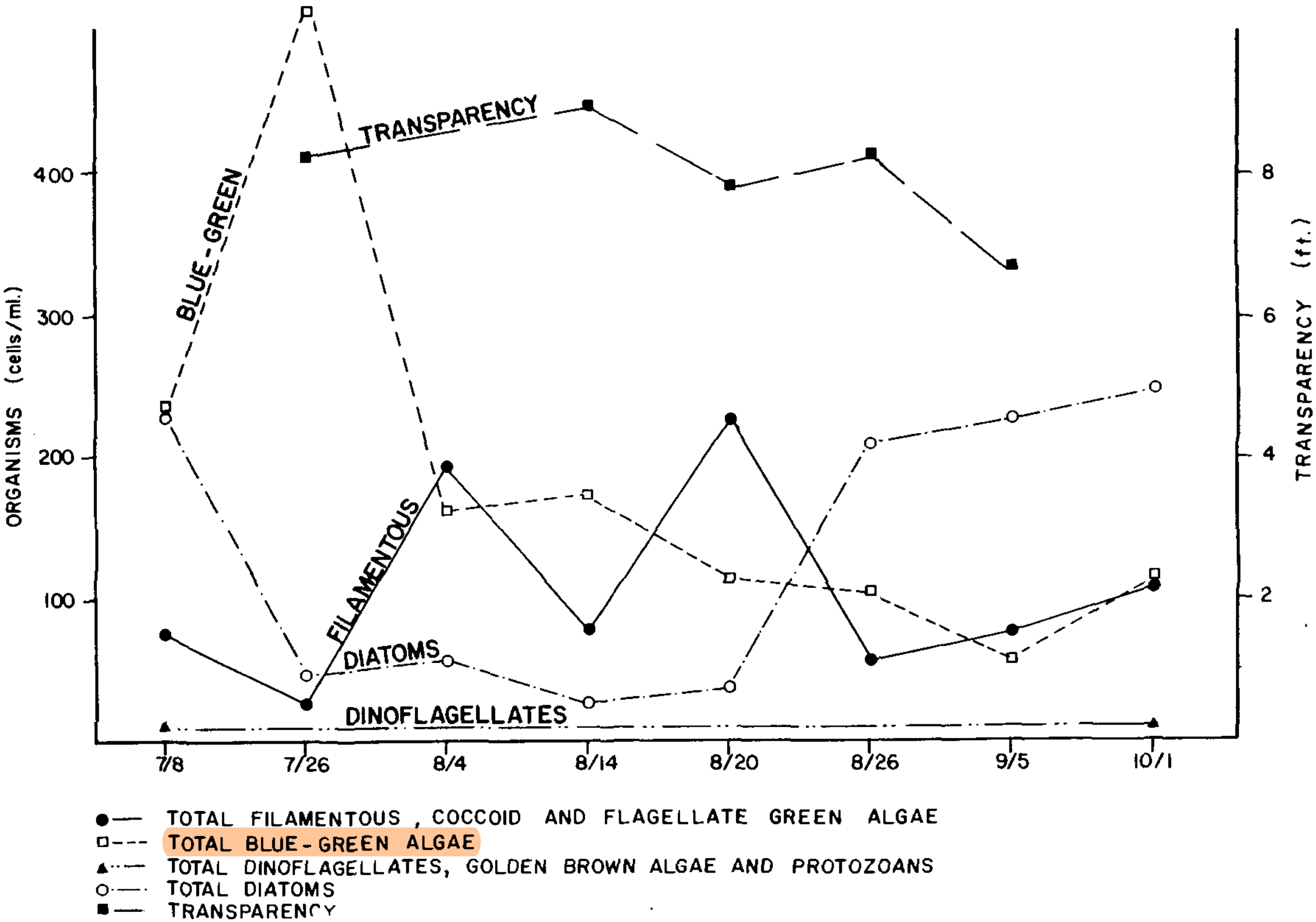
Key:
- S - sparse
- C - common
- D - dense

is suggested that further sampling be conducted to monitor the algal composition and densities in these coves.

Transparency remained relatively high at Lake Massapoag throughout the summer monitoring program with a maximum of 8'8" in August. Secchi disk readings began to decrease to a minimum of 6'8" on September 5th, corresponding with an increase in diatoms within the water column. The transparency readings in general remained lower during the 1982 summer sampling program in comparison with 1981 possibly due to the presence of colonial blue-green algae on the water surface throughout the summer. However, the presence of surface blooms of blue-green algae has not impacted recreational use of Lake Massapoag with transparency readings consistently above the state standard of four feet for public bathing areas. Figure 26 summarizes the results of transparency readings and phytoplankton distribution.

Generally speaking, the phytoplankton densities were lower in the summer of 1982 than 1981. The bloom of Chrysochromulina that was observed through the spring and early summer of 1981 and accounted for extremely high algae counts in 1981 was not present in the 1982 sampling program. One possible explanation for the overall lower algae densities in 1982 may be the absence of an overwinter drawdown in the winter of 1981/1982. Nutrients that are released into the water column and sediments upon dessication and freezing of macrophytes through drawdown may have been retained in the vegetation during the winter of 1981/1982. Thus, greater competition for available nutrients by macrophytes and phytoplankton may have accounted for lower densities of algae during the following spring and summer.

FIGURE 26
LAKE MASSAPOAG, SHARON, MA.
SUMMER DISTRIBUTION OF PHYTOPLANKTON AND TRANSPARENCY
JULY - OCTOBER 1982 IEP, INC.



4.0 HYDROLOGIC BUDGET

Lake Massapoag, similar to most natural waterbodies, is not an isolated stagnant pool. It represents a dynamic environment through which water moves at different rates and in different forms. Water is supplied to the Lake from a 1811 acre watershed as surface water inflow from streams, direct overland flow, and as groundwater inflow. Three major streams contribute surface water to the Lake from the southern and southeastern shoreline. Direct overland flow is contributed by the remainder of the watershed that is not drained by the streams. Groundwater enters the Lake through sediments that line the western, southern and eastern portions of the lake basin. Water leaves the Lake as surface water outflow through Massapoag Brook at the northern end of the Lake, as evaporation from the Lake surface, and as groundwater passing through sediments lining the northern lake basin. Water movement through the Lake is quantified in the following text in the form of an average annual hydrologic budget. Factors of the budget are later used to calculate the annual nutrient load to Lake Massapoag (section 5.0) in order to help establish the extent of biological activity in the Lake.

The average annual hydrologic budget for Lake Massapoag equates the total volume of water entering and leaving the Lake in a single year. The following equation describes this relationship:

$$\text{INFLOW} = \text{OUTFLOW}$$

$$P_L + Q_i + R + Gw_i = Q_o + E_v + Gw_o$$

where, P_L = precipitation on Lake

Q_i = stream inflow to Lake from watershed

R = direct surface runoff to Lake from watershed

Gw_i = groundwater inflow to Lake from precipitation on watershed

Q_o = stream outflow from Lake

E_v = Lake evaporation

Gw_o = groundwater outflow from Lake

Upland watershed precipitation (P_u) and evapotranspiration (E_t) are incorporated in the Lake's hydrologic budget by the following relation:

$$P_u - E_t = Q_i + R + Gw_i$$

The annual volume of Lake precipitation was calculated by multiplying the average annual depth of precipitation derived from thirty years of data (NOAA, Mansfield, Mass., 1941 - 1970) by the area of Lake Massapoag. This value was used instead of the precipitation data collected during the study period because a thirty year average more accurately describes the long-term hydrologic characteristics of the Lake.

Stream outflow from the Lake occurs solely through Massapoag Brook. Its discharge was monitored by the USGS using a continuous water-stage recorder from 1969 through 1971. In order to obtain a long-term discharge value from the Lake, these short-term discharge values were correlated with long-term discharge values of a similar basin gaged by the USGS downstream of the East Branch Neponset River at Canton. A linear regression analysis was performed on the data sets, and it was determined that the discharge patterns of the basins were similar. A regression equation was determined to relate the basin discharges and an average annual stream outflow value was calculated for Massapoag Brook.

Annual Lake evaporation was calculated using an average annual evaporation value measured over a 16 year period at Rochester, Massachusetts (NOAA, Rochester, MA, 1952 - 1967). The Rochester figure was used because it was the nearest climatically similar source of long-term lake evaporation data.

Groundwater inflow and outflow were calculated using Darcy's Law on the different hydrologic zones that form the Lake. Four groundwater flow zones were selected on the basis of hydraulic conductivity, hydraulic gradients, and drainage basin characteristics (Figure 27). Three groundwater inflow zones were established in stratified drift deposits along the northwest, southwest and southeastern edges of Lake Massapoag. A fourth groundwater outflow zone was delineated in deeper, finer lake bottom sediments in the northeastern region of the Lake.

Hydraulic conductivity values were selected after integrating information from surficial geologic maps (IEP, 1982, Figure 1) soil maps (USDA SCS, 1982, Figure 2), borings (GHR Environmental, Inc., 1982), well logs (USGS, 1973), and slug injection tests (IEP, 1982) that were performed in stratified drift deposits (wells A1, A2, B1; Figure 19). Hydraulic conductivity values calculated from these slug injection tests ranged between 64 and 506 gpd/ft^2. After comparing data from all of these sources, a representative hydraulic conductivity value of 500 gpd/ft^2 was selected for the stratified drift deposits comprising three inflow zones (USGS, 1977), whereas a value of 10 gpd/ft^2 was selected for the finer lake bottom sediments (Jaquet, 1976) that form the outflow zone. Hydraulic gradients were approximated by an IEP employee using appropriate stream gradients, and swamp versus lake elevation differences. Drainage area characteristics such

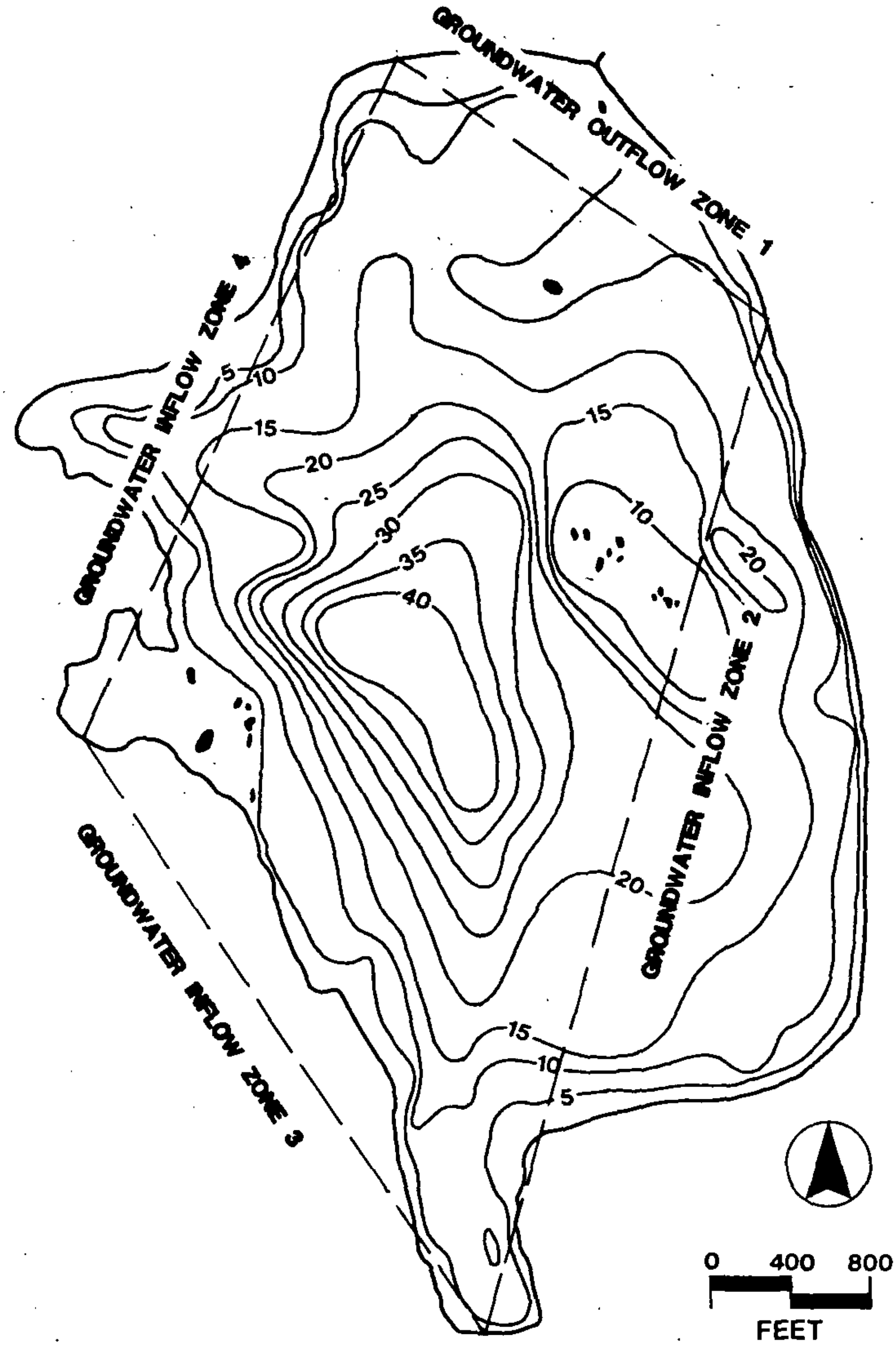


FIGURE 27

GROUNDWATER INFLOW AND OUTFLOW ZONES

LAKE MASSAPOAG DIAGNOSTIC / FEASIBILITY STUDY, IEP Inc.

as size and the areal percent of till and bedrock as compared to stratified drift helped to distinguish zones of variable groundwater inflow.

Once groundwater zones were established, the cross sectional area of each flow unit was calculated by multiplying the width of the flow zone by a representative depth in that zone. Using a representative groundwater gradient and the appropriate hydraulic conductivity value, Darcy's Law was used to obtain the average annual groundwater inflow and outflow volumes.

Information about stream inflow and surface runoff is limited for Lake Massapoag. Although stream inflow was measured several times over a period of six months (MDWPC and IEP, 1981-1982), the data were not sufficiently representative to calculate an average annual surface water inflow. Instead, stream inflow and surface runoff were isolated as one unknown and solved for by balancing the hydrologic budget.

The annual volume of watershed precipitation was calculated by multiplying the average annual depth (44.7 inches) of precipitation (NOAA, Mansfield, MA, 1941 - 1970) by the upland watershed area. Evapotranspiration from the watershed surface was calculated as the difference between precipitation on the upland watershed minus the sum of stream inflow, runoff and groundwater inflow to Lake Massapoag ($E_t = P_u - (Q_i + R + Gw_i)$).

Values calculated for the hydrologic budget components are tabulated below.

Watershed Surface	$10^7 ft^3/yr$	$10^5 M^3/yr$	% total inflow to or outflow from Lake
(P_u) precipitation on watershed	29.892	84.654	-
(E_t) evapotranspiration from watershed	3.521	9.971	-
Lake			
Inflow			
(P_L) precipitation on lake	6.441	18.241	19.63
(Q_i) stream inflow (R) surface runoff	15.469	43.808	47.14
(Gw_i) groundwater inflow	10.902	34.412	33.23
100.00Outflow			
(Q_o) stream outflow	29.220	82.751	89.06
(E_v) lake evaporation	3.141	8.895	9.57
(Gw_o) groundwater outflow	0.451	1.277	1.38
			100.00

The evapotranspiration value calculated for the upland watershed surface is lower than the average expected value for the same geographic location (New England River Basins Commission, 1975). This can be explained as a result of two major factors. First, the extent to which the Massapoag watershed is developed reduces the amount of vegetation transpiring. Second, conforming with the time and budgetary constraints of this project, the data was collected from different sources, may have spanned different years, and was sometimes interpolated or extrapolated. Inescapably, some reasonable error has resulted.

In summary, the hydrologic dynamics of Lake Massapoag are best described by balancing the inflow and outflow components of the hydrologic budget. The

dominant inflow component is the combined factor of stream inflow and surface water runoff (predominantly from Sucker Brook) followed by lesser amounts of groundwater inflow and finally from precipitation on the Lake.
Outflow from the Lake occurs largely as stream outflow (solely from Massapoag Brook), followed by relatively small losses through groundwater outflow (Figure 27) and evaporation from the Lake surface. Inflow components calculated for the hydrologic budget will be utilized to calculate the nutrient loading to Lake Massapoag in section 5.0.

5.0 NUTRIENT BUDGETS AND TROPHIC STATUS

This section will focus upon the sources and amounts of nutrients entering Lake Massapoag. In order to quantitatively relate these nutrient inputs, or loadings, to what the Lake can tolerate without suffering from diminished quality due to excessive weed or algae growth, the Lake's trophic status (oligotrophic, mesotrophic, eutrophic) has been determined using two mathematical models. In this manner, current loadings (in kilograms/year) of macronutrients (nitrogen and phosphorus) are used to classify Lake Massapoag as either oligotrophic (nutrient poor), mesotrophic (tolerable nutrient levels), or eutrophic (nutrient enriched). As a further check to the credibility of the models used, results are compared to actual chlorophyll a and secchi disk measurements. Watershed and in-lake management strategies are then examined to determine if nutrient loadings can be reduced enough to lower the Lake's trophic status (i.e. eutrophic to mesotrophic), thus improving lake water quality and usage potential.

5.1 Nutrient Budget

The "bottom line" of the diagnostic portion of a lake eutrophication study is the "nutrient budget," which quantifies nutrient loadings by source type. Phosphorus and nitrogen are the most easily measured, primary nutrients in the freshwater environment. At Lake Massapoag the weight ratio of total nitrogen to total phosphorus (N:P) in the epilimnion is greater than 15:1, thus suggesting that phosphorus is the limiting nutrient and controls the extent of biological activity (USEPA, December 1980). Although phosphorus is the nutrient in least supply (the limiting nutrient), both the nitrogen and phosphorus budgets are presented.

5.1.1 Phosphorus Budget

The ultimate source of phosphorus in the Massapoag watershed is probably igneous rocks (section 2.2). Weathering of bedrock and sediments frees the phosphorus to be recirculated in the environment. Notable secondary phosphorus sources are soils, human and animal waste, various detergents, fertilizers, decaying plants and animals, and the atmosphere. For our modelling purposes, these phosphorus sources have been categorized as: (1) watershed surface, (2) groundwater, (3) shoreline septic systems, and (4) atmospheric. Although not substantial enough to factor into the budget, gull and waterfowl excreta were also evaluated as a potential nutrient hazard.

Table 19 shows the annual phosphorus budget for Lake Massapoag itemized by the four components listed above. The methodologies used to calculate the phosphorus contribution from each component are described in detail in the following text. Note that although one method was used to calculate the groundwater contribution and another was used to calculate the atmospheric contribution, two methods were used to calculate the watershed surface and two others were used to calculate the shoreline septic system contributions. The phosphorus loading from these last two sources was calculated using different methods because the highest and the most variable phosphorus contributions are likely to originate from them. Thus, presenting a range of potential values is appropriate and provides for a basis of comparison. In order to describe the resulting spread in potential loading impact of each component, a *minimum* and *maximum* percent of the possible total phosphorus loading was calculated (Table 19). The minimum percentages were calculated by comparing the minimum possible source load to the maximum total phosphorus loading with that source value. The maximum percentages were calculated by comparing the maximum possible source load to the minimum total phosphorus loading possible with that source value.

Watershed Surface

The watershed surface component of the budget incorporates all phosphorus reaching Lake Massapoag via storm drain outlets, stream inflow, and direct surface runoff. Common phosphorus sources in the Massapoag watershed surface component are landfill, atmosphere, animal wastes, vegetative litter, fertilizers, motor vehicle residue, detergents (such as laundry and car washing), and surface pooling or leachate from defective septic systems. It is evident from previous studies (Reckhow et. al., 1980), although not easily confirmed by phosphorus concentrations measured at Massapoag, that different land use types yield different concentrations of phosphorus. This assumption is the basis of the first method used to calculate phosphorus loading from the watershed surface. Phosphorus loading from each different land use type within each subwatershed (Figure 15) was calculated as the product of EPA export coefficients (Reckhow et. al., 1980) and the individual land use areas (Table 20).

All land use unit loadings, except the landfill, were derived from USEPA coefficients (Reckhow et al., 1980) that were developed as part of a nationwide study of lake eutrophication problems. Unit loads representative of New England lake watersheds indicate that industrialized, institutional, actively used agricultural and residential areas, tend to produce higher concentrations of phosphorus than do pasture, forest and open land. In the Massapoag Watershed, phosphorus is generated largely from residential and forested land. Phosphorus generated from the landfill is included in the watershed surface component and was derived from a method developed by CEM

Table 19

Lake Massapoag Annual Total Phosphorus Budget

SOURCE	COMPUTED ANNUAL LOADINGS (kg/yr) MINIMUM	COMPUTED ANNUAL LOADINGS (kg/yr) MAXIMUM	TOTAL PHOSPHORUS CONTRIBUTION(%) MINIMUM	TOTAL PHOSPHORUS CONTRIBUTION(%) MAXIMUM
Watershed Surface (including Septic Systems >300' from shoreline)	185[A]	267[B]	34.56	67.77
Groundwater	40	40	6.48	12.82
Shoreline Septic Systems (<300' from shoreline)	47[C]	270[D]	11.93	50.47
Atmospheric	40	40	6.48	12.82
Total Phosphorus Loading	312	617		

A - Method 2; see text

B - Method 1; see text

C - Phosphorus loading calculated using EPA estimates; see text

D - Estimate of septic phosphorus loading determined using CEM Report #4199-558, 1977; see text.

TABLE 20

Watershed Surface Phosphorus Loading (kg/y) to Massapoag Lake, Method 1, Land Use Export Coefficients (EPA, 1980)

Land Use	Sub-watersheds and Direct Drainage Area													Watershed Total
	2	3	4	7	8	9	10	11	12	13	14	15	DD	
Forest	1.39	0.67	0.74	41.14	3.84	0.57	0.01	0.36	2.10	44.18	5.90	0.04	10.69	111.63
Open Land				0.89	0.34				0.87	0.06			4.25	6.41
Pasture				1.05	0.03					1.52	0.31		0.53	3.44
Agriculture										22.97				22.97
Residential		1.83	0.95	26.15	4.28	3.97	0.25	1.64	5.29	15.25	5.23	0.25	35.85	100.94
Industrial				9.27						1.65			3.50	14.42
Land Fill				7.44										7.44
LAND USE TOTAL:	1.39	2.50	1.69	85.94	8.49	4.54	0.26	2.00	8.26	85.63	11.44	0.29	54.82	267.25

(1977), which incorporates landfill area, average soil permeability, loading rate and a phosphorus concentration factor.

In Method 2 (Table 21), watershed surface phosphorus loadings were calculated as the product of discharge and concentration. The phosphorus concentrations were measured at several intervals (Section 3.2) during base flow, and once (Section 3.3) during storm discharge. In order to estimate the total annual phosphorus loading contributed by base flow as compared to storm runoff, it was necessary first to quantify separately the annual volumes of base flow and storm water. This separation was achieved by comparing the Massapoag hydrologic basin drainage characteristics to those of another, similar hydrologic basin (Nashoba Brook, Acton, Mass.) for which the proportion of storm flow to base flow was defined (Lycott Environmental Research, Inc. 1981). Applying this relationship, it was determined that approximately 40% of the total annual watershed surface inflow to Lake Massapoag is storm flow, and the remaining 60% of that total flow is base flow. The resulting total phosphorus loading from the watershed component is presented in Table 19.

As Table 19 shows, the maximum watershed surface loading (calculated using Method 2) is 1.4 times as great as the minimum loading that was calculated using Method 1. This may be partially explained by the fact that although the EPA export coefficients used for Method 1 are based on long-term data collection, they are independent of stream discharge. Method 2 utilizes estimated stream discharge and actual phosphorus concentrations measured as part of a limited sampling program. Thus, these two values are used to specify the probable range of annual loadings from this component. As shown in Table 19, the watershed surface component represents 34.56 to 67.77 percent of the total annual phosphorus loadings to Lake Massapoag.

Groundwater

The annual phosphorus loading from inflowing groundwater is estimated to be 40 kg/yr, or 6.48 to 12.82 percent of the total annual phosphorus budget. Average values of phosphorus concentration were measured twice (IEP, 1982) in seven well points along the shoreline of the Lake. IEP employees attempted to locate the well points away from other sources of phosphorus (i.e. septic systems) to insure background values. However, phosphorus concentrations measured in well points 5 and 7 were higher than the expected normal background levels of phosphorus in groundwater. It is suspected that septic leachate may have registered in these wells, thus the values were not factored into the average phosphorus concentration used to calculate the background groundwater contribution of phosphorus. Concentrations measured in well points located within defined groundwater inflow zones (see section 4.0) were factored with the annual groundwater inflow value in order to calculate the annual background groundwater phosphorus loading.

TABLE 21

Watershed Surface Phosphorus Loading to Lake Massapoag,

Method 2, Sample/Discharge

Sub-watershed	Total Phosphorus mg/l		Discharge (Q) $Qm^3/yr\text{-}x10^4$		Phosphorus Loading (kg/yr)	
	STORM	BASE	STORM	BASE	STORM	BASE
2	*	*	0.513	0.771	0.235	0.306
3	*	*	1.424	2.143	0.652	0.851
4	*	0.13	1.186	1.786	0.542	2.322
7	0.03	0.036	60.366	90.882	18.110	32.718
8	0.10	0.037	6.197	9.330	6.197	3.452
9	0.05	*	2.116	3.186	1.058	1.266
10	0.12	*	0.105	0.157	0.126	0.062
11	0.13	*	1.148	1.729	1.492	0.687
12	*	*	4.973	7.487	2.277	2.974
13	0.03	0.042	58.791	88.511	17.637	37.175
14	0.21	*	8.759	13.187	18.394	5.238
15	0.01	*	0.152	0.229	0.015	0.091
Direct Drainage	*	*	29.267	44.063	13.403	17.502
Total					80.138	104.644

* interpolated data - The loading factor for the unmonitored areas was calculated by summing the total loading from the monitored areas and dividing that sum by that total area. The resulting unit area loading factor was used for the unmonitored areas.

The storm flow loading factor = 0.04 kg/yr/acre

The base flow loading factor = 0.06 kg/yr/acre

Septic leachate that may have entered the Lake in the groundwater zone will be accounted for in the shoreline septic system loading calculations.

Shoreline Septic Systems

Phosphorus loading from septic systems is the most difficult component of the budget to quantify accurately. This is due to the complexity of mechanisms involved in the soil attenuation of phosphorus and the inability to monitor these mechanisms. With some variation, soils are very effective in removing (mostly by adsorption) phosphorus from septic leachate. Generally, soil mineralogy or chemistry controls the amount of phosphorus that is attenuated. The average rate of phosphorus bearing leachate infiltration through soil allows almost complete phosphorus attenuation provided that the soil environment is mineralogically and chemically appropriate. Soil constituents that maximize phosphorus attenuation are clay minerals, iron and aluminum oxides, and limestone.

When septic leachate leaves a septic system, it transmits through the soils in the leach field and enters the groundwater system. Phosphorus in the leachate is attenuated by the soils until the soil attenuation capacity is reached (the soil is then saturated with phosphorus). Leachate continues to transmit through the phosphorus - saturated soils following the groundwater flow pattern. Once the soil attenuation capacity is depleted for the shoreline septic systems located in the groundwater inflow zones surrounding Lake Massapoag, phosphorus-bearing leachate will contaminate the Lake directly. The resulting nutrient-rich water may accelerate in-lake algal growth.

Two methods were used to calculate comparative values of potential phosphorus loading from shoreline septic systems. The resulting phosphorus loading values that were calculated were 47 and 270 kg/yr. These values represent a minimum of 11.93 and a maximum of 50.47% of the total annual phosphorus loading from shoreline septic systems.

In the first method, the assumption was made that the septic plumes detected during the Septic Leachate Detector Survey (IEP, 1982) represented septic leachate. The number of plumes detected by the survey was multiplied by the appropriate number of people using the system, an average of 2.8 people per home (Carr, 1979), times the average loading factor of 1.6 kg/yr or 0.5 kg/yr per person (USEPA, December 1980), to obtain the loading value. The 1.6 kg/yr factor was determined to be an average expected load per person, assuming the use of phosphorus-based detergents. The 0.5 kg/yr factor was used as an average estimated load, assuming the use of nonphosphorus-based detergents. Results from a similar study performed by IEP indicated that only 50% of those homes potentially contributing septic leachate to the Lake utilize phosphorus-based detergents. Thus, an average of these two factors

(1.05 kg/yr) was used for the calculation. It was assumed that leachate from camp and beach facilities would not contain phosphorus-based detergents and that the facility would be used for less time per person per day (assumed 2/3 the normal time). The resulting loading factor was reduced to 0.3 kg/yr per person.

All of the 13 plumes were located within the established groundwater inflow zones, thus transmission of septic leachate would be inevitable and expediated in these zones. Plumes 1 through 8 and 10 were located near private residences. Plumes 11 and 12 were located near tributaries to the Lake, and plumes 9 and 13 were located near the public beach and a summer camp. Further information about specific locations and critical physical parameters for each site are shown on Figure 22 and is discussed in section 3.5.

The second method employed an empirical model (CEM, 1977) that incorporated information about the age of the septic system, set back distance from the Lake, depth to the water table, soil type attenuation capacity, number of occupants and the frequency of use in order to estimate whether or not the system is contributing phosphorus to the Lake. These factors are considered because they control the amount and rate at which phosphorus from septic leachate will reach Lake water. Ten zones where these physical characteristics are similar were established around Lake Massapoag (Figure 22). It was determined that Shoreline Septic Systems in zones 1, 2, 9 and 10 are contributing phosphorus to the Lake. The actual loading from each zone was calculated by multiplying the number of contributing units by then multiplying by the appropriate number of people, then multiplying by the phosphorus loading estimates described in the septic plume section. The resulting phosphorus loading calculated using this method was 270 kg/yr.

The total loading determined by each method differs because although both methods are valid, they are both, by necessity, simplifications of a very complex process. Therefore, the resulting values of phosphorus loading must be viewed as 'best estimates' and not as definitively accurate. Where the contributing areas established by each method differ can also be attributed to the divergent methodologies. Septic plumes are localized features that can occur as a result of an old or a new failing shoreline septic system. Based on a number of IEP septic leachate surveys, IEP employees have noted that leachate plumes from similar aged shoreline septic systems, set at comparable distances from the shoreline, and at similar heights above the water table, are more often detected when the septic system is located in till rather than in stratified drift deposits. The explanation for this is hypothetical at this point, but noting that most of the shoreline septic systems are in stratified drift, this phenomenon may partially explain the lower phosphorus loading value calculated using this method. In addition, the zones selected for the CEM method are based on averaged information, consequently the results reflect this, and some divergent conditions should be expected.

Atmospheric

Atmospheric precipitation of phosphorus includes that contained in rain, snow and dry fallout from dust, ash and industrial air pollution. This loading is applied to the surface area of the Lake only because atmospheric phosphorus falling on the upland watershed is incorporated in the watershed surface component. The average annual atmospheric phosphorus loading was calculated using an export coefficient derived from a nationwide data base (Reckhow et. al., 1980) of precipitation sampling. The resulting loading (40 kg/yr) represents 6.48 to 12.82 percent of the total annual phosphorus loading. This phosphorus source is uncontrollable on a local scale.

Other Nutrient Sources

The only other nutrient source noted at Lake Massapoag was that of gull and waterfowl excreta. At Lake Massapoag, gulls dominate the bird population year round, and other waterfowl inhabit the Lake in accordance with migration patterns. Their numbers vary collectively in response to wind or ice cover. To obtain a worst case value for the annual phosphorus loading from gull and waterfowl excreta, it was assumed that the maximum number of birds sited (Gordon, March 1983, personal commun.) during the fall of 1982 (2000 birds/waterfowl) inhabited Lake Massapoag year round. Using values for bird nutrient loading (Bedard, Therriault and Berube, 1980) of 4.9 mg (dry weight) per bird per day, an annual total phosphorus loading of 3.57 kg was calculated. This value represents 0.6 to 1.0% of the total annual phosphorus loading, and as such, plays a minor role in the overall increase of eutrophic conditions in the Lake.

It is unlikely that this maximum number of birds inhabit the Lake year round. Instead, it is more likely that their numbers are fewer, and that the nutrient and bacteria loadings would be most problematic during migration, after ice melt and where waterfowl congregate to feed. Assuming a maximum of three months (September, October and November) during which 2000 birds rest on Lake Massapoag during migration, 0.88 kg of phosphorus could be added to the Lake. Similarly, assuming continuous ice cover for three winter months (December, January and February) and a similar number of birds resting continuously on the ice, another 0.88 kg of phosphorus could enter the Lake upon ice melt. Such nutrient loading could cause or accelerate algal blooms. Also, if substantial numbers of waterfowl congregate to feed, the resultant nutrient and bacterial loading from their excreta could enhance local biological activity and create health hazards for bathers.

At Lake Massapoag however, the heavier phosphorus loadings resulting from the influx of migrating birds is probably minimal due to their short residence time. Similarly, according to local sources (Gordon, March 1983, personal commun.), insignificant numbers of birds rest on the Lake during periods of ice cover; consequently, excreta buildup and subsequent excessive phosphorus loading from ice melt is unexpected and indistinguishable in the biological (i.e., subsequent algal bloom) record. Feeding waterfowl tend to flock in deep water near the deep hole water quality station, therefore potential algal blooms and higher bacteria levels should not effect bathers.

5.1.2 Nitrogen Budget

The annual total nitrogen budget for Lake Massapoag is presented below in Table 22. Discussion of the nitrogen budget and the methodologies utilized to calculate it is brief because the methodologies used are the same as those used in the phosphorus budget. Also, nitrogen is not the limiting nutrient, therefore the nitrogen budget need not be covered in the same detail as the phosphorus budget.

For budgeting purposes, nitrogen sources have also been simplified into Watershed Surface, Groundwater, Shoreline Septic Systems, and Atmospheric components. Nitrogen originating in the watershed surface may come from elemental nitrogen that is fixed by bacteria in the soil and converted into nitrate, decaying plant and animal matter, fertilizers, and septic leachate (>300 feet from the shoreline). Nitrogen in the groundwater is largely from microbial fixation of molecular nitrogen by bacteria in the soil. shoreline septic systems produce nitrogen as a byproduct of decaying waste, and atmospheric nitrogen (from precipitation and direct fallout) can originate as ammonia released from decomposing terrestrial organic matter, electrical discharges, volcanic eruptions and possible industrial pollution.

The nitrogen budget was calculated by using methods similar to those used for calculating the phosphorus budget. The watershed surface component was determined using both the EPA land use export coefficient (Reckhow et. al., 1980) method, and the measured nitrogen concentration and estimated discharge methodology. The resulting watershed surface component comprises 31.68 to 39.44% of the total annual nitrogen budget.

The annual nitrogen loading from inflowing groundwater is estimated to be 2624 kg/yr or 19.85 to 22.39% of the total nitrogen budget. This value was calculated by multiplying nitrogen concentrations in groundwater times the annual groundwater inflow into Lake Massapoag.

Nitrogen loading from shoreline septic systems constitutes 2304 kg/yr, or 17.43 to 19.66% of the total nitrogen budget. This value was calculated using the CEM (1977) method because it yielded a more conservative (larger) estimate of nitrogen loading from septic systems.

Atmospheric precipitation of nitrogen was determined using an export coefficient calculated from a nationwide data base (Reckhow et. al., 1980). A resulting 3078 kg/yr, or 23.28 to 26.27% of the annual nitrogen budget enters the Lake via atmospheric precipitation.

Table 22

MASSAPOAG LAKE ANNUAL TOTAL NITROGEN BUDGET

Source	Annual Loading (kg/yr)	% Total	
		Minimum	Maximum
Watershed Surface	3712[A] - 5214[B]	31.68	39.44
Groundwater	2624	19.85	22.39
Shoreline Septic Systems	2304	17.43	19.66
Atmospheric	3078	23.28	26.27
Sum of Total Nitrogen	11718 13220		

A - Same as Method 1 in phosphorus section; see text.

B - Same as Method 2 in phosphorus section; see text.

5.2 Internal Nutrient Cycling

It is widely accepted (USEPA, December 1980 and Reckhow, 1979) that on a net annual basis, most ponds and lakes act as phosphorus sinks that retain more phosphorus than they release. Indeed, this concept is implicit in most eutrophication models. It has also been shown (Snow and Digiano, 1976) that lake bottom sediments may alternately act as a source or a sink at various times during a given year, thus changing the in-lake nutrient concentration and distribution. Therefore, when developing a program for lake water quality improvement and control, it is not only important to establish the external nutrient loading to the Lake, but also to better define when the sediments act as a sink or a source, what volume of nutrients are released from them, and how they are recycled within the Lake.

The factors that determine whether the sediments act as a sink or a source include nutrient concentrations in the hypolimnion, sediments and interstitial water, dissolved oxygen and pH at the sediment/water interface, redox potential, the presence or absence of major cations (Ca, Fe, and Al), particulate settling velocity, and flushing time. Most of these factors may be highly variable throughout the year, thus monitoring them sufficiently to estimate nutrient release/sedimentation is, at best, difficult. The trophic state models (Dillon-Rigler and Vollenweider in Reckhow, 1979) applied in this study have simplified estimates of phosphorus retention by a lake as functions of morphological features such as retention time and mean depth which have proven to correlate well with retention ability.

The Dillon-Rigler-Kirchner formula for estimating the annual fraction (R) of the phosphorus loading which is retained by a lake is:

$$R = 0.426\ e^{[-0.271(z/t)]} + 0.574\ e^{[-0.00949(z/t)]}$$

Solving the equation for Lake Massapoag yields a value of R=0.65, which indicates that 65% of the total annual external phosphorus load is retained annually by the sediments.

Phosphorus which may be recycled into the overlying waters of Lake Massapoag is likely to do so after Fall and Spring turnover. Analysis of temperature and dissolved oxygen profiles for Lake Massapoag revealed that the Lake was thermally stratified on August 31, 1981, and had developed an anoxic hypolimnion. These reducing conditions were further substantiated by a dramatic increase in phosphorus that was released from sediments and observed in the hypolimnion. Fall turnover, which occurred between August 31 and October 15, 1981, could have circulated this high nutrient concentration into the Lake. Calculations using measured phosphorus concentrations in the hypolimnion indicated that a potential 65 kg of phosphorus could have been circulated into the Lake after Fall turnover. A contrasting mass of 8 kg of phosphorus remained in the hypolimnion after Fall turnover, thus freeing 57 kg of phosphorus for circulation in the Lake. These values were calculated by multiplying lake volume increments times phosphorus concentrations measured within those increments. To calculate the mass of phosphorus potentially circulated after Fall turnover, it was assumed that an existing mass of phosphorus prior to thermal stratification had to be subtracted from the total phosphorus mass calculated for the hypolimnion prior to Fall turnover. Documentation of the additional phosphorus circulated in the Lake was attempted by observing phosphorus concentrations following Fall turnover. However, no commensurate increases in phosphorus concentration were observed. It is possible that the reintroduction of oxygen to the hypolimnion resulting from the turnover initiated reprecipitation of the phosphorus, thus subduing the increase in phosphorus concentration. Indeed, iron and manganese concentrations which increased with depth after the Fall turnover, substantiate this hypothesis of nutrient release and removal.

Internal nutrient recycling following Spring turnover was not evident from in-lake phosphorus concentrations. Phosphorus concentrations measured at the Lake surface and bottom just prior to Spring turnover were equivalent to 0.03 mg/l. Although phosphorus concentrations increase in the trophic zone following Spring turnover, this is.

Two recorded instances of algal blooms appear to be associated with seasonal lake turnover and internal lake recycling processes. In September of 1968 a single plankton sample analyzed by the Federal Water Pollution Control Administration revealed bloom conditions of diatoms in Lake Massapoag. It was determined that this diatom pulse may reflect a periodic response to Fall turnover, succession after summer die-off of green-algae or several other phenomena. Another recorded algal bloom occurred in 1981 following Spring turnover, comprised primarily of golden brown algae and diatoms. Subsequent algal pulses were not always coincident with spring and fall internal lake recycling. Most algal pulses were below bloom classification (Table 16) except for a summer surface bloom of colonial blue-green algae in 1982 which does not appear to be associated with internal lake recyling. At this time it cannot be concluded that algal blooms are commonly associated with internal lake recycling processes.

It is apparent from these data that internal lake nutrient recycling does not have a major impact on the Lake trophic status. Instead, it is probable that external nutrient sources have a much greater influence on Lake water quality. A more detailed, longer term water quality sampling program would enable a more definitive statement to be made about the actual impact of nutrients recycled from bottom sediments on the Lake trophic status.

5.3 Trophic Status

Essentially, the determination of the trophic status of a lake involves a comparison of the actual total phosphorus loading to that lake with the maximum permissible loading which that waterbody can tolerate before the occurrence of excessive weed and algae growth. By making this comparison, the models developed by several researchers provide classification of the lake as oligotrophic, mesotrophic, or eutrophic. Additionally, they demonstrate changes in classification which would result from implementing selected management strategies.

Two models have been selected for the analysis of Lake Massapoag: (1) the Dillon-Rigler (1975), and (2) the Vollenweider (1976) (Reckhow, 1979) models. Both models have been widely used and well documented. Each predicts the tolerance of a lake for phosphorus as a function of two lake morphological parameters: (1) mean depth (z), and (2) hydraulic residence (or "flushing") time (t). These factors have proven to be the primary determinants of permissible phosphorus loading. Lakes with short flushing times and large mean depths can generally tolerate high phosphorus loadings. Therefore, trophic status may be improved by management strategies that increase z, decrease t, or decrease phosphorus loading. The Dillon-Rigler model also considers phosphorus retention by the pond sediments.

Table 23 defines the trophic boundary loadings resulting from application of the two models to Lake Massapoag. The resulting loading values and ranges differ. Generally, the Dillon-Rigler model results show the Lake to be more tolerant to phosphorus loading than does the Vollenweider results. The differences are probably due to the Dillon-Rigler model's consideration of phosphorus retention by the sediments.

Table 23.

Lake Massapoag Trophic Boundaries as a Function of Phosphorus Loading

Model	Oligotrophic/Mesotrophic Loading Boundary (kg/yr)	Mesotrophic/Eutrophic Loading Boundary (kg/yr)
Dillon-Rigler (1975)	234.6 - 338.1	472.0 - 694.0
Vollenweider (1976)	160.2 - 240.4	320.5 - 480.8

The combined model results show that a eutrophic condition would be likely for Lake Massapoag if the phosphorus loading were to exceed 320 to 694 kg/yr. The measured and calculated estimates of the existing annual loadings range from 312 to 617 kg/yr (section 5.1). Therefore, the Lake may be currently classified as borderline mesotrophic/eutrophic based on the calculated loadings.

Figure 28 is a graphical representation of the existing trophic status of Lake Massapoag based on the Dillon-Rigler model. It is a plot of phosphorus loading (in different units after sediment retention) versus mean depth, and shows the zones of oligotrophy, mesotrophy and eutrophy. The Lake Massapoag loading range centers in the mesotrophic zone.

Figure 29 is a graphical representation of the existing trophic status based on the Vollenweider model. It is a plot of annual phosphorus loading versus the hydraulic load, q_s, on the lake, where $q_s = z/t$. These loading values plot somewhat higher on this trophic scale, straddling the mesotrophic/eutrophic boundary. The basis for development of all eutrophication models which relate phosphorus loadings to trophic status is the in-lake phosphorus concentration taken as an annual mean value because the models assume completely mixed, annualized loading conditions. The oligotrophic/

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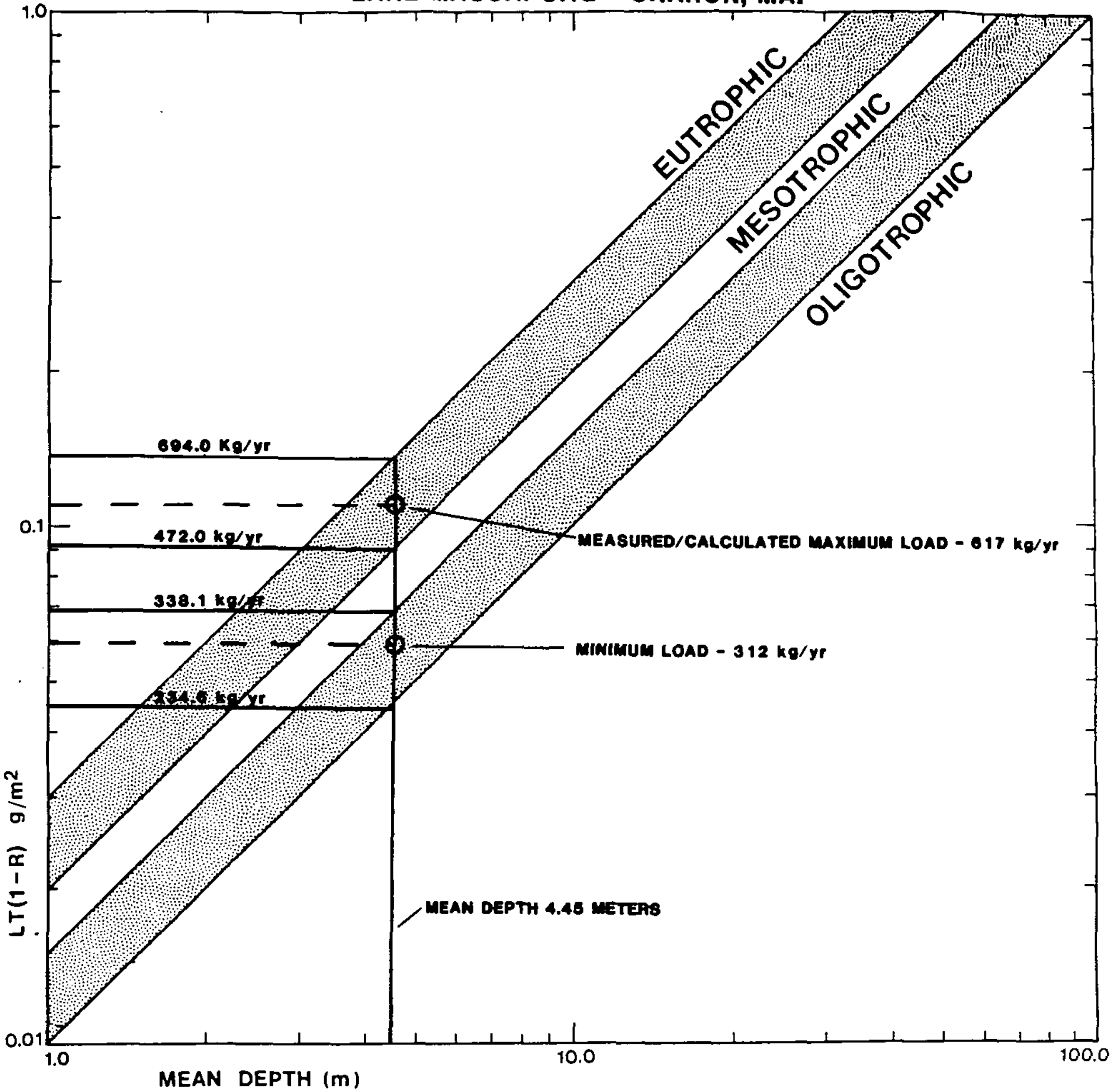
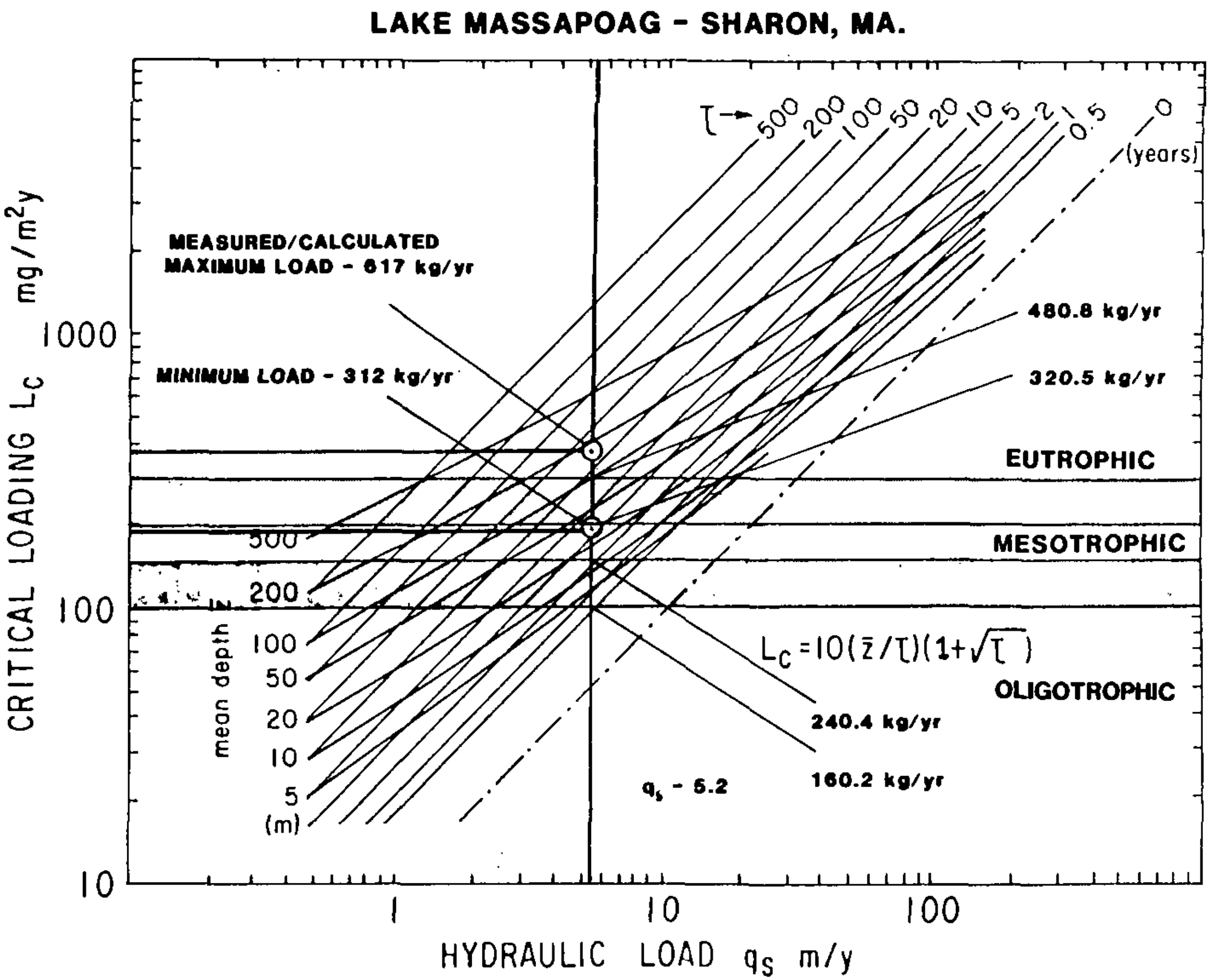


L = AREAL PHOSPHORUS LOADING ($g/m^2/yr$)
R = PHOSPHORUS RETENTION COEFFICIENT (DIMENSIONLESS)
T = HYDRAULIC RETENTION TIME (yr)

FIGURE 28 DILLON/RIGLER TROPHIC STATUS

FIGURE 29



Vollenweider's Phosphorus Loading Criterion (1976), L versus q_s, z, and τ mesotrophic boundary condition corresponds to an in-lake phosphorus concentration of between 0.010 and 0.015 mg/l, and the mesotrophic/eutrophic boundary to between 0.020 and 0.030 mg/l (USEPA, December 1980). The annual mean phosphorus concentration in Lake Massapoag derived from the eight rounds of water quality sampling at 12 depths, was 0.034 mg/l. This value would categorize Lake Massapoag as being slightly eutrophic. Therefore, the water quality sampling results tend to confirm the loading tolerance and trophic status derived by the Vollenweider model.

A final check on the trophic status involves the comparison of calculated and measured values with boundary values (USEPA, 1980) of summer secchi disk transparency and chlorophyll a concentration, both of which are primary indicators of trophic status. Table 24 allows these comparisons. The calculated values of both parameters describe Lake Massapoag as having advanced mesotrophic characteristics, whereas the measured values (only one sampling date: August 31, 1981) indicate early mesotrophic conditions. This is considered consistent with the classification range established using the Vollenweider and Dillon-Rigler models.

In conclusion, the consensus of methods classifies the existing trophic status of Lake Massapoag as being mesotrophic to borderline mesotrophic/eutrophic. The minimal disagreement of results among methods is expected due to their empirical nature.

Table 24.

Concentration of Chlorophyll a and Secchi Disk Transparency in Lake Massapoag

	Chlorophyll a concentration (mg/l)	Secchi Disk transparency (m)
Oligotrophic/Mesotrophic Boundary	0.002 - 0.004	3-5
Mesotrophic/Eutrophic Boundary	0.006 - 0.010	1.5-2
Calculated Value (using summer P value)	0.0103	1.58
Measured Value (8/31/81)	0.00436	4.572

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5.4 Future Nutrient Loadings and Trophic Status

Defining what the trophic state of Lake Massapoag will be in the future (year 2000) without initiating corrective and preventive nutrient controlling environmental changes, further points out the importance of controlling nutrient loading to the Lake in order to maintain an environmentally satisfactory trophic state. Accurate determination of the nutrient load to Lake Massapoag in the year 2000 is difficult using current methodologies. However, it is possible to determine which of the current nutrient sources will increase the nutrient load and to provide a reasonable estimate of how much the loading will increase.

Of the four major nutrient sources, the annual phosphorus loading from the watershed surface and from shoreline septic systems is most likely to increase by the year 2000. Annual phosphorus loading from atmospheric and groundwater sources should remain the same.

Total phosphorus loading from the watershed surface was calculated using Method 1, described earlier in this section (USEPA export coefficients associated with land use types). It was assumed that the area of residential land use would increase proportionally with the Town's projected population increase of 17.44% (MAPC, March 28, 1983, personal commun). An equivalent decrease in land use area was assumed for forest, open land, pasture and agricultural land use areas. The magnitude of decrease in these areas was determined to be directly proportional to the percent of total watershed area covered by each of those land use types. A resulting total phosphorus load of 278 kg/yr, or an increase of 4.1% in the annual phosphorus loading from the 1983 watershed surface component is projected for the year 2000.

Total phosphorus loading from shoreline septic systems in the year 2000 was calculated using the CEM method described earlier in this section. A resulting 289 kg/yr, or a 7% increase from the 1983 annual phosphorus load originating from shoreline septic systems was projected. Table 25 presents the projected phosphorus loading from the four major phosphorus sources for the year 2000. Furthermore, this table indicates that without the effectuation of watershed and lake management strategies designed to curb nutrient input, Lake Massapoag will clearly be classified a eutrophic waterbody by the year 2000.

Table 25.

Lake Massapoag Projected Total Phosphorus Budget in the Year 2000

Source	Annual Loading (kg/yr)	% of Total
Watershed Surface	278[A]	42.97
Atmospheric	40	6.18
Shoreline Septic Systems	289[B]	44.67
Groundwater	40	6.18
Total	647	100.00

A - Calculated using method 1; see text

B - Estimate of septic phosphorus loading determined using the CEM Report #4199-558, 1977; see text

6.0 Evaluation of Watershed Management Strategies

6.1 Land Use Regulation

A community has, through its various regulatory avenues, the ability to affect watershed parameters such as land use types and densities; drainage and roadway design; placement, type and sizing of septic systems. All of these parameters influence the flow of nutrients to Lake Massapoag, thus by regulating them properly, the Town of Sharon can lessen and control future nutrient loading to the Lake. Existing Sharon zoning bylaws and subdivision regulations affecting these watershed parameters are effective, but could be adapted for better nutrient control.

6.1.1 Zoning

The foundation of local land use control rests in the zoning bylaw. Through this piece of local legislation a community sets forth use and intensity requirements throughout the Town.

The Lake Massapoag watershed is zoned as a Rural District (R-2) in which the minimum lot size is 80,000 s.f. per dwelling unit or other use. The Board of Appeals can also grant a Special Permit for Cluster Development in the watershed. The latter development alternative could reduce the allowable lot size to 40,000 s.f. Cluster development can double the potential loading of phosphorus to the lake from a future development by doubling the number of dwelling units permitted in the development. However, some advantages to cluster development do exist: reduction in disturbed vegetation; reduction in land disturbed by construction; reduction in adapted waterways; less volume of cut and fill associated with construction; more area preserved in a natural state; reduced number of on-site disposal systems; and decreased area covered by impermeable surfaces.

Future development is further restricted in areas bordering certain wetlands by the Wetland Setback regulation (Section 3320). This regulation reduces the scope of development within 75 feet of Lake Massapoag and Sucker Brook in order to avoid reduction in water retention and water quality resulting from development within or in proximity to wetlands. The Lake Massapoag watershed has also been zoned as a Water Resource Protection District (Section 4500). This regulation is aimed at preventing development that could potentially degrade surface water used for public recreation or municipal groundwater supplies.

Many of the zoning changes beneficial to the Lake have been incorporated in the zoning bylaw. However, much of the area around and near the Lake was well developed before R-2 zoning, Wetland Setback and the Watershed Protection District were established. As an example, many of the existing shoreline lots cover far less than the 80,000 s.f. parameter adopted with R-2 zoning. Thus, the impact of existing and future zoning changes is limited.

In an attempt to phase out such nonconformities, the Town has amended the zoning bylaw with the subsection 6410 entitled "Nonconforming Uses." This amendment insures that when the site is abandoned, not used for 2 years, or until the Variance or Special Permit authorizing the nonconforming use expires, "no land or structure shall be permitted to revert to a nonconforming use or structure."

An additional, more effective zone adaptation might be the creation of a Lake front district. To be most effective this zone should incorporate all land within 300 feet of the Lake. Some suggested restrictions to be imposed are the use of nonphosphate detergents, minimal lawn fertilization, and the like. Guidelines for such a district could be formulated through the Planning Commission. Control of the district would be most effective if a Lake Association of shoreline residents was formed to assume the responsibility of their home environment.

Two other zone adaptations may be advisable. First, the Wetland Setback regulation could be expanded to encompass the unnamed tributary system entering the Lake south of the Community Center (inlet 13, Figure 15), and the small, unnamed tributary that enters the southwest corner of the southernmost cove (inlet 8). Second, the Town should try to preserve any undeveloped or less developed shoreline areas, particularly near Camp Wonderland, the Hill Crest Community Center, Camp Gannet, Horizons for Youth Camp, and the Yacht Club. The Town could preserve these areas most effectively by purchasing the land or by obtaining a written agreement with land owners which establishes the type of existing and future land use. Funds for land purchase may come directly from town funds, or available state and federal resources. The Massachusetts Self-Help Program and the Land and Water Conservation fund are aid programs that might be applied in the Lake Massapoag watershed.

6.1.2 Subdivision Control Regulations

The Subdivision Regulations of the Town of Sharon contain some provisions that allow for protection of the water quality of Lake Massapoag via design and construction standards. For the most effective use of the present regulations, it is recommended that the following points be emphasized when reviewing subdivision plans for development in the Lake Massapoag watershed:

- Section 4.1.2 Paragraph a2 - Reduce the area over which vegetation will be disturbed especially within 200 feet of the Lake or tributary streams.

- Section 4.1.2 Paragraph a6 - Reduce the increase in peak rates of stormwater transport from the site.

- Section 4.1.2 Paragraph a10 - Reduce soil loss or instability during and after construction.

- Section 4.1.3.4 Paragraph a - Improvements to minimize adverse environmental impact installed when required during construction, and all possible measures taken to minimize dust and erosion during construction (particularly near the Lake).

- Section 4.5.2.1 (also Zoning Paragraph 4521) - Stormwater runoff resulting from development shall be minimized; channeled into natural drainageways; and spread over vegetated areas for infiltration where possible.

Changes to the Subdivision Regulations could be made to increase protection of the Town's resources. Suggested changes include requirements that the proposed development does not alter the quality of runoff from the site; or increase the peak discharge or total volume of runoff.

No matter how protective written performance standards are, they will be ineffective unless properly enforced. As well as careful review of subdivision plans, regular inspection of sites during construction is recommended for maximum effectiveness.

6.1.3 Board of Health Regulations

Homes in the Lake Massapoag watershed operate on sewage disposal systems such as cesspools or septic systems. The installation of new septic systems is governed by State Title 5 Regulations and must be approved by the Sharon Board of Health.

Existing septic systems and cesspools that surround Lake Massapoag contribute septic leachate to the Lake, and will continue to do so in increasing amounts. In large part, the community can control the impact of leachate contamination using several approaches that are enumerated here and discussed in section 6.2. It is recommended that the Town of Sharon:

1. Perform more leachate surveys to better define where septic leachate may be entering the Lake.

2. Check the origin of septic leachate plumes and enforce corrective measures.

3. Establish a septic system inspection and maintenance program.

4. Explore means of reducing loadings to septic systems.

5. Explore alteratives for replacing shoreline septic systems, such as community septic systems located away from the Lake.

6.1.4 Wetlands Protection

The Town of Sharon established the Wetland Setback regulation (see Zoning) which limits the scope of development surrounding most of the wetlands in order to prevent reduced water quality and retention capacity. This regulation prohibits activities within 75 feet of the wetlands such as filling, placing or dumping natural or manmade debris; draining, excavating, or dredging natural debris; any act that would alter land contours, or otherwise detrimentally alter the surface or subsurface environment. The enforcement of this regulation is performed by the Town Board of Appeals with advice from the Conservation Commission, Board of Health and the Planning Board.

An additional, broader-ranged tool for protecting the quality of wetlands, surface and groundwater is the Massachusetts Wetlands Protection Act (MGL Ch.131, s.40). The Act defines wetland resource areas and identifies seven values which are to be defended under the Act. Values include public and private water supply, groundwater, pollution prevention, flood control, storm damage prevention, fisheries and shellfish. Specific activities proposed within 100 feet of a wetland resource area may fall under the jurisdiction of the local Conservation Commission. In its regulatory capacity, the Conservation Commission may require that certain runoff quality criteria are met, or that erosion control measures are established and implemented.

On April 1, 1983, the Massachusetts DEQE promulgated new regulations under Ch.131, s.40. These greatly restricted filling and alteration of contiguous wetland systems, such as those along Sucker Brook, two unnamed tributaries that drain into the southernmost cove, and the wetlands abutting the northwestern reaches of Lake Massapoag.

It should be stressed that the Wetlands Protection Act is used to regulate, rather than to prevent, development in wetland areas. Thus, development can take place, provided that the restrictions established by the Wetlands Protection Act are met. Use of the Wetlands Protection Act as a means of controlling nutrient loading from development is limited in the following ways: (1) the regulating agency of the Massachusetts Department of Environmental Quality Engineering does not consider lake eutrophication a form of pollution. Thus, there is no control over any development, meeting the Wetlands Protection Act standards, that provides a nutrient source (such as septic systems or road runoff to the Lake); (2) unless the Town places its own more stringent restrictions on septic system siting and design, the State Title 5 regulations preempt any restrictions imposed through the Wetlands Protection Act.

Another value of the Wetlands Protection Act in the Lake Massapoag watershed is its use for regulating forestry activities in areas sensitive to silviculture-related impacts. Considering the large proportion of forested land in the watershed, pollution from silvicultural activities should be recognized as a potential threat to water quality; and careful review given by the Conservation Commission to proposed projects in the Lake watershed. In order to facilitate protection of Lake Massapoag through the Wetlands Protection Act, mapping of protected wetlands and resource areas throughout the watershed is recommended.

The philosophy underlying the State Wetlands Protection Act is the protection of the functions or values of these resource areas. As previously stated, one of the statutory values of wetlands is the prevention of pollution. Many of the wetland areas in the Lake Massapoag watershed may function to buffer the impact of stormwater, and other runoff of poor quality, to the Lake. In order to use wetlands regulation for the protection of Lake Massapoag water quality, the specific pollution prevention functions of wetland areas in the watershed should be studied and documented, recognized by the local Conservation Commission, and protected to the degree warranted by their value. Town ownership of the most significant wetland areas would ensure a high degree of protection. As with other land use regulation recommendations, implementation of such a watershed wetland inventory and protection program would not act to reduce present nutrient loading to Lake Massapoag; but would curtail future increases in loading that might occur as a result of loss of wetland area. Enhancement of the pollution prevention value of existing wetlands, in order to provide additional nutrient attenuation, is discussed in section 6.5.

6.2 Sewage Disposal

Based upon the results of the nutrient budget, a conservaitve estimate of the current phosphorus loading to Lake Massapoag as a result of subsurface sewage disposal systems located within 300 feet of the Lake's shoreline is approximately 44% if the total loading. A major portion of the total phosphorus contribution to Lake Massapoag is attributed to the overall watershed surface runoff - which includes amounts of phosphorus generated by subsurface sewage disposal systems located greater than 300 feet from the shoreline. In future years, the percentage of phosphorus contribution from these sources is anticipated to increase, as existing systems age, the attenuation capacity of the soil diminishes, and additional dwelling units are constructed within the watershed.

The Section 208 Areawide Waste Treatment Management Plan prepared by the Metropolitan Area Planning Council included the following recommendations for the Town of Sharon:

- The Town should initiate a Step 1 facilities plan to evaluate the need for sewering and long-term disposal alternatives.
- The Town should develop and implement a septic system inspection and preventive maintenance program.
- The Town should promote a water conservation program.

All of Sharon is presently served by on-lot subsurface sewage disposal systems. There are no public sewers in Sharon. The Town of Sharon has not completed a facilities plan to evaluate the need for and/or alternatives to municipal sewerage. The Town does not plan to complete such an evaluation in the near future.

The following subsections examine various options available to the Town of Sharon to reduce phosphorus loadings to Lake Massapoag from subsurface sewage disposal systems. Options evaluated include: extending sewer lines to the Lake Massapoag area; implementing a septic tank inspection/maintenance program; constructing communal septic systems (leaching facilities); and requiring the installation of holding tanks or nondischarge toilets to service identified problem waterfront lots.

6.2.1 Municipal Sewerage

The conventional, standard long-term approch to eliminating problems resulting from septic system leachate is the construction of a municipal sewage system. Although Sharon is not presently a member community of the Metroplitan District Commission (MDC), the Town has been identified as a possible future member community. The EMMA (Eastern Massachusetts Metropolitan Area) Study - Main Report, dated March 1976, completed by Metcalf & Eddy, Inc. for the Metropolitan District Commission listed the Town of Sharon as a possible new member.

The EMMA Study suggested that an extension interceptor sewer would be necessary to allow Sharon to discharge to the existing MDC sewage conveyance and treatment system. Estimated construction costs for the interceptor which would run from Canton center to the Sharon town line, are 2.21 million dollars (ENR-CCI-4000). In addition, collection sewers and conveyance structures would be required throughout the sections of Sharon proposed for municipal sewerage. Since a plan has not been completed, accurate cost information is not available. For the purposes of this diagnostic/feasibility study, it is assumed that it would cost an estimated 7.5 million dollars to extend sewer lines to, and completely around Lake Massapoag. Individual home owners would have to pay an additional estimated $1,000/home to connect to the municipal system and an anticipated annual operation and maintenance cost of $100/year.

Once constructed, such a system could serve most, if not all, of the homes within 300 feet of the lake, virtually eliminating 44% of the Lake's present phosphorus loading. However, there are numerous problems in effectuating such a plan. The town has not completed a facilities plan to date. It appears as if the majority of the residents of Sharon wish to continue to rely upon subsurface sewage disposal systems. The MDC is unlikely at this time to accept new member communities, due to discharge constraints stemming from pollution problems in Boston Harbor. Consequently, the sewering option as presented herein is basically for comparison purposes only - the liklihood of implementing such a project appears remote.

In 1977 the Town of Sharon was advised by MDC that an agreement for the disposal of septage generated within Sharon would be terminated in December 1979. In December 1977 the Board of Selectmen established a Septage Study Committee and the Sharon 1978 annual town meeting appropriated money for a study of septage disposal and authorized Selectmen to apply for, contract for, and expend any grants of financial assistance from federal and/or state agencies. Towards the end of 1978 a pre-qualification conference was held with federal and state officials to outline the required scope of work for a facilities plan to be funded with a 90% combined grant from federal and state agencies. However, a condition of such a grant was that the Town address the matter of disposal of all wastewater generated within the Town in a broad manner and not limit the study to just one means of disposing of septage.

Following a ruling from Sharon Town Counsel that the wording of the town meeting article limited the scope of the study to means of septage disposal only, a revised engineering contract/scope of services with Bethel, Duncan and O'Rourke, Inc., was prepared which limited the study to septage disposal only. A final report dated June 27, 1980 entitled Report to Town of Sharon, Upon Septage Disposal Methods included the following conclusions and recommendations:

1. There appears to be no long range viable and permanent solution whereby Sharon might dispose of its septage by contractural arrangement except an MDC option which involves Sharon becoming a member of the MDC Sewerage Division. The actual costs of that option could only be determined by completion of a Step I, Facilities Planning Report because federal and state Grants would be necessary. The matter of disposal to Brockton and to the Charles River Pollution Control District's plant might be investigated by Town personnel. However, substantial transporation costs could be involved.
2. If Sharon does not become a member of MDC, the present method of acceptance of Sharon's septage by MDC at a cost of $2.50 per capita per year depends entirely upon policy established by the MDC Commissioners. At present, their policy is to accept septage from non-member communities at this rate but only until the community finds a permanent solution.

3. The cost of all town-owned and operated alternatives is predicated on the fact that no federal or state grants would be available.

4. If a Step I, Facilities Plan were prepared, an alternate to be studied would undoubtedly be a connection to the MDC system. The total annual costs of such a connection to Sharon might be attractive when compared with other alternatives. Under this plan, a Sewer District might be created in Sharon, with the approval of the MDC and necessary legislation, to serve about 1,500 persons. The remaining persons would continue to be served by on-lot systems with the septage discharged to MDC sewers.

5. It was recommended that in the light of MDC policy relative to accepting septage from non-member communities, that the present contractural arrangement with MDC for septage disposal be recognized as only a temporary solution, pending development of a permanent solution by Sharon.

6. The Town of Sharon should consider applying for a Step I, Facilities Planning Grant to study alternatives available to Sharon.

7. A mandatory operation and maintenance program should be instituted by the Board of Health to ensure that on-lot systems are properly operated and maintained.

6.2.2 Non-Discharge Toilets

An available alternative for reducing lake nutrient loadings is to retrofit all conventional toilet fixtures with non-discharging toilets. This could eliminate an estimated 30% of the sewage-derived phosphorus and 80% of the sewage-derived nitrogen inputs to Lake Massapoag. Assuming that this were accomplished in the 110 homes which border Lake Massapoag, and further assuming an average of 2.0 toilets per home, this would cost approximately $220,000 (Table 26, column 2), with no extraordinary operation and maintenance fees. Cost-effectiveness would be $305/kg-P removed, ignoring a slight reduction in groundwater recharge to the lake. Environmental impacts include inconvenience to homeowners during the retrofitting process, and potential aesthetics and odor problems sometimes associated with improperly operated or poorly functioning non-discharging toilets. If retrofitting is to be mandated, it may prove to be enough of a cost burden or social disruption to cause some families to move.

The two identified major difficulties with effectuation of such a plan are financing and public acceptability. Because these would be individually owned units, they would not be funded under any existing public water pollution abatement construction grant program. It is unreasonable to believe that a significant percentage of homeowners would choose to install and regularly use such an unconventional toilet, even if it were publicly funded.

A more realistic application of the use of non-discharging toilets would be voluntary in nature, in conjunction with a comprehensive shoreline sewage management program. For certain waterfront lots, following a site specific evaluation, utilization of non-discharging toilets may be the only practical cost-effective abatement approach. Sections 15.16 and 15.17 of the State's Environmental Code - Title 5 (Minimum Requirements for the Subsurface Disposal of Sanitary Sewage - 310 CMF 15.00) regulate the installation of privies, chemical toilets and humus toilets. These systems may not be constructed or continued in use unless the Board of Health grants written approval based upon the determination that no person's health will be endangered, a nuisance will not be caused, and excessive accumulated solids will be disposed of in a sanitary manner.

6.2.3 Holding Tanks

It would be possible to install holding tanks for each of the 110 homes which are located within 300 feet of Lake Massapoag. The installation of holding tanks would eliminate all future sewage discharges from these homes. However, there are problems with this option which make it particularly unattractive for widespread implementation. It is unlikely that this

TABLE 26

Relative Costs and Cost-Effectiveness of Various Alternatives for Mitigation of Loadings from Subsurface Sewage Disposal Systems

Alternative	Components	Capital	Extraordinary Annual O&M	10 Year Total (C)	Effectiveness Kg-P/yr. Removed (E)	C/E $/Kg-P	Comments
(1) Sewering	• Construct Sharon extension sewer as recommended in MDC's EMMA Study. • Construct sewage collection/conveyance system in Sharon to service the Lake area. • Individual costs (110 x $1000/home) • O&M = $100/home/yr. • TOTAL	$2,210,000 $7,500,000 110,000 $9,820,000	$ 11,000/yr. $ 11,000/yr.	$9,930,000	270	$3,678	• Local support uncertain. • Significant capital investment required. • Lengthy implementation requirements. • Numerous environmental concerns. • Provides long-term effectiveness.
(2) Non-Discharge Toilets	• Equipment (110 units x $1500/unit) • Retrofit (110 units x $500/unit) • Solids disposal (110 units x $25/unit/yr). • TOTAL	$ 165,000 55,000 $ 220,000	2,750/yr. $ 2,750/yr.	$ 247,500	81	$ 306	• Not fundable. • Problems with local/state approval. • Socially unattractive. • Minimal environmental impacts. • Site specific utilization possibilities. • Partially (30%) reduces P loading.
(3) Septic System Inspection/Maintenance Program.	• Program implementation & administration • Individual required improvements 10 homes ($3000/home) 50 homes ($1500/home) • Maintenance - 3 yrs. (110 homes x 1/3 x $75/home). • TOTAL	$ 13,250 105,000 $ 118,250	$ 5,000/yr. 2,750/yr. $ 7,750/yr.	$ 195,750	47	$ 416	• Relatively easy to implement. • Immediate short-term improvement at minimal expense to the Town. • Low/average individual cost-certain individual costs may be high. • Partially (15%) reduces P loading.
(4) Holding Tanks	• Provide equipment installation (110 homes x $2500/home). • Monthly pumping (110 homes x 12/yr. x $150). • TOTAL	$ 275,000 $ 275,000	198,000/yr. $198,000/yr.	$2,255,000	270	$ 835	• High individual capital and O&M costs. • Construction costs not fundable. • Problems with local/state approval. • Socially unattractive • Site specific utilization possibilities.
(5) Communal Septic Systems	• Required Study and Design • Construction Costs for pressurized collection sewers • Individual Costs (106 homes x $2000/home). • Maintenance-ind. ($50/home/year) • Maintenance-pressurized collection system. • TOTAL	$ 100,000 390,000 212,000 $ 702,000	5,300/yr. 21,500/yr. $26,800/yr.	$ 970,000	270	$ 359	• Further detailed study (facilities plan) required. • Local maintenance responsibility • Not readily implemented. • Some individual costs may be high. • Eligible for up to 94% Federal/State funding. • Provides long-term effectiveness.

alternative would be fundable under EPA's 314 program, Massachusetts' 628 Clean Lakes Program or under the federal/state municipal sewerage construction grants program. Thus, a heavy financial burden would be placed on individual property owners. Although this alternative is relatively cost effective, and would remove virtually all of the sewage-derived phosphorus (270 kg-P/yr.), individual pumping costs render this an impractical option if it is to be uniformly applied to all 110 shoreline homes. In certain situations, evaluated on a case-by-case basis, utilization of holding tanks may be the only practical cost-effective abatement approach. Installation of a holding tank requires the submission of a request for a variance (310 CMR 15.20) to the DEQE by the Sharon Board of Health on behalf of the property owner.

Title 5, Section 15.02 (19) - "Maintenance" states:

> "Every owner or agent of premises in which there are any private sewers, individual sewage disposal systems, or other means of sewage disposal shall keep the sewers and disposal systems in proper operational condition and shall have such works cleaned or repaired at such time as ordered by the Board of Health. If the owner or agent of the premises fails to comply with such order, the Board of Health may cause the works to be cleaned or repaired and all expenses incurred to be paid by the owner. Sewage disposal works shall be maintained in a manner that will not create objectionable conditions or cause the works to become a source of pollution to any of the waters of the Commonwealth."

While an initial septic tank inspection program and follow-up maintenance pumping is a highly recommended practice which is relatively easy and inexpensive to implement, it is only assumed to be partially effective in reducing nutrient loading on a long-term basis from properly designed and functioning septic tank/leaching facility subsurface sewage disposal systems. As reported in the EPA published document entitled Design Manual - Onsite Wastewater Treatment and Disposal Systems Oct. 1980, 15% removals of phosphorus (p.99, section 6.2.4) can be achieved by proper septic tank maintenance.

The initial inspection program should result in the development of site-specific recommendations to correct or eliminate the 10 plumes found during the septic leachate detector survey.Following the initial inspection phase, it is assumed that sewage disposal systems found to be inadequate or improperly located (in addition to the 10 documented problem systems) will be repaired, improved and/or relocated to comply with Title 5. It is possible that variances to Title 5 may be required or that the installation of a holding tank or non-discharging toilet as previously discussed may be the recommended cost-effective sewage disposal solution.

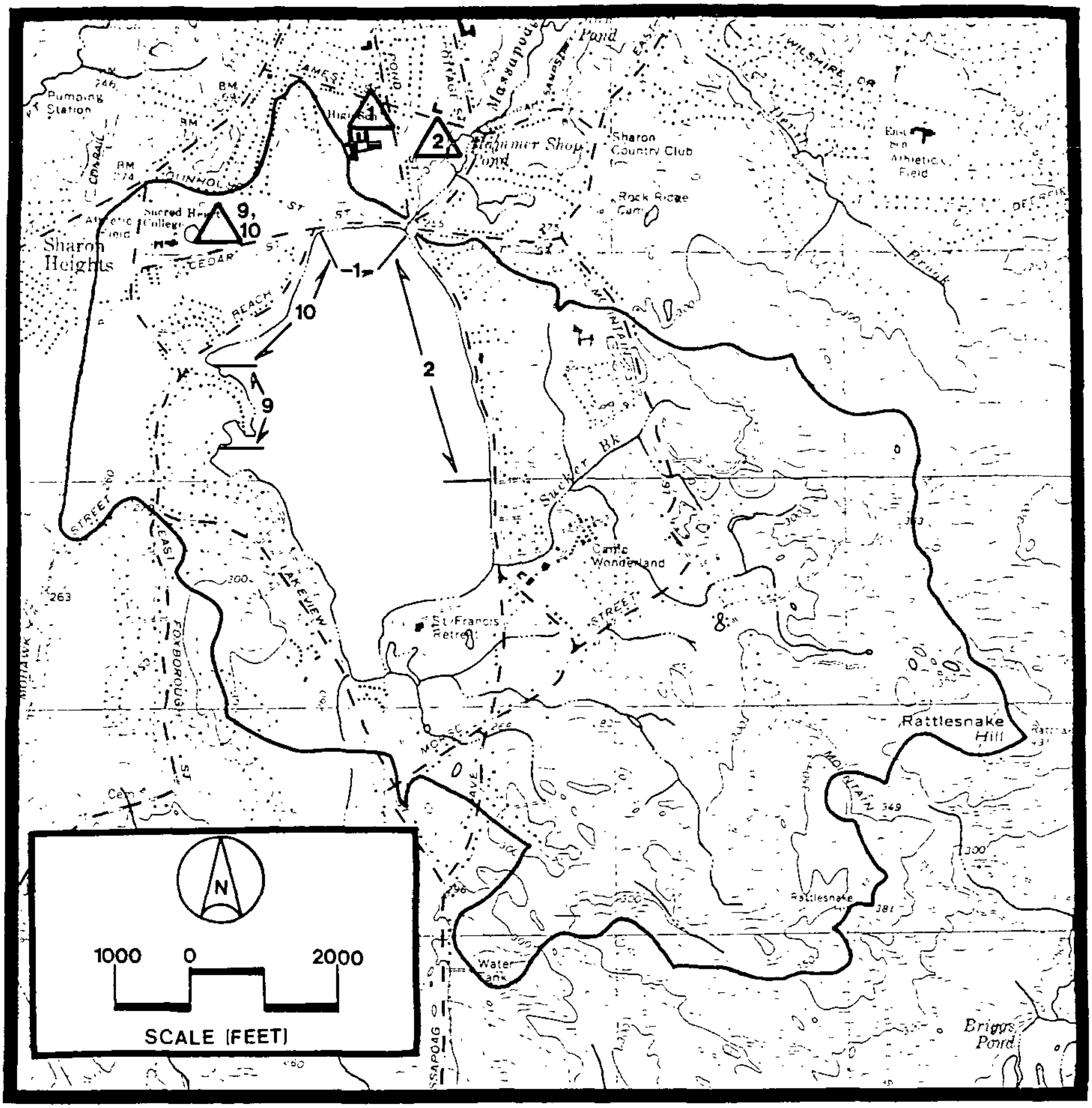
Although Sharon is not a member community of the MDC, the Town has had the privilege, through agreement with the MDC, of disposing the septage originating in the town into sewers tributary to or part of the MDC sewerage system which serves the towns of Walpole, Canton and Stoughton. According to the June 27, 1980 Report to Town of Sharon, MA Upon Septage Disposal Methods by Bethel, Duncan & O'Rourke, Inc., "Sharon, with a current population of about 14,000, pays MDC $2.50 per capita [$35,000/year] for this privilege." As previously summarized in section 6.2.1, the report states that it is the present policy of MDC "to accept septage from non-member communities, such as Sharon, on a temporary basis only while the community makes other arrangements or develops facilities for disposal of its septage.

6.2.4 Communal Septic Systems

Construction of communal septic systems to serve shoreline residences could be accomplished in several lakeshore areas. In order to develop the most effective plan for local sewering and disposal, the CEM zones outlined for the nutrient budget were referenced (see Figure 22). The CEM method indicated that four of the ten shoreline zones contributed significantly to phosphorus loading of Lake Massapoag; zones 1, 2, 9 and 10. Sewering of residences in these zones could effectively eliminate the 270 kg/yr phosphorus input due to shoreline septic systems. Several sites in reasonable proximity to these zones could be used as treatment sites. The proposed construction and associated costs for each of the targeted shoreline zones is discussed below. The cost effectiveness of this alternative is summarized in Table 26.

Zone 1 consists of the septic system serving the Town park on Beach Street. The facilities have undergone only seasonal use; and the phosphorus loading from this source was calculated to be approximately 12.5 kg/yr. Although the input is relatively low, less than 5% of the total shoreline septic system loading, the proximity of the high school sewage disposal system (which presumably receives less use in summer) offers a possible cost-effective alternative. The disposal system for the high school includes sand filtration and chlorination, and discharges to a storm sewer which empties into Massapoag Brook. Tie-in of the Town Beach facilities would therefore allow removal of the sewage, not only from the Lake shoreline area, but from the Lake watershed as well. Connecting the beach house to the existing high school system would involve the construction of aproximately 500 line-feet of force main, and installation of a small pumping unit at the beach area. The estimated capital cost is $10,000, with additional operation and maintenance costs of $1,500/year. With removal of 12.5 kg P/yr, the cost-effectiveness of this alternative is $200/kg P removed.

Zone 2 includes approximately 46 homes within 300 feet of the Lake, along the northern part of the eastern shoreline. This zone was calculated to contribute 103.04 kg/yr of phosphorus to the Lake. Sewering of these homes to a leaching field to be located west of Pond Street and south of Ames Street (see Figure 30) would remove this sewage-derived phosphorus from the Lake Massapoag watershed. The proposed project would involve construction of about 4,000 linear feet of pressure sewers; construction of a pumping facility; construction of a new subsurface sewage disposal system in



iEP inc.

FIGURE 30

LAKE MASSAPOAG WATERSHED

PROPOSED PLAN FOR SMALL-SCALE OFF-SITE SEWAGE DISPOSAL

←1→ CEM ZONE: TO BE SEWERED

△1 SEWAGE TREATMENT/DISPOSAL AREA

LAKE MASSAPOAG DIAGNOSTIC/FEASIBILITY STUDY

compliance with local regulations and Title 5; and connection of individual home systems to the sewer. Assuming a cost of $2,000/tie-in, the capital cost is estimated at $292,000, with annual operation and maintenance costs of $12,300. With a phosphorus removal effectiveness of 103 kg, the cost-effectiveness of the proposed plan for Zone 2 is approximately $403/kg P removed.

Zones 9 and 10 consist of approximately 60 homes along the northwestern shore of the Lake, that are within 300 feet of the Lake shore. The two zones combined contribute 154 kg P/yr to Lake Massapoag. Sewerage for these zones could be tied into the existing subsurface disposal unit at the Town recreation area on East Foxborough Street. Although this sytem is within the Lake watershed, the sewage would be removed from the shoreline area; treated by a system meeting the state sanitary code; and could receive a higher degree of treatment, if desired, in a more cost-effective manner by upgrading one larger unit rather than 60 home units. This project would entail the construction of approximately 5,000 linear feet of pressure sewers and a pumping facility; and the connection of individual home systems to the sewer. The estimated capital cost is $300,000, with an annual opration and maintenance cost of $13,000. With removal of 154 kg of phosphorus annually, this project has a cost-effectiveness of $279/kg P removed. Some of the problems associated with conventional sewering are shared by the communal systems alternative. Initially, further detailed study would be required to be eligible for federal/state Construction Grants funding, though this work would only entail a 10% local contribution. Secondly, there would be some nonfundable public and private costs imposed, such as installation of septic tanks by individuals currently served by cesspools and maintenance, pumping and energy requirements of the systems. Finally, construction would occur proximal to the Pond over a distance of approximately 8,000 feet of shoreline, posing a potential adverse environmental impact.

If implemented, the proposed project would likely be eligible for I and A (Innovative and Alternative) funding, which includes a 3% incentive public contribution. Through the Construction Grants program, then, this sewage management alternative could quite possibly be funded at the 93% level from non-local sources.

One disadvantage of this alternative is the time required for actual implementation. Due to the planning and engineering steps involved, and the probable delays in securing funding, the benefits of the communal septic systems may not occur for a decade or more.

Interim measures for reduction of phosphorus loading through shoreline septic systems should be instituted as soon as possible. These measures should include a Town-supervised septic system inspection/maintenance program and education of shoreline residents about the functioning and water quality impacts of septic sustems. The details of implementing a septic system inspection/maintenance program are discussed in section 6.2.5.

The use of non-phosphate detergents by homeowners can provide a significant reduction in phosphorus entering the septic system. This change, which can occur with little inconvenience and no cost to the homeowner, will increase the useful life of the septic system, as well as reducing the nutrient loading to the Lake from failed systems, or those in which the soil's phosphorus attenuation capacity has been reached. Water conservation by the homeowner can also extend the life of the septic system, and aid in its efficient functioning.

An association of shoreline or watershed residents can encourage implementation of water conservation and the use of non-phosphate detergents in two ways:

- by promoting an educational campaign to enlighten homeowners as to the benefits of these activities both to themselves, in long-term cost savings; and to their environment, Lake Massapoag;

- by becoming a non-profit supplier of non-phosphate detergent products and water conservation devices.

This two-point program; septic system inspection and pumping, administrated by the Town; and homeowner water conservation and non-phosphate detergent usage, coordinated by a watershed association; should prove to be an adequate interim step for reduction of phosphorus loading from shoreline septic systems.

6.2.5 Septic System Inspection/Maintenance Program

Implementation of a municipal septic system inspection/maintenance program would serve to improve existing sewage disposal practices and reduce sewage disposal system failures and inadequacies which presently contribute in part to nutrient loadings impacting Lake Massapoag. Periodic pumping of a septic system or cesspool is a necessary operation in order to maintain the system's long term viability. Without maintenance pumping, solids move into the leaching area clogging soil interstices, which eventually results in system malfunction or failure. Prior to implementing an effective septic system maintenance program, all existing sewage disposal systems must be inspected to determine system adequacy and compliance with Title 5. A maintenance program requires that all individual sewage systems include an accessible septic tank.

The implementation of a septic system inspection/maintenance program could provide a reduction of at least 47 kg/yr in the existing phosphorus loading of Lake Massapoag; and would also serve to extend the lifespan of adequately functioning systems. Such a program is recommended as an interim measure for reduction of nutrient loading from shoreline septic systems. Although the communal septic systems will provide a much higher degree of nutrient reduction, the time period involved before actual construction could take place would allow the Lake to deteriorate further. Compliance of home systems with Title 5 is one step in the implementation of communal septic systems, and the iniation of an inspection/maintenance program can be seen as the first phase of the communal septic system plan.

In order to implement a septic system inspection maintenance program, the following tasks should be completed for each of the estimated 110 dwellings within 300 feet of the Lake Massapoag shoreline:

1. Research and tabulate information available from the Board of Assessors records and maps.

2. Contact directly each lot owner to obtain background information regarding the subsurface sewage disposal system.

3. Complete detailed site inspection of each lot to determine location and condition of the existing subsurface sewage disposal system.

4. Complete site inspection form and property sketch for each lot. Property sketch should locate the dwelling unit, additional structures, lake shoreline, sewage disposal system, approximate property line, surface or subsurface drains, steeply sloping areas, and private wells.

5. For lots determined to have inadequate sewage disposal systems based upon discussions with the property owner and conductance of the site inspection, specific recommendations to improve each inadequate system will be formulated.

Estimated cost to complete the initial septic system inspection program is based upon $75/lot and totals $8250.

Following completion of the initial inspection program it is recommended that a continuing septic system maintenance program be established. In order to implement an effective septic system maintenance program ,it is essential that each dwelling unit have a properly operating, accessible septic tank. It is anticipated that the initial inspection program will identify dwelling units which have inadequate septic tanks. It is estimated that it will cost approximately $5,000 to actually set-up and make operational an effective septic system maintenance program. The costs include required administrative and bookkeeping tasks.

The septic system maintenance program will help property owners keep their systems in good working condition by regularly pumping the waste that can cause systems to fail. The Town of Sharon can adopt a by-law which establishes a "Septic System Maintenance Program" - a program of regular septic tank inspections and pumping as a public service. This program would be administered according to rules and regulations adopted by the Sharon Board of Health. It is suggested that each septic tank be inspected at least once every 3 years. A system should be pumped whenever the volume of sludge, solids and scum is found to be greater than one-third of the septic tank volume. The Board of Health should require more frequent inspections and pumpings of any septic tank whenever it finds that additional pumping is necessary to the proper operation of the septic system. It is estimated that once set-up, it will cost approximately $5,000 per year to administrate this program.

Refer to Septic System Maintenance Programs, April 1980, by the Southeastern Regional Planning and Economic Development District (summarized in Appendix E) for additional discussion of the legal/administrative requirements of establishing a septic system maintenance program.

6.3 Municipal Sanitary Landfill

Section 5.1 of this report evaluated the contribution of Sharon's existing landfill operation to the overall nutrient budget determined for Lake Massapoag. Table 20 indicates that the landfill contributes 7.44 kg/year of phosphorus out of total computed annual loadings of 312 kg/year to 617 kg/year. The existing landfill operation contributes only 1-2% of the total calculated phosphorus loading to Lake Massapoag. Although the calculated phosphorus contribution to the Lake is rather low, leachate entering Sucker Brook directly may contribute not only higher loads of phosphorus; but likely increases nitrogen loading, and may introduce potentially toxic substances to the Lake. Field observation and sampling of the upper reaches of Sucker Brook indicate that the landfill is causing a violation of Class B water quality standards in this stream segment.

6.3.1 Existing Sanitary Landfill Operation

The town's existing Mountain Street landfill operation is located within the Sucker Brook - Lake Massapoag watershed. The landfill site is approximately 35 acres in size and has reportedly been in operation for an estimated 60 years.

A report entitled, Disposal of Refuse, Town of Sharon, Massachusetts, dated June 1974, prepared by SEA Consultants, Inc., Boston, Massachusetts included the following conclusions and recommendations:

1. The estimated remaining life of the present site for disposal of solid waste is from 7 to 9 years.

2. The present landfill operation is contributing leachate to Sucker Brook and possible contamination could result if this situation is not corrected. (The report recommended that an existing 24-inch pipe be extended by 220 feet to prevent leachate from entering Sucker Brook directly. This has been constructed as recommended).

In recent years the usage rate of the landfill has reportedly been reduced due to the implementation of a user fee system. It is projected that the landfill will not be at final completion elevations until the year 1988. However, recent Sharon town meeting action mandates that the existing landfill site be permanently closed no later than April 1985.

1983 Annual Town Meeting Article 11 - passed

"That the Town shall raise and appropriate a sum of money deemed sufficient for the completing of preliminary engineering studies of alternative solid waste disposal options and sites, both in-town and out-of-town, with the objective and purpose being the permanent closure of the existing town site by no later than a date certain in April 1985. The said engineering studies to also include capping, closure and drainage management of existing solid waste disposal area, or act any way relating thereto.

6.3.2 Future Solid Waste Management/Disposal Options

The Town of Sharon's Solid Waste Committee is currently evaluating future solid waste management/disposal options. The April 1983 town meeting appropriated $10,000 to conduct required engineering studies. As of August 1983, the Committee had not retained the services of an engineering consultant. A detailed evaluation of available future solid waste options is well beyond the intended scope of the Lake Massapoag Diagnostic/Feasibility Study. It is assumed that any future long-term solid waste management/disposal solution will not involve a site located within the Lake Massapoag watershed. It is recommended that composting capabilities be investigated in conjunction with the development of plan for a new disposal site; or separately, as a means for disposal/reuse of vegetative litter such as lawn clippings, leaves, and aquatic weeds raked from exposed sediments during drawdown.

6.3.3 Proposed Landfill Closure

The 1974 SEA report recommended that 'final sealing' of the landfill (Phase V) consist of a minimum 6-inch layer of gravelly clay and a minimum 6-inch final cover layer of seeded loam. It is recommended that the proposed final layer of cover material be revised to be consistent with section 19.15 of the DEQE regulations (310 CMR 19.00: Disposal of Solid Wastes by Sanitary Landfill), which requires that the final layer of cover material have a total minimum depth of 2 feet. A minimum two feet thick final cover will effectively seal the landfilled refuse from percolating water and will support vegetation for erosion control. DEQE normally requires that the final cover include a minimum 12 inch thick layer of clayey-silty sand or silt having a maximum coefficient of permeability of 10^{-5} cm/sec.

Following the placement of final cover material (which should include a minimum of 4 inches of loam), the site should be planted with a ground cover such as rye, red top, timothy, red or tall fescue. The ground cover will provide permanent vegetation as well as rapid initial growth and consequently slope protection and erosion control.

As mandated by the April 1983 Sharon annual town meeting, the existing landfill operation is to be permanently capped by April 1985. Assuming that the final cover is properly constructed, the impermeable layer of material should effectively eliminate the continued generation of leachate. Until the landfill is totally capped, some leachate will continue to be generated. Provisions should be made to collect the leachate if feasible, and dispose of it in accordance with DEQE regulations, at least until such time as the landfill is closed. The existing wetland area downstream from the landfill site will continue to play a very important role in the capturing of leachate prior to discharge via Sucker Brook to Lake Massapoag.

6.4 Stormwater Management

Stormwater can be an important contributor to accelerated lake eutrophication. During dry weather, pollutants accumulate on watershed surfaces; then, are transported rapidly to the receiving water body during a storm event. The phosphorus budget for Lake Massapoag indicates that a loading of 80 kg P/yr was due to stormwater inflow from all tributary watershed areas (Table 21). Although stormwater contributes only slightly more phosphorus per unit flow than does baseflow, (stormwater represents 43% of the total watershed surface phosphorus loading; and 40% of the surface water runoff) stormwater runoff may offer more opportunity for water quality management. Most often, the bulk of accumulated pollutants are transported from the watershed surface at the beginning of a runoff event. Treatment of this "first flush" of stormwater can result in removal of a large proportion of runoff related pollutants. Such treatment usually consists of some type of velocity reduction to induce settling of pollutants. If treatment of stormwater runoff is not feasible or cost-effective, an alternative control method is reduction or removal of pollutants at their source - the watershed surface. This approach usually involves the implementation of "BMPs", or best management practices, designed to limit the distribution of pollutants in the watershed; to periodically remove pollutants before they can be washed away and to maintain proper functioning of storm drainage/treatment systems. In order to evaluate stormwater management techniques for the Lake Massapoag watershed, contributing sub-drainage areas were grouped according to their amenability to various management techniques. One group consists of strictly storm-drainage collection systems with direct discharge to the Lake. In these systems, overland flow is routed to catch basins, which discharge to underground pipelines. Stormwater is conveyed rapidly via pipe flow to the drainage system outlet. These systems depend largely on man-made structural components, and serve the more highly developed shoreline residential areas of the watershed. Because flow paths are controlled and base flow is largely eliminated, storm drainage systems are amenable to structural measures for stormwater treatment. Watershed management for pollution source control can also be an effective measure in this type of watershed. The type of land use which requires storm drainage systems is also associated with higher pollutant loading rates per unit area than most watersheds without artificial drainage systems. Therefore, efforts aimed at a smaller area can have a greater impact. Also, the percentage of publicly maintained property, such as streets and highways, is considerable. Public control of a portion of the watershed can help to assure implementation of watershed surface management programs.

The second group of sub-watershed types examined for stormwater control is areas with direct drainage to the Lake. This group consists of shoreline areas without sufficient upland drainage for stream channels to have developed. Stormwater reaches the Lake by overland flow or through shifting, ill-defined channels or rills lacking baseflow. Flow paths are dispersed or uncontrolled and, because stormwater cannot readily be concentrated at a point, the treatment approach is not applicable or cost-effective. As with storm drainage systems, however, watershed surface management for control or removal of pollutants may be an effective technique; the more so in areas with more intense development and greater proportions of Town-owned land.

A third type of sub-drainage, and that which encompasses the greatest area of the Lake Massapoag watershed, is the natural drainage areas; those with well-defined natural stream channels occupied by perennial or ephemeral streams. This type of drainage system is the least amenable to stormwater management for a number of reasons. Stormwater treatment is not an effective approach because, although flow is concentrated in a channel, stormflow and baseflow are combined. Baseflow dilutes the concentration of pollutants, and renders necessary the treatment of a larger volume of water. The cost-effectiveness of treatment is thereby greatly reduced. Watershed management may be more appropriate for these drainages. However, in the larger, less developed watersheds, surface pollutants may be more dispersed, and land management practices more difficult to implement, enforce and evaluate. For most effective use, watershed management practices should be aimed at those areas within each drainage which are more easily controlled, or where potential pollutants are more concentrated.

Table 27 presents a breakdown of stormwater phosphorus loading to Lake Massapoag by sub-drainage areas; and groups the sub-drainage areas according to the three types discussed above. The information on phosphorus loading is derived from the nutrient budget discussed in Chapter 5. The locations of referenced sub-drainage areas are shown in Figure 15. Table 27 indicates that combined stormwater - transported phosphorus originating in all storm drainage-type catchments contributes approximately 4.1 kg P to the Lake on an annual basis. This value represents just over two percent of the total watershed surface P loading, and about one percent of the total annual P loading to Lake Massapoag. Although stormwater treatment is typically the desired approach to storm runoff management in this type of drainage, the small contribution of phosphorus from this source indicates that such action is not warranted. Even the simplest type of stormwater quality control structures, such as infiltration pits or detention ponds, would cost over $1,000 - $2,000 per drainage system, exclusive of engineering design and land purchase, if necessary. Implementing controls of this type in even three or four drainages for the purpose of reducing a 4 kg P contribution to the Lake would not be cost-effective; or cost-competetive with management of other areas or phosphorus sources.

TABLE 27

Stormwater Phosphorus Loading to Lake Massapoag

Sub-watershed	Phosphorus Loading (kg/yr)	% of total watershed surface loading (185kg)*	% of total P loading (312-617kg)
2	.235		
3	.652		
4	.542		
9	1.058		
10	0.126		
11	1.492		
15	0.015		
Total: storm drainages	4.12	2.2	1.3 - 0.6
Total: direct drainage (includes 5, 6)	13.403	7.2	4.3 - 2.2
7	18.110		
8	6.197		
12	2.277		
13	17.637		
14	18.394		
Total: stream drainages	80.138	43.3	25.7 - 13.0

* Watershed surface loading calculated by Method 2.

However, the implementaton and continued performance of best management practices in these sub-watersheds is highly recommended. Best management practices for storm drainage areas and other subdrainage types in the Lake Massapoag watershed are summarized in Section 6.6.

The contribution of direct drainage to stormwater phosphorus loading of Lake Massapoag is estimated at 13.4 kg annually. This figure represents 7.2% of the total watershed surface loading, and approximately 2% - 3% of the total annual phosphorus loading to Lake Massapoag. (These calculations somewhat over-estimate the contribution due to direct drainage since two undelineated drainages served by storm sewers were included here, rather than as storm drainages). Because of the dispersed nature of flow in these areas, structural controls are difficult to apply. Since the direct drainage areas are located along the shoreline, interspersed between storm drainages and stream channels, a blanket application of BMPs throughout the Lake shoreline area would extend stormwater management to the direct drainage areas in a cost-effective manner. Therefore, it is recommended that BMPs be applied as a stormwater management technique in the sub-watersheds having direct, unchanneled drainage to Lake Massapoag.

Table 27 also includes the stormwater phosphorus contributions of each of the five inlet streams to Lake Massapoag. For the most part, phosphorus loadings are proportional to the hydrologic contributions of the streams. However, due to the comparatively high phosphorus concentration of the stormwater sampled at subdrainage station 14, this relatively low flow stream is indicated as providing the highest loading (18.4 kg P, or 9.9% of the total watershed surface loading). The two largest inlets, 7 and 13, also contribute comparable amounts of phosphorus. Streams 8 and 12 contribute 6.2 and 2.3 kg P, respectively, a combined value of less than 5 percent of the total watershed surface loading. As discussed above, natural stream channels are not usually appropriate for treatment of stormwater. However, certain watershed characteristics may provide opportunities for reduction in phosphorus loading from these streams during high flow periods. Four of the five inlets have wetland areas of one or more types associated with the stream channels. In many cases, these wetland areas are located near the mouths of the inlets. Wetlands often function naturally to reduce peak stormflows in associated streams; and act to attenuate pollutants by providing area for settling and filtration. Management of existing wetlands to enhance this pollution attenuation value is appropriate for the Lake Massapoag watershed. Specific recommendations concerning stormwater attenuation by wetland enhancement are discussed in section 6.5, Wetland Management.

In addition to wetland enhancement, the implementation of BMPs is recommended for control of nutrient input. The stream watersheds are characterized by a diversity of land uses, so management practices may vary among watersheds. The discussion in Section 6.6 outlines the specific BMPs recommended for various land use categories in the Lake Massapoag watershed.

6.5 Watershed Best Management Practices

Best management practices (BMPs) are activities aimed at reducing non-point sources of nutrients, and controlling their movement in the environment. Best management practices have several advantages over structural watershed management techniques. BMPs are adaptable to a variety of land uses and problem pollutants; the costs may be lower than structural controls, may be spread evenly over the implementation period, and may be distributed over a large group of watershed/non-watershed residents. In addition, most BMPs have additional benefits besides water pollution prevention. However, the implementation of BMPs is often, to a greater or lesser degree, dependent on citizen participation for success; and the results (and therefore the actual cost-effectiveness) are difficult to predict and evaluate.

As indicated in Table 2, the primary land use/cover type in the Lake Massapoag watershed is forest (58%). In terms of area, residential land use is also of significance, comprising 18% of the watershed. For the most part, therefore, management practices should be aimed at reducing pollutant loading and runoff from these cover types. Other land uses, such as institutional and open land, may be significant to pollutant runoff in terms of their specific use or location in the watershed. In such areas, management recommendations for residential areas and forest land may be adapted. A watershed association can play a key role in facilitating implementation. Education about the various BMPs and their positive effects on both the immediate environment, and the future quality of Lake Massapoag can begin with interested residents at regular watershed association meetings. Distribution of literature such as the booklets:

Fertilizers and Your Lake,
Detergents and Your Lake,
Septic Systems and Your Lake;

and pamphlets such as those previously prepared for Lake Massapoag, to other watershed residents will serve to educate a larger group, as will regular informational articles in local newspapers. A task force made up of members of Town boards, the watershed association, and local media personnel, should target specific management practices to be emphasized each year, in addition to the on-going educational campaign. Advantage should be taken of any opportunities for coordination of management practices with Town services.

Although residential use is not the primary land use in the Lake Massapoag watershed, it is among the most critical land use in terms of pollutant loading. Residential land uses have a higher contribution of phosphorus per unit area than do most of the other land use types in the watershed. In addition, much of the residential land in the watershed is in close proximity to the Lake, and therefore may have an even greater impact than land use export coefficients would indicate. Because of the potential for impacting Lake water quality, and the potential for effective management, the implementation of best management practices in areas of residential and similar land uses is highly recommended.

Specifically, the following types of management activities should be encouraged:

1. Road surface and storm drain maintenance

Recommended practices should include at least seasonal street sweeping to remove litter and accumulated solids; and regular (monthly) inspection of catch-basins with cleaning as needed to remove accumulated solids and to maintain the settling function of basins. In addition, Town sponsored curbside pick-up of leaves and brush (collected by watershed residents from their yards) in the spring and fall would help to encourage removal of vegetative litter from the watershed. These activities should be conducted by the Town, either with Town personnel and equipment, or through contracting of the appropriate services. These management practices will reduce nutrient loading to the Lake from accumulated solids; and will also protect the proper functioning of storm drainage systems. A decrease in solids flushed into the Lake will be advantageous in terms of weed control, by slowing sedimentation of shoreline areas. Costs for such a program are estimated to be in the range of $2,000 per year, in additional maintenance plus salary costs for Town-owned equipment and Town personnel.

2. Residential area management practices (also applicable to institutional, and some open land uses).

Recommended practices include controlled lawn fertilization; proper disposal of leaf litter and lawn clippings; on-site control of erosion, particularly from exposed soil or unpaved drives; and on-site control of stormwater, designed to minimize quantity and velocity of runoff leaving the property.

For best protection of Lake water quality, unnecessary lawn fertilization should be eliminated. However, healthy lawns are important for sediment control, particularly in erosion - sensitive areas. Generally, chemical companies recommmend fertilization 3-4 times a year. In areas where water quality is of concern, the Agricultural Extension Service (Mary Owen, pers. comm.) recommends that only one fertilizer application be made each year in the early fall. If the lawn clippings are not too coarse, they may be returned to the lawn during the summer months in order to provide an organic fertilizer. If lawn fertilization is deemed necessary by a property owner, it is advised that the above procedure be followed. These recommendations are also applicable to Town and institutionally - maintained lawns and playing fields, especially those in close proximity to the Lake and its tributaries.

Generally, lawn clippings and leaf litter should be removed as much as possible from access to the Lake and its tributaries. If such vegetative material is not collected and composted for re-use by the property owner, it is recommended that it be collected and removed to the landfill or an appropriate site out of the watershed. As mentioned previously, regular well-publicized curb-side collection will serve as an incentive for homeowners to implement this practice, and ensure proper disposal.

Management practices designed to reduce erosion can help control both sedimentation in the Lake, and transport of pollutants via sediment. During

IEP's watershed investigation, a few problem areas were observed, such as unvegetated, rapidly eroding soil on the slope west of the Community Center parking lot; and potential problem areas such as unpaved parking lots near the Lake or its tributaries. Instituting erosion control management practices should involve both identification and remedy of existing problem areas; and implementation of stabilization measures in erosion sensitive areas. Technical assistance for this management alternative should be sought through the Norfolk Conservation District.

On-site control of stormwater runoff can go a long way toward reducing peak storm flows, and may substantially benefit stormwater quality. Lawn spreading and infiltration of water from downspouts is preferable to rapid discharge of stormwater to driveways or street gutters. Here again, the local Conservation District may provide technical assistance to homeowners.

Erosion/sedimentation control and careful design of stormwater disposal are also critical factors to be considered in association with new construction anywhere in the watershed. BMPs may reduce present pollutant loading to Lake Massapoag; but regulation governing new construction can help to ensure control of future increases in water pollution. Such reguation is addressed in section 6.1 of this report.

As mentioned above, forest land makes up a large proportion of the Lake Massapoag watershed. Proper management of this forest land, and regulation of forestry activities can provide additional protection to the Lake. Deciduous forests can impact water quality through annual leaf fall. The accumulation of vegetative matter in tributaries, and in the Lake itself, results in a direct input of nutrients, and may also result in highly colored water. Forest management in shoreline areas and adjacent to tributaries can reduce nutrient input through leaf fall. Removal of leaf litter has been recommended above, and is advised for all shoreline areas, residential or otherwise. For long-term benefit, a planned program of gradual replacement of deciduous tree species with evergreen species is recommended for shoreline areas. In forested areas of the watershed, activities associated with timber harvesting may pose a threat to water quality. Erosion from access roads, disturbance of the soil by heavy equipment, slash piles in or near streams, or burning of slash may all contribute to water quality problems. Regulation of forestry activities in or near wetland areas is the responsibility of the local Conservation Commission, and is discussed in section 6.1. Further regulation is provided by the Massachusetts DEM.

6.6 Wetland Management

Wetlands cover sizeable areas of the Lake Massapoag watershed, and play a determining role in both the hydrologic regime and water quality of the Lake. Existing wetland areas which function to protect the quality of Lake Massapoag should be protected and enhanced, if appropriate, to provide greater benefit.

For the most part, wetland areas in the watershed are associated with the inlet streams. Typically, groundwater discharges to streams from bordering wetlands, maintaining base flow in dry weather. During periods of high stream flow, flood water spreads over wetland areas, and peak flows are attenuated. When flooded, wetlands may provide water quality benefits such as settling of particulates, and vegetative uptake of nutrients. It can be presumed that wetland areas associated with Lake Massapoag tributaries are presently functioning to control downstream flooding and prevent pollution. For this reason, it is recommended that existing wetlands be preserved so as to allow continuance of their present function. The wetlands Protection Act (discussed more fully in Section 6.1), when properly administered, provides a high degree of protection to wetlands of value. An even greater degree of protection can be provided by public ownership of valuable wetland areas. Such areas could be maintained in their natural state; and would also provide other benefits such as open space and wildlife habitat. Funding may be available for land purchase through the Massachusetts Self-Help program or Land and Water Conservation Fund, administered by the Division of Conservation Services.

Enhancement of wetlands to increase their pollution attenuation value may also be an effective method of wetland management for control of eutrophication. Wetland enhancement may consist of any alteration designed to increase the natural physical, chemical or biological cleansing ability of a wetland system. However, planning of alterations to wetlands must consider the potential for detriment caused by disturbing existing vegetation or organic soils, or altering the wetland hydrology.

In order to assess the feasibility of wetland management for improvement of Lake Massapoag's water quality, the potential for wetland management was assessed for each of the five inlet streams. In the case of streams 8 and 12 (see Figure 15 for reference numbers), the existing wetlands are considered to provide valuable functions and should be maintained. However, the nutrient inputs from these streams was not judged to be great enough to warrant the expense and adverse consequences of structural enhancement. The wetlands associated with inlets 7 (Sucker Brook) and 14 should be preserved; however, the potential for undesirable impacts from structural modifications for wetland enhancement make such a recommendation inadvisable. Inlet 13 has already been modified somewhat, and further recommendations are made for enhancing the pollution attenuation value of its associated wetland areas. Each of these streams is discussed in more detail in the following paragraphs.

Inlet 12, which discharges to Lake Massapoag west of the Town Beach, contributes approximately 5.2 kg P/yr, or 2.8% of the total watershed surface loading (See Table 27). From the location of the inlet, one may conclude that nutrients entering Lake Massapoag are flushed rapidly to the outlet, and hence have less influence on the long-term quality of the Lake. The inlet presently has natural flood detention areas both north and south of Beach Street. During high flow periods, these flood plain areas provide storage and allow settling of particulate pollutants. Although enhancement of these detention areas to increase storage volume might provide additional nutrient removal, other factors make such an option undesirable. The culvert and swale associated with this ephemeral stream presently allow drainage of the High School athletic fields. Altering flow patterns may adversely affect drainage of the fields during periods of wet weather or high groundwater table. Additionally, the cost of structural alterations such as installation of a weir, or raising the elevation of the existing culverts, is not warranted for reduction of such a small proportion of the Lake's nutrient budget.

Inlet 8 is a low flow stream discharging to the southern cove of Lake Massapoag via a culvert under Lakeview Street. Table 21 indicates that approximately 9.7 kgP/yr are contributed to the Lake from this stream, or about 5.2% of the total watershed surface loading. Extensive wetland areas are associated with the streams headwaters, and the construction at its mouth has created an area of ponded water. The existing conditions function to retain stormwater and spring high flows, and allow for some settling to occur. Vegetative uptake of nutrients could perhaps be enhanced by replacement of shrubs and snags with other species known to cycle nutrients more rapidly. However, the existing vegetative community, being somewhat unique to the lakeshore area, has value as wildlife habitat. The diversity that this area provides within the local ecosystem is also beneficial to nature studies at nearby camps. It is recommended that the wetland area at the mouth of inlet 8 be protected from any alteration that would impair its existing function of flood control and prevention of pollution. Because of its value in its present state, and its relatively minor contribution to the Lake's nutrient budget, enhancement of this wetland area is not recommended as either cost-effective or environmentally desirable.

Inlet 13, which enters Lake Massapoag at its southern tip, drains about 35% of the entire Lake watershed. Because of its large hydrologic contribution to the Lake, this stream also contributes a proportionately high phosphorous load to the Lake. The annual loading from this inlet is approximately 55 kgP/yr, or 30% of the total watershed surface loading. Wetlands are associated with many of the headwater tributaries of this stream and, more importantly for effective management, with the stream's outlet. Presently, the tributaries feeding the inlet flow into a small pond before entering Lake Massapoag. The three-acre pond is separated from the Lake's southern end by a low berm, and flow between the two occurs through a small man-made channel.

The existing wetland area is providing a "prevention of pollution" function to Lake Massapoag through settling, adsorption by organic soils and absorption by vegetation. Maintenance of this value should be provided by management of existing flows to this area, thereby preventing any decrease in water levels.An analysis of the phosphorus retention function of the existing pond (Kirchner-Dillon, 1975) yields a retention function coefficient of .20; in other words, the pond retains 20% of the incoming phosphorus. In order to evaluate the potential for increasing the phosphorus retention capability of this wetland area, a series of calculations was made to dtermine the most effective method of expanding the pond area. The results of these calculations and indicate that the creation of a separate pond would be more effective than expanding or deepening the existing pond.

Based upon existing topographic information, a preliminary sketch of a proposed settling basin, or pond, for the purpose of reducing phosphorus inflow from inlet 13 has been prepared (see Figure). Assuming that the proposed pond will have a minimum surface area of 100,000 ft^2, a mean depth of 2.5 feet, and will receive inflow from two-thirds of the watershed a phosphorus retention coefficient of .21 should be achieved. Retention of 21% of the incoming phosphorus by the proposed pond; and 20% of the incoming phosphorus by the existing pond would result in a net reduction in phosphorus loading from this stream of 7.7 kgP/yr.

The creation of such a pond would involve some clearing (tree removal); construction of a retaining dike with a standpipe outlet and emergency spillway; channel bed alterations downstream to prevent erosion below the outlet; and perhaps some revegetation of the site after construction. The estimated cost for the proposed pond is $30,000. Assuming a minimum project effectiveness of 10 years, this aspect of the wetland management plan would have a cost-effectiveness of $390/kgP removed. (See Figures 31 and 32).

The proposed settling basin will function as a phosphorus retention area, similar to the existing pond. Dredging the existing organic soils would not enhance the ability of the area to retain phosphorus and would significantly increase the cost of the project (an estimated $44,444 for dredging of 3 feet of organic soils; $222,2220 for dredging of 15 feet). Initially, dead shrubs and trees, floating-leaved plants, and submergent vegetation will dominate. However, with passage of a few years, emergent vegetation will become established.

In addition to the above recommendations, it is advised that the channel connecting the existing pond to Lake Massapoag be maintained so as to discourage transport of plant material from the pond to the Lake. Closure of the channel, and replacement with a permeable dike or screened stand-pipe would help to inhibit movement of vegetative material out of the pond. The estimated cost for design and alteration of the pond outlet is $10,000.

Inlet 14 drains an area almost entirely composed of wetland, and enters the Lake through a cove on the western shore. Table 21 indicates that this inlet provides approximately 236 kgP/yr to Lake Massapoag, or 13% of the total watershed surface phosphorus loading. Given that the subdrainage area for this inlet comprises less than 4% of the total watershed area, a phosphorus input of 13% indicates elevated phosphorus loading at this site. Information in Table 21 points to stormwater as the major contributor to phosphorus loading. Part of this apparent elevation is due to the sampling procedure and calculation methods used. Stormwater sampling at station 14 took place on two occasions, and composite samples showed phosphorus concentrations of 0.21 and 0.06 mg/l (Tables 10 and 12). The higher value was used in calculating total phosphorus loading due to stormwater from inlet 14. In addition, the stream was sampled at the outlet of a culvert which runs under

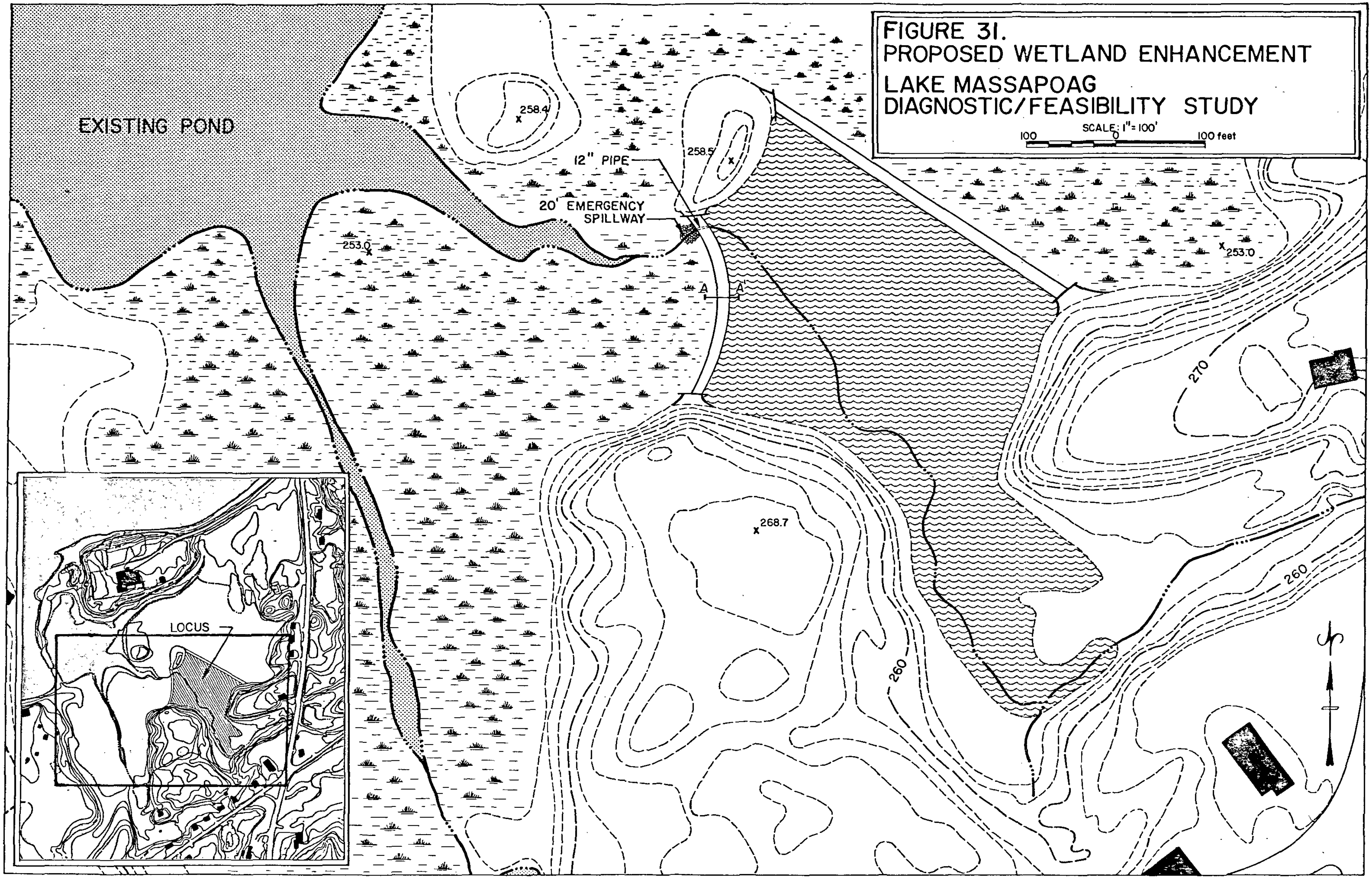
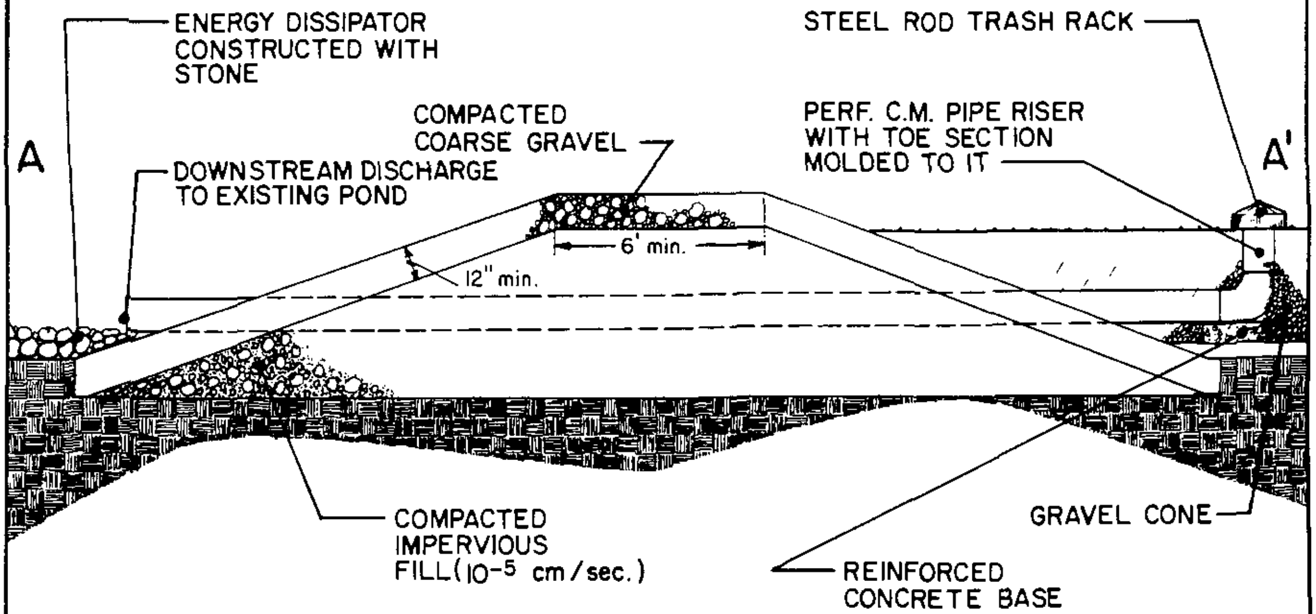


FIGURE 31.
PROPOSED WETLAND ENHANCEMENT
LAKE MASSAPOAG
DIAGNOSTIC/FEASIBILITY STUDY
SCALE: 1" = 100'
100 0 100 feet
EXISTING POND
258.4
258.5
12" PIPE
20' EMERGENCY SPILLWAY
253.0
253.0
A A'
270
268.7
260
260
LOCUS

SECTION A–A'

Detail of Proposed Wetland Enhancement Berm



WATER DEPTH: 2.5'

MAXIMUM SLOPE: 3:1

SCALE: 3/16" = 1'

FIGURE 32

East Foxboro Street, at least 500 feet upstream from the Lake. In the intervening segment (between East Foxboro Street and Lake Massapoag), the stream passes through a densely vegetated wooded swamp which may provide some unaccounted pollution attenuation.

Assuming that this inlet does provide a disproportionate amount of phosphorus to Lake Massapoag, some potential for nutrient attenuation may exist. The constructon of a weir at the mouth of the inlet to pond water to an elevation of 254 to 255 feet; and replacement of existing wooded swamp with shallow fresh marsh vegetation such as cattails, could create an environment for settling and uptake of nutrients that would reduce phosphorus inputs from inlet 14. However, there is a potential for adverse impacts from such a project. Removal of trees from the area would be difficult to accomplish on wet soils, and may end up releasing more nutrients and nutrient-laden sediments than would be retained by the proposed structure over a period of years. In addition, raising of the water level in this area could impair the function of septic systems, or aggravate basement flooding during periods of high water table elevation. It is recommended that no action be taken at present to alter the existing situation. After implementation of the recommended sewage disposal alternative for this area of the shoreline, further study of the nutrient input from this inlet, and the function of its associated wetlands could be conducted to determine the need for and effectiveness of structural management measures.

Inlet 7, Sucker Brook, has a slightly larger drainage area than inlet 13; and contributes approximately 50.8 kgP/yr to Lake Massapoag, or 27% of the total watershed surface phosphorus loading. As with inlet 13, the phosphorus input is proportionate to the hydrologic input of the stream. Unlike the other inlet streams however, wetlands of the Sucker Brook watershed are to a large degree associated with the headwaters of the tributaries. Functionally, the most significant wetland area on Sucker Brook is located at the junction of its tributaries north of Camp Wonderland. Water quality sampling upstream and downstream of this wetland area supports its pollution prevention function. (See Table 11, Stations 7A and 7B). The existing role of this wetland in attenuating pollution is especially important to Lake Massapoag since landfill leachate is apparently entering the headwaters to Sucker Brook east of Mountain Street. In the past, this wetland has served to buffer the Lake against more severe pollution from the landfill site. It is recommended that this wetland area (bounded approximately by the 270 feet contour) be protected and preserved in its existing state.

The option of enhancing this wetland area by creation of a settling basin, such as that recommended for inlet 13, was considered. A phosphorus retention pond could be effective in reducing nutrient loading to Lake Massapoag; however, several other factors make this recommendation environmentally undesirable. Construction of a pond would involve either removal or subsequent death of trees now populating the wooded swamp. Either of these results would adversely affect downstream water quality. Tree removal, and other construction activities associated with creation of a pond, would disturb organic soils which are likely to contain both nutrients and metals. It would be difficult to prevent downstream movement of these pollutants during and immediately after construction. Given that the wetland soils may contain elevated concentrations of metals as a result of years of upstream landfill use, the creation of a pond above these soils should be considered carefully. Standing water of significant depth could alter the chemical conditions at the soil interface (particularly the Eh potential), and induce re-release of soil-adsorbed pollutants to Sucker Brook. In light of the potential for such adverse impacts, the creation of a phosphorus retention pond is not recommended for this area.

7.0 EVALUATION OF IN-LAKE RESTORATION AND MANAGEMENT OPTIONS

7.1.1 Drawdown

Aquatic vegetation in moderate amounts is beneficial to a lake's environmental stability. It provides rearing areas for juvenile fish and refuge for adults. Macrophytes also store nutrients from the sediments and water column for growth, thus creating competition for available nutrients with phytoplankton, the latter which may cause blooms. In limited quantities, macrophytes contribute to the oxygen supply. Aquatic vegetation also serves as a potential food source for invertebrates, certain mammals and waterfowl. However, aquatic vegetation can become a nuisance when undesirable species or dense populations interfere with recreational activities. The goal of aquatic plant management is to maintain a plant population beneficial to the lake ecosystem, which is also compatible with recreational use.

Plant growth may be managed in various ways by using biological, chemical or physical means, or by a combination of these three methods. Water level fluctuation has been shown to be one successful physical management technique for control of aquatic vegetation. Through manipulation of water levels in the littoral zone, the vegetation that occupies this area of light penetration becomes stressed and most plant species are unable to survive.

In Lake Massapoag the major mode of aquatic vegetation control is through annual water level manipulations. This consists of lowering the water level within a range of 1-2 feet commencing in November, with a maximum decrease in mid-winter and refilling of the lake in March to coincide with spring runoff. This yearly drawdown exposes 6-13% of the lake's bottom area. The Town of Sharon has performed this annual fluctuation since the fall of 1976; primarily in an effort to control the growth of watermilfoil, the dominant nuisance species in Lake Massapoag at that time. In the winter of 1981-82 there were complications achieving the overwinter drawdown, and the Lake was maintained at a normal, high level to facilitate vegetation control (Newman, pers. comm.).

In order to assess the effectiveness of drawdown as a management technique at Lake Massapoag, and guide its future implementation, other case studies were examined. An extensive literature search conducted by IEP biologists looked at the effects of drawdown on aquatic vegetation in northern temperate climates. Researchers throughout North America were contacted regarding studies of drawdown effectiveness on natural waterbodies and impoundments. Table 28 summarizes such data on species endemic to Lake Massapoag, including data on relative abundance and modes of reproduction of the aquatic plants surveyed.

The effects of water level fluctuation appear to be species specific. Lake drawdown destroys some seeds and vegetative reproductive structures through exposure to drying and freezing conditions and by altering the substrate with

TABLE 28. Reported Effectiveness of Drawdown in Controlling Aquatic Plants Found in Lake Massapoag

Species	Relative Abundance 9/24/81	Modes of Reproduction in Northern Temperate Lakes	Reported Control Following Drawdown: Good Control	Little or No Control	Increase Following Drawdown
Emersed:					
Nuphar variegatum (spatterdock)	S	○ Rhizomes	(1,9,15,16)	(8,19)	-
Pontederia cordata (pickerelweed)	S	+ Primarily rhizomes, possibly seeds	(14,15,16)	(7,8)	-
Typha latifolia (cattail)	S	● Rhizomes	-	(6,7,8)	(14)
Floating:					
Filamentous algae	S	▲ Cellular division	-	-	(1)
Utricularia sp. (bladderwort)	S	+ Winter buds	(10,14,16)	(5)	(11)
Submersed:					
Elodea canadensis (American elodea)	S-M	○ Lateral shoots	(1,4,13)	(20)	(11,15)
Gratiola aurea (golden-pert)	S	No data reported	No data reported		
Isoetes sp. (quillwort)	S	■ Spores	No data reported		
Myriophyllum heterophyllum (variable watermilfoil)	M	+ Fragmentation, winter buds, seeds	(2,9)	-	-
Nitella flexilis (brittlewort)	M	+ Spores	No data reported		
Nitella sp. (brittlewort)	M-D	+ Spores	(12)	-	(17)
Potamogeton bicupulatus (snailseed pondweed)	S	No data reported	No data reported		
Potamogeton epihydrus var. ramosus (ribbonleaf pondweed)	S	• Seeds, rhizomes	-	(2,15)	(14,16)
Potamogeton pusillus var. pusillus (slender pondweed)	M	★ Seeds, overwinter turions	(1)	(3)	-
Scirpus sp. (bulrush)	S	▼ Seeds	(7)	(2,8)	(2,8,14,15, 16,18)

S - sparse
M - moderate
D - dense

Data Source - Reproduction

★ Beard (1981, pers. comm.)
▲ Bold (1973)
■ Fassett (1980)
+ Hellquist (1981, pers. comm.)
● Hellquist (1981)
▼ Martin et al (1951)
• Miller (1981, pers. comm.)
○ Sculthorpe (1971)

Data Source - Drawdown

1 - Beard (1981, pers. comm.)
2 - Beard (1973)
3 - Goldsby (1981, pers. comm.)
4 - Gorman (1979)
5 - Hall et al (1946)
6 - Hestand and Carter (1975)
7 - Holcomb and Wegener (1971)
8 - Kadlec (1962)
9 - Lantz (1974)
10 - Lantz (1964) cited in Nichols (1974)
11 - Martin (1979)
12 - Mathis (1965) cited in Goldsby and Sanders (1977)
13 - Nestico (1978)
14 - Nichols (1975a)
15 - Nichols (1975b)
16 - Nichols (1972) cited in Nichols (1974)
17 - Smith (1982, pers. comm.)
18 - Steenis (1950)
19 - Tarver (1980)
20 - Wile and Hitchin (1977)

consolidation of sediments (Cooke, 1980). Fluctuating water levels expose shallow areas, making them unsuitable for macrophytic growth. The deeper end of the littoral zone becomes more shallow. However, adaptation by deep water species cannot take place if the waterbody is reflooded to its original or greater water depth (Nichols, 1975b). Thus, water level manipulation may place a considerable stress on aquatic vegetation. Stanley et. al. (1968) states that the repeated stress of high and low water levels could have a considerable detrimental effect on aquatic plants by upsetting metabolic relationships.

The primary reproductive mode of most aquatic plants is vegetative. Beard (1969) hypothesizes that when exposed to low water conditions, the plants may not develop mature fruit and most of the vegetative parts are destroyed. Conversely, in some species, reproductive structures such as seeds may be very resistant such that exposure and dessication are not detrimental but beneficial or necessary for germination (Nichols, 1975a and 1975b). In this respect, tolerant seed reproducing species may become established following a drawdown.

Fluctuating water levels may also result in a change of dominant species. Sculthorpe (1971) cites American elodea as replacing communities of watermilfoil (Myriophyllum sp.). Nestico (1978) found impacted areas eradicated of E. canadensis to be reinvaded by coontail (Ceratophyllum demersum) and pondweed (Potomogeton sp.). Although complete eradication of aquatic vegetation rarely occurs, the species reinfesting the area may not be as much of a nuisance problem as the original dominant plant (Enser, pers. comm.). It is thus beneficial to manage the littoral zone such that vegetation which is not considered a nuisance to human activities (e.g. Nitella sp.) will be encouraged to grow, thereby out-competing the less desirable high-profile macrophytes.

In 1976, a survey completed by the MDWPC showed watermilfoil (Myriophyllum sp.) to be the dominant nuisance macrophyte. Since the initiation of the annual drawdown program, watermilfoil has substantially decreased in density and distribution, and presently inhabits the eastern shore in moderate amounts with sparse growth around the southern and western shorelines. Walter Newman, Chairman of the Lake Management Study Committee, carried out an underwater survey of the southern end beach area in the early 1970's. He observed heavy infestations of milfoil within 75 feet of the shoreline growing 6-8 feet high. Since the initiation of the annual fall/winter drawdown program in 1976, very little milfoil has been observed inhabiting that area (Figures 23 and 24). It should also be noted that new sand is deposited along the northern and southern beaches every few years, possibly helping to discourage plant growth.

Goldsby (pers. comm.) states that in several Tennessee Valley Authority (TVA) reservoirs, fall/winter drawdown is an effective means of control of M. heterophyllum. Watermilfoil however, does produce a land form that creates a turion-like structure adaptive to drawdown. Goldsby notes further that this adaptive land form structure mav have influenced Lantz's results (Table) that indicate an increase in watermilfoil following drawdown. If there is any moisture present in the exposed substrate, the turion will not dessicate and the plant may spread. At present, there have been no reports of turions developing at Lake Massapoag. However, it is important to allow for maximum exposure of sediments over winter such that land form turions, if developed, would freeze and dry. It is therefore suggested that the water level be drawn down as early in the fall as would be feasible from a recreational and engineering perspective.

In northern states, seeds are not a significant means of reproduction in M. heterophyllum. Thus, low viable seed production, as well as the annual drawing down of the water level following seed germination, to allow for drying and freezing, has likely helped to control sexual reproduction of watermilfoil in Lake Massapoag.

Because only a 2 foot drawdown is presently being implemented, all of the milfoil is not exposed, for it grows out to a water depth of 12 feet. The milfoil that inhabits the lake bottom beyond the four foot depth contour is not directly affected by the fluctuation, although it is stressed. Fragments that may float from the deeper to shallower areas do not pose a problem for they do not become established in the shallow areas before refilling of the lake in March. Fragments that may enter the deeper (12 ft.) littoral zone die off, following refill of Lake Massapoag to its original depth. Thus, drawdown has been an effective management strategy for control of watermilfoil in Lake Massapoag, markedly reducing its density and distribution throughout the lake. Walter Newman observed the milfoil growing in the deep marsh at the southern end of the lake before the drawdown program was established. Although the dike that occurs at its outlet to the lake has recently been repaired, milfoil in this area is not prevented from fragmenting into the lake.

A macrophyte that is presently found in sparse to moderate densities but not reported in earlier surveys, is American elodea (Elodea canadensis). As previously mentioned, elodea has replaced areas once dominated by milfoil (Sculthorpe, 1971). It is not known when American elodea became established in Lake Massapoag but several investigators have noted its successful control by drawdown. Sculthorpe (1971) states control by drying to be extremely successful and Beard (pers. comm.) in Wisconsin found elodea to be one of the dominant species affected by a fall/winter drawdown. Nichols (1975a) found that in Wisconsin, American elodea exhibited good control during two consecutive fall/winter drawdowns. However, once the drawdowns were suspended, it was able to recover to greater densities than prior to drawdown. Nestico (1978) found eradication of American elodea in Connecticut following a fall/winter drawdown.

From the above investigations, it may be stated that good control by drawdown has been achieved for American elodea with dessication being the primary cause of reduction. It is again stressed that complete drying of the sediments is extremely important and the longer exposure can be maintained, the more beneficial the drawdown will be.

American elodea may also be competing with two species of the macroscopic algae, brittlewort (Nitella sp. and Nitella flexilis). Nitella sp. is presently the dominant plant in the lake, growing close to the substrate. Five consecutive years of drawdown in a lake in Arkansas signicantly reduced the population of Nitella sp. (Mathis, 1965) but often this algae reinfests drawdown areas. Nitella sp. competes with macrophytes with its low growth patterns, inhibiting the taller species from establishment. Thus at this time Nitella is favored in Lake Massapoag due to its ability to successfully compete with nuisance species. The species in Lake Massapoag that have remained stable or have slightly increased since the implementation of the drawdown program include spatterdock (Nuphar variegatum), cattail (Typha latifolia), quillwort (Isoetes sp.), golden-pert (Gratiola aurea), and pickerelweed (Pontederia cordata). These species grow in shallow water and are not considered to be a nuisance in Lake Massapoag. Species that are widespread such as golden-pert and quillwort are low growing and do not interfere with recreational activities. Other plants such as pickerelweed and spatterdock are sparsely distributed. Thus, these species are not expected to become a nuisance in Lake Massapoag.

Three species of pondweeds are distributed throughout the shoreline and appear to be increasing along the eastern portions of the lake. Two species were recorded 1976. It is not known which pondweeds were present before the initial drawdown and what new species have invaded Lake Massapoag since that time.

Snailseed pondweed (Potamogeton bicupulatus) is sparsely distributed throughout in Lake Massapoag. Control of this specie by drawdown has not been previously investigated. Most thin leaf pondweeds are prolific seed producers. However, it is not known what percentage of seeds in northern areas are viable. Hutchinson (1975)cites an experiment in which seeds of snailseed pondweed were stored in cold water (1-3 C) for six months, followed by germination of over half the seeds. Thus, it appears that actual freezing (0 C) of the seeds would be extremely important for control of this plant as well as dessication. Because snailseed pondweed has remained a sparse species of pondweed in Lake Massapoag following six years of fall/winter drawdowns, it is felt that this plant will not become a nuisance macrophyte.

Ribbonleaf pondweed (P. epihydrus) is a vegetative species that has mixed reports on its control by drawdown. Because it has not become a prominent macrophyte following several fall/winter drawdowns, it is not considered a problematic species in Lake Massapoag. Slender pondweed (Potamogeton pusillus var. pusillus) is found in moderate densities throughout the lake, being most prevalent on the eastern shore. In Tennessee Valley Authority (TVA) reservoirs, Goldsby (pers. comm.) found that slender pondweed is a reinvasion type species. Although it is a perennial, having a life span of more than two years, it produces great numbers of viable seeds in Tennessee. Beard (pers. comm.) found in Wisconsin flowages that slender pondweed shows good control following fall/winter drawdowns but that it produces seeds which may be resistant. Because Massachusetts has similar climatic conditions to Wisconsin, slender pondweed is most likely stabilizing itself in Lake Massapoag, being somewhat controlled by the annual drawdowns but also releasing some viable seeds which aid in its propagation to present densities.

Evaluation of Former, Present and Proposed Water Level Manipulation Practices

A former management strategy for aquatic weed control in Lake Massapoag was the chemical treatment of the deep fresh marsh at the south end of the Lake, in 1969. It was proposed that this technique would control the heavy concentration of macrophytic vegetation within the deep marsh at the southern portion of the lake that may have been contributing to the weed problem within the lake.

A second practice was the incidental increase in water level in the early 1970's. The flashboards within the flume house were left stationary during the fall, thus the water level increased to its maximum height during the winter months. It was hypothesized that light penetration would be limited in the deeper portions of the littoral zone, resulting in a decrease of vegetative growth in this area. However, the flooding also caused lake resident's wharfs to be pushed out from shore by the ice, and basements of homes to be flooded (Walter Newman, pers. comm.). High water levels may have facilitated some regulation of plant growth in deeper waters. However, from a lakeshore resident's perspective, this endeavor was more of a nuisance than a benefit.

In evaluating the present management strategy of annual drawdown at Lake Massapoag, it must be noted that much control of aquatic vegetation has been achieved by this technique. The dominant nuisance macrophyte, watermilfoil has exhibited a significant decrease, whereas pondweed, Nitella and American elodea may be inhabiting the milfoil's former niche. The low growing brittlewort, quillwort and golden-pert extend across the lake's bottom in shallow areas competing with the high profile species for dominance. Thus, the present trend in Lake Massapoag appears to be the replacement of nuisance vegetation with more favorable species that are more compatible with recreational uses of the Lake.

It is felt that annual fall/winter drawdowns of 2 feet are presently exhibiting beneficial results and that increasing drawdown to as much as 6 feet could benefit additional areas. (Calculations of drawdown depths achievable within the environmental constraints established to protect downstream concerns indicate that greater than two feet of drawdown is not likely to be attainable, except in very dry years.) However, long term control may not be maintained following several years of this management strategy. In the Chippewa Flowage, Wisconsin, Nichols (1975b) determined that after 50 years of consecutive fall/winter drawdowns, the overall species composition shifts to those tolerant of water level manipulation. Thus, the yearly water fluctuation in the flowage presently appears to be the stable condition. Annual drawdowns did eliminate those plants which could not adapt, however the drawdowns were beneficial to vegetation able to survive the stress. Several macrophytes common to the Chippewa Flowage are also present in Lake Massapoag. In particular, Nichols demonstrated that American elodea and ribbonleaf pondweed were species showing preference for fluctuating water levels. American elodea is a new inhabitant to Lake Massapoag, since the initiation of annual drawdown, possibly reinfesting areas once dominated by watermilfoil. The study in Wisconsin is presently the only comparable long-term investigation of annual drawdowns.

One disadvantage of the annual drawdown of Lake Massapoag is the reported impact to the downstream environment. Mitigative measures in the form of minimum and maximum flow releases are proposed in section 8.2, Environmental Assessment. In order to implement this mitigative measure, a flow gage should be installed at or downstream of the outlet. A staff gage in an appropriate reach should be erected, and flow measurements made over a range of flows so that a stage-discharge curve can be developed. The cost of the gage, and rating curve, is estimated at $1500.

In Lake Massapoag, the initial fall/winter drawdowns provided significant control of nuisance aquatic weeds. It is hypothesized that presently, the vegetative community in Lake Massapoag may be gradually altering from species less tolerant of drawdown to those more tolerant of the annual water level fluctuation. The absence of drawdown in the winter of 1981-82 was followed by an increase of pond weeds. However, due to limited data, conclusions may not be made at this time as to whether any correlation between lack of drawdown and increased weed growth may be made. Vegetation monitoring programs should be carried out in the future to determine which tolerant species are replacing those susceptible to drawdown and if a staggered schedule of drawdowns is necessary to control tolerant species. It is suggested that the annual program be continued, for past data suggests that drawdown has shown good control of nuisance vegetation. Yearly vegetation surveys will enable the Town to make future management decisions on the effectiveness of annual drawdowns. The present cost of macrophyte surveys is estimated at $800 per survey.

7.1.2 Mechanical Harvesting

Mechanical harvesting of nuisance aquatic vegetaion has sharply increased in popularity and use during recent years and has proven to be an effective lake management technique. Today's manufacturers of harvesting equipment offer a variety of different sized machines ranging in price from approximately $18,000 - $75,000. Firms offering harvesting services on a contractual basis have also contributed to the recent increase in the number of ponds and lakes utilizing this method of weed control.

Unlike chemical treatments, no foreign substances (herbicides) are added to the pond or lake water, during the harvesting operation. The cut plants are simultaneously removed from the waterbody, thereby reducing the availability of recycled nutrients for potentially troublesome blooms of microscopic algae. Harvesting does not necessitate temporary restrictions on lake usage for swimming, fishing, etc., as is required with most herbicides. Harvesting is seldom followed by reductions in dissolved oxygen concentrations as may often occur during the decomposition of macrophyton after a herbicide treatment. On the other hand, mechanical harvesting is generally considered a short-term management approach, necessitating at least one cutting per summer and often times multiple cuttings, with little promise of achieving a sustained reduction in macrophytic growth from one year to the next.

The USEPA (December 1980) "Clean Lakes Program Guidance Manual" describes mechanical harvesting along with other lake management/restoration techniques. The position of EPA with respect to harvesting as stated in the manual is: "The Clean Lakes Program considers harvesting to be a palliative approach to lake restoration in most cases, and therefore rarely eligible for financial assistance." Nevertheless, EPA has funded two harvesting programs, one at Lake Bomoseen in Vermont and the other program at a large lake situated in Wisconsin. EPA and other researchers do agree, however, that harvesting can aid to the eventual recovery of a lake if the amount of nutrients removed in the cut vegetation exceeds the lake's net nutrient income.

Contiguous and dense growth of nuisance aquatic plants are presently not a widespread problem throughout Lake Massapoag. Although the 1981 and 1982 aquatic vegetation surveys (Figures 23 and 24, respectively) reveal diverse macrophyton communities found throughout the Lake's shallow littoral zone, several of the more common plants observed were low growing macroscopic algae (Nitella flexilus) and vascular types such as Isoetes sp. and Gratiola aurea. The above species are relatively innocuous and do not normally interfere with swimming and boating activities as compared to high profile (taller) macrophytes such as watermilfoil.

A limited and selective program of mechanical harvesting may be warranted at Lake Massapoag, especially along the western shoreline. Although the Town beaches do not presently have a weed problem, excessive weeds do present a nuisance to private shorefront property owners who abut the western shoreline and southern coves. Along the eastern shoreline of the Lake, aquatic vegetation is generally less dense, but still some selective harvesting of the taller growing slender pondweed and American elodea may be justified there as well.

In total, we estimate that a maximum of approximately 55 acres of nuisance vegetation could be harvested at Lake Massapoag. Harvesting priority areas and potential shoreline off-loading sites are shown in Figure 33. We recommend that most of the harvesting effort be directed towards managing the nuisance growth of slender pondweed, watermilfoil, and American elodea in water depths greater than four feet. In water less than four feet, the continuing program of fall/winter drawdowns should provide acceptable control of potentially nuisance weed growths and therefore 'spot' harvesting should suffice.

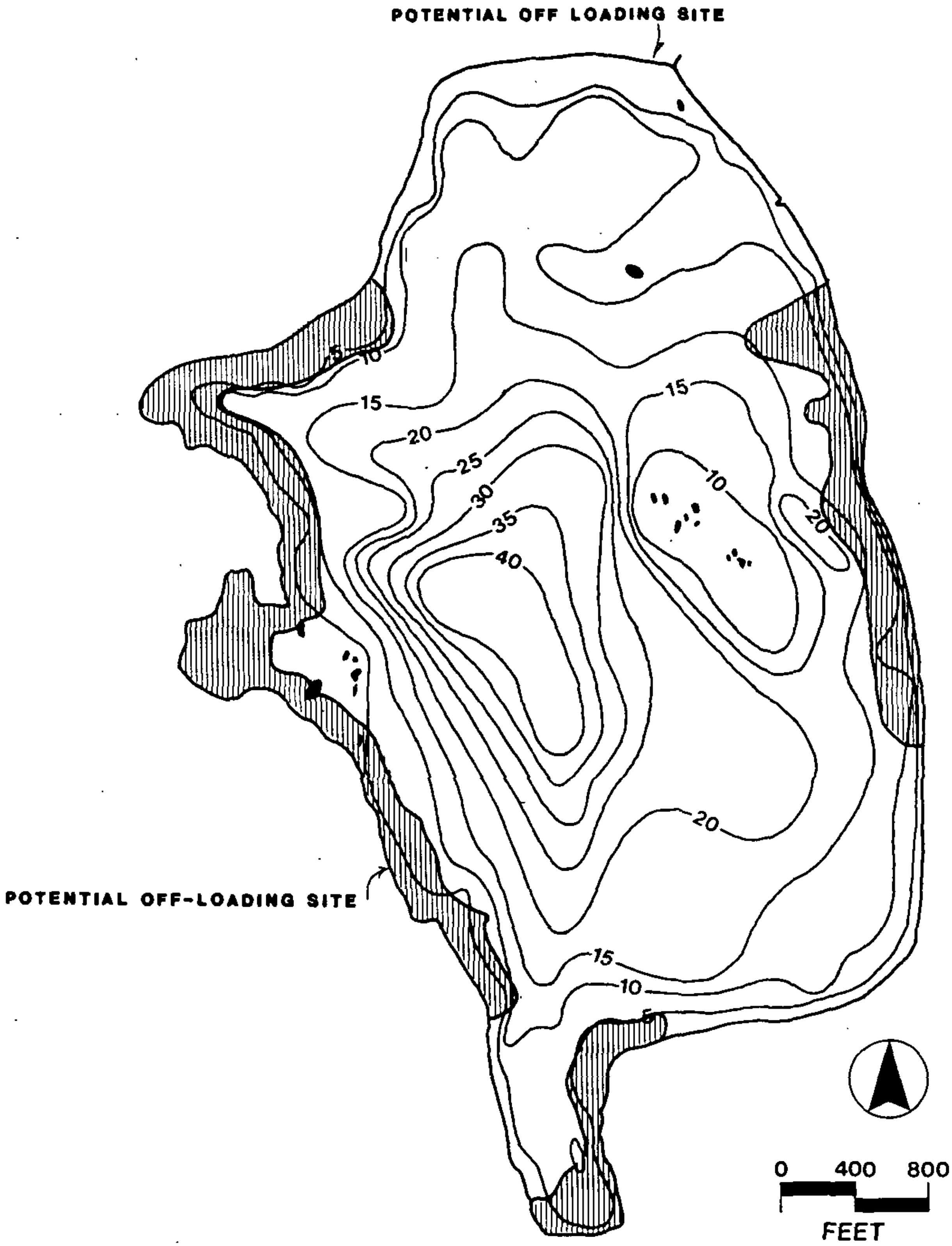


FIGURE 33
SUGGESTED AREAS FOR MECHANICAL HARVESTING

LAKE MASSAPOAG DIAGNOSTIC / FEASIBILITY STUDY, IEP Inc.

Initially, we suggest that mechanical harvesting be performed by an independent contractor. Contract harvesting rates presently range between $300-$375/acre of vegetation, excluding trucking/disposal. In most communities, the local Department of Public Works will handle the trucking aspect of the project. Based upon 55 acres of vegetation at a cost of $350/acre, a single harvest would cost approximately $19,250 at Lake Massapoag. Depending upon the local support for the harvesting program, its effectiveness, and future availability of Town/State funds for capital purchases, the Town may want to consider direct purchase and operation of a small machine. The apropriate sized harvester for Lake Massapoag currently sells for approximately $30,000 plus trailer and freight. In general direct purchase becomes more attractive financially with more acreage to be harvested. Although USEPA has funded few harvesting projects, the MDWPC "Clean Lakes and Ponds Program" may provide 50% towards the cost of either contract harvesting or the purchase of equipment.

Harvesting in combination with drawdown is viewed as an effective weed control program for Lake Massapoag. Neither technique will remove a significant quantity of nutrients from the Lake however, considering the rather small percentage (14%) of bottom area that supports macrophytic growth, relative to the total bottom area of the Lake. Lacking site specific plant biomass and stem analyses for nutrients at Massapoag, Wile (1977) estimated that for each acre harvested, approximately 2.7 kg of phosphorus and 22.7 kg of nitrogen will be removed. The actual phosphorus and nitrogen removal rates for Lake Massapoag are likely to be less than cited above, due to the comparatively low macrophyton densities observed by visual survey at Massapoag. The potential for significant nutrient removal at Lake Massapoag and long-term reductions in macrophytic densities attrituable to harvesting alone are low. Nevertheless, harvesting combined with other watershed management/restoration strategies will help to prevent further eutrophication of the Lake.

7.2 Other Alternatives Evaluated

7.2.1 Dredging

Dredging of ponds and lakes may be undertaken to: (1) remove nutrient enriched bottom sediments which contribute significantly to internal nutrient recycling, (2) expose a nutrient deficient bottom type such as coarse sand and gravel, which is less than conducive to the growth of rooted aquatic plants, or, (3) deepen a cove or shoreline which has filled in, to increase water depth for swimming/boating while precluding light required by aquatic plants. Figure 6 shows the different substrate types and predominant type according to location, throughout the littoral zone of Lake Massapoag. With the exception of the southern cove and a small area along the western shore, a firm bottom comprised of sand, gravel and boulders characterizes the remaining shoreline of the Lake.

Sediment removal utilizing hydraulic dredging equipment such as the 'Mudcat,' is not a cost-effective alternative at Lake Massapoag. Dredging of the

Lake's littoral zone or bottom areas currently supporting rooted aquatic vegetation has no assurance of providing long term relief from nuisance conditions unless deepening were to occur beyond the photic zone (deeper than 12 feet). The dominant submerged macrophytes were not restricted in their distribution to soft muck type sediments only. Along the majority of Lake shoreline, the bottom type was predominantly sand/gravel, yet nuisance densities of macrophytes were still observed.

Dredging costs vary dramatically depending upon the method of dredging used (hydraulic, drag-line or conventional equipment), distance to and construction costs for sediment disposal sites, and geographic locale of the project. Dredging costs for projects conducted by the Army Corps of Engineers throughout the northeastern United States were reported at $4.96/cu. yd. (Peterson, 1979). The Corp of Engineers' cost information seems to be a representative average for the two more recent lake dredging projects conducted here in Massachusetts - Morses Pond, Wellesley and Nuttings Lake, Billerica. Unquestionably, the cost for dredging the littoral sediments to a finished depth that would no longer support rooted plant growth at Lake Massapoag, would exceed $1,000,000. Hydraulic dredging is not recommended.

The recommended continuing program of fall/winter drawdown of at least four feet and perhaps on occasion six feet, would allow for sediment excavation with conventional track-mounted equipment. Bulldozing and removal of selected nearshore sediments would only be recommended to either: (1) increase water depth for boating and swimming, or (2) control dense nuisance macrophyton growth where a permeable organic substrate is predominant. Sediment excavation for either purpose cited above cannot be substantiated, nor do we believe that public funds should be allocated in order to benefit a minority of the Lake-front property owners. Sediment removal would have no significant benefit towards maintaining or reversing the Lake's trophic status.

7.2.2 Hydro-Raking

The Hydro-Rake was designed several years ago by Virgilio Construction Company of Pittsfield, Massachusetts. Unlike a mechanical weed harvester, the Hydro-Rake literally rakes the lake bottom with an eight foot wide York Rake attached to a light-weight back-hoe. The back-hoe is mounted on a pontoon barge. Propulsion of the barge is provided by paddle wheels powered by a diesel engine.

The Hydro-Rake will remove aquatic plants, root material and bottom muck to a depth of 12 feet. The maximum lifting capacity of the back-hoe is approximately 600 lbs. with an average rake-full weighing 300-400 lbs. In that the Hydro-Rake has no on-board storage capacity, each rake-full of material must either be deposited directly on-shore or else loaded onto a transport barge.

One advantage of the Hydro-Rake as compared to a conventional cutter/

harvester is that the Rake removes nuisance aquatic vegetation at the sediment/water interface. The cutting depth on a harvester must constantly be readjusted for changes in bottom contours, which makes it more difficult to constantly maintain the cutter bar just off the bottom. The maximum cutting depth for the harvester is only five feet as compared to a 12 foot working depth for the Hydro-Rake.

Past experience with the Hydro-Rake has shown it to be equally as effective on removing emersed and submerged aquatic vegetation. One thorough raking per summer has provided good control of white waterlilies, spatterdock and other macrophytes possessing a tuberous type of rhizome which the Rake can easily dislodge from the bottom (Aquatic Control Technology, Inc.). Good carry-over benefit or control of the above macrohytes for one to two years following the initial raking has been observed.

On submerged aquatic plants such as those species common in Lake Massapoag (P. pusillus and E. canadensis) use of the Hydro-Rake is less cost-effective, due to their fine root system which precludes a high percentage of root removal. One raking per summer is likely to be required with little potential of reduced vegetative regrowth during the following year.

The productivity of the Hydro-Rake is slow in comparison to most mechanical harvesters. Contracting rates for Hydro-Rake weed removal are likely to run $700 - $900/acre for submerged macrophytes or more than twice the cost of harvesting. In view of the above discussion, use of the Hydro-Rake is not recommended at Lake Massapoag. The recommended and combined program of fall/winter drawdown and mechanical harvesting should be equally if not more effective than hydro-raking, at a substantially lower cost.

7.2.3 Herbicide/Algicide Treatment

Chemical treatment of nuisance aquatic vegetation using State and USEPA approved herbicides is still the most common method of weed control, due primarily to its favorable (low) cost, as compared to other management/restoration techniques and the relative simplicity by which it can be accomplished. Prior to the application of any herbicide/algicide in ponds and lakes throughout the Commonwealth, a permit must first be filed with the Massachusetts Department of Environmental Quality Engineering - Waterways Division, and municipal approval must also be obtained from the local Conservation Commission. All chemical treatments must be performed by a state/federal certified commercial applicator, licensed to dispense aquatic herbicides. Both herbicides and algicides kill the aquatic plants by either disrupting the normal pattern of cell division or breaking down the cell wall. Herbicide treatment of aquatic plants is considered by many lake specialists, including USEPA, to be a "cosmetic or palliative" approach to managing aquatic nuisances. Following herbicide treatment, the decomposing aquatic plants release the nutrients stored in their tissues back into the surrounding water. This sudden pulse of nitrogen and phosphorus may then in-turn be assimilated by nuisance causing microscopic algae, potentially leading to bloom conditions.

Another potential drawback of herbicide/algicide treatment is the long term concerns regarding safety of the materials applied. Although any herbicide/algicide to be used for aquatic plant control must be registered and approved by both the USEPA and Massachusetts Pesticide Board, there have been several chemicals (i.e., silvex and sodium arsenite) that were once thought safe and used, which have since been taken off the market due to their residual/cumulative characteristics and potential adverse effects on non-target organisms. At present, the extensive testing and toxicological data required by EPA prior to product registration and labeling should insure a higher degree of safety than in years past. Yet a certain degree of risk will always remain.

Lake Massapoag is stocked annually with trout by the Massachusetts Division of Fisheries and Wildlife (MDFW). Although an abundance of habitat suitable for year-round survival of cold water game species is not found at Massapoag, some carry-over of stocked trout from one year to the next does occur (Bergin, personal communication). In addition to requiring cool water temperatures (<70°F) trout also need dissolved oxygen concentrations generally of 5 mg/l or greater in order to survive. Herbicide or algicide treatment of Massapoag could potentially reduce the existing marginal habitat for trout there, by further lowering of the oxygen levels. Microbial respiration that follows a herbicide/algicide treatment as the plants decompose tends to suppress oxygen concentrations below ambient levels. Although difficult to quantify, any further reduction in D.O. levels would jeopardize the survival of hold-over trout at Massapoag.

In view of the long-term concerns regarding safety of the herbicides, coupled with the potential adverse impact on the Lake's trout fishery and potential for increasing algal density, chemical (herbicide) treatment of nuisance weed growth is not recommended. Copper sulphate, the most commonly used algicide, is very toxic to trout in low alkaline waters such as Massapoag, and should not be applied either.

7.2.4 Algae - Considerations with Respect to Control, Future Monitoring and Surveillance

Various procedures and parameters used to describe the algae community of Lake Massapoag are discussed and found in section 3.6.2 of the Diagnostic Report. Unlike many other lakes, the algae community at Lake Massapoag did not follow predictable seasonal trends with respect to species composition and density, throughout the course of our 1981/1982 monitoring program. To the contrary, a maximum transparency (secchi disk) reading of 14.5 feet recorded on August 31, 1981 may be compared to a transparency of only 8 feet on August 26, 1982. During 1981, a golden brown alga, Chrysochromulina, attained densities up to 10,173 cells/ml causing unpleasant odors and reduced transparency during spring and early summer. Other than its apparent preference for soft waters, little is known about Chrysochromulina's environmental requirements (Estabrook, personal communication).

At Lake Massapoag, Chrysochromulina was not observed during the 1982 summer monitoring program. The plankton assemblage was comprised largely of common green and filamentous blue-green genera. Transparency ranged between approximately 6.5 to 8.5 feet, which is acceptable for swimming and other water contact usages assigned to Class B waterbodies such as Lake Massapoag. Transparency exceeded the Commonwealth's minimum standard of 4 feet on all sampling dates at Lake Massapoag, except one. On June 11, 1981 a secchi disc reading of approximately 3.0 feet was recorded. By early July however, transparency increased to about 6.0 feet and improved to 14.5 in late August.

Control of Microscopic Algae

In-lake control of microscopic algae utilizing chemical, mechanical or other management strategy is not warranted at the present time. The water at Lake Massapoag remains sufficiently clear to allow for safe swimming. Furthermore, internal phosphorus recycling following the spring and fall overturns did not reveal a substantial increase for in-lake phosphorus and nitrogen concentrations. Watershed phosphorus loadings to Lake Massapoag (range 312 - 617 kg/yr) are high in comparison to the phosphorus mass present in the Lake's hypolimnion (65 kg) during late summer. This 65 kg of phosphorus could have recirculated throughout the Lake after the fall turn-over but apparently did not, possibly due to recombination and precipitation of the phosphorus with iron following the introduction of oxygen.

Mechanical aeration/destratification or a hypolimnetic aeration system cannot be justified at this time for Lake Massapoag. Chemical inactivation or precipitation of phosphorus with alum is also not warranted at this time. Efforts to curb watershed derived phosphorus inputs to Massapoag are recommended, as opposed to in-lake strategies that would attempt to reduce phosphorus availability.

Future Monitoring/Surveillance

The unpredictable algae community at Lake Massapoag and tendency for the development of Chrysochromulina blooms, warrants continued monitoring. At a minimum, we recommend that samples be collected and examined biweekly from spring to fall turn-over. A surface grab sample in addition to a column sample should be regularly taken at the deep-hole sampling site. Near shore surface samples for algae identification (especially buoyant blue-greens) and counts are also suggested for comparison with the summer 1982 sampling program data.

Temperature/dissolved oxygen profiles and multi-depth analyses of phosphorus and nitrogen parameters are also recommended. Nutrient analyses are especially important during late summer and immediately before and after spring and fall turnover. This data would be useful to further define the significance of internal phosphorus cycling and inputs to Lake Massapoag. The estimated cost for a sampling and analysis program of this scope is $7500 per year.

8.0 RECOMMENDED MANAGEMENT PROGRAM AND PROJECT IMPLEMENTATION

8.1 Program Summary and Costs

Lake Massapoag is a kettle pond situated in southeastern Massachusetts, with a long history of industrial and recreational uses. As the population of the watershed and surrounding towns have grown, both the use of, and demand for, recreational opportunities at Lake Massapoag have increased. Correspondingly, the watershed has been subject to alterations; and, due to its many desirable aspects, will continue to attract development of a residential/institutional nature.

The Lake is presently characterized as mesotrophic and phosphorus limited. The greater proportion of the Lake's phosphorus budget is contributed by sources in the watershed surface, and shoreline septic systems. Without counteractive measures, both sources can be expected to increase phosphorus loading with time and increased development, thereby accelerating the eutrophication of Lake Massapoag.

Presently, the visible characteristics of the Lake's trophic status are moderate growth of aquatic weeds, and sporadic algae blooms. Both of these 'symptoms' are in large part nutrient-related, and would be expected to worsen with time if the trophic status of the Lake is not improved.

The goal of the recommended management program resulting from the diagnostic/feasibility study is three-fold; to reduce current annual phosphorus loading to Lake Massapoag in order to improve its trophic status; to restrict future increases in nutrient loading in order to preserve desirable water quality; and to maintain shoreline areas for recreational use. The proposed management plan is outlined below.

Recommended Management Program

Lake Restoration Aspects

- improved sewage disposal to reduce nutrient loading from shoreline septic systems by means of small scale off-site sewage disposal for targeted shoreline areas; with interim measures to provide some short-term benefit

- wetland enhancement to reduce nutrient transport from watershed surface areas by means of flow retention for phosphorus removal.

- relocated solid waste disposal to eliminate pollutant loading from the present landfill site by closure/sealing of the existing site, and future solid waste disposal outside the watershed.
- manual vegetation removal by shoreline residents during drawdown control.

Lake Preservation Aspects

- control of future nutrient loading from stormwater, construction, forestry, etc. via strengthened land use regulation and implementation of best management practices.

- control of future nutrient loading from tributary watersheds by preservation of key wetland areas.

- control of future spread of nuisance weeds from abutting wetland area by construction of a permeable barrier.

Lake Maintenance Aspects

- annual drawdown of water (2 feet) in Lake Massapoag between October and April to control growth of nuisance macrophytes.

- mechanical harvesting of nuisance aquatic vegetation in areas uncontrolled by drawdown.

The projected cost for various aspects of the recommended management program are given in Table 29. Figure 34 shows the present trophic status of Lake Massapoag, and the projected future status (year 2000) with and without corrective action. It is estimated that, without preventive action, the Lake's trophic status will continually worsen from mesotrophic to eutrophic. However, implementation of the proposed management program should improve the Lake's water quality close to a borderline mesotrophic oligotrophic status. Some aspects of the program provide benefits which are not apparent in terms of the trophic state model used. Table 30 includes a listing of the benefits of all aspects of the recommended program, including phosphorus loading reduction.

8.2 Environmental Assessment

The recommended management program has been developed on the basis of a limited goal: the improvement and preservation of Lake Massapoag as a recreational resource. However, other environmental impacts, both positive and negative, may occur in association with the implementation of this program.

8.2.1 Improved Sewage Disposal

The major negative impacts associated with the proposed plan for improved sewage disposal are construction-related. Increase in noise and dust, disruption of vegetation, disruption of local traffic and defacement of local residences will result from installation of pressure sewers, tie-in connections to homes, and construction of new leaching facilities. Pumping associated with the plan will result in a minor increase in long-range energy demand. By means of its impact on Lake Massapoag, the proposed project will improve aesthetics, safety and recreational opportunities in the area.

Table 29. Recommend Management Program Costs*

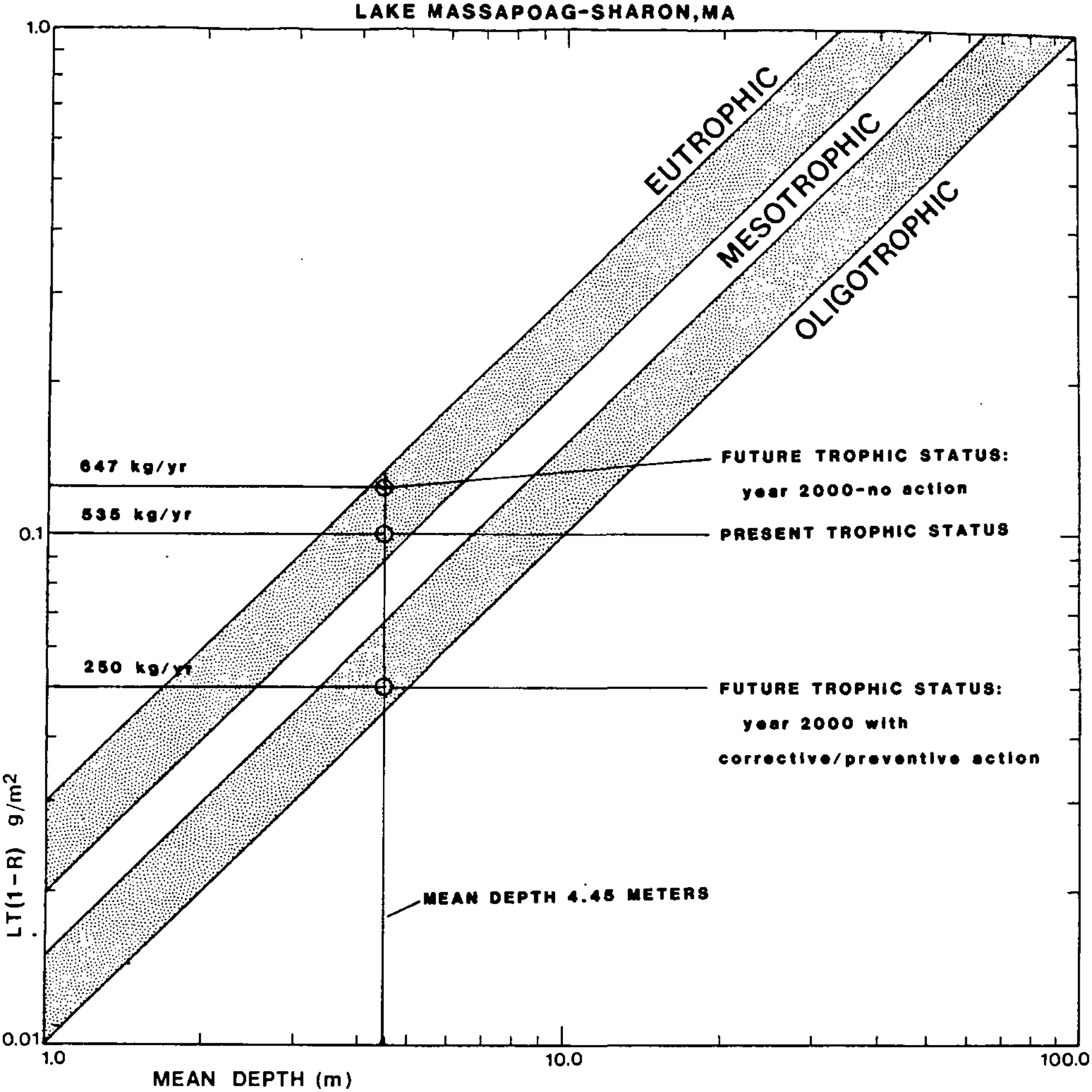
Program Element	Capital Cost	Permits/Final Design	10 year O&M	10 year Total Cost	Possible Funding Source	Estimated Funding Amount
Communal Septic Systems	$502,000	$100,000	$ 26,800	$970,000	DWPC/EPA Construction Grants (93%)	$466,860
Interim Measure: Septic System Inspection/ Maintenance	$118,250	-	$ 7,750	$195,750	DWPC Clean Lakes (75%)	$ 21,563[1]
Landfill Closure	$250,000	$ 10,000	$ 20,000	$280,000 (Approximate)	None	0
Wetland Enhancement		$ 5,000	$ 2,500	$ 40,000	DWPC Clean Lakes (75%)	$ 24,375
. New Pond	$ 30,000					
. Existing Pond	$ 2,500					
Wetland Preservation	(Determined by assessed land value and negotiation)				OCS Self-Help (80%)	-
Stormwater Management/BMPs	$ 2,000	-	$ 18,000	$ 20,000	None	0
Drawdown				$ 9,500	DWPC Clean Lakes (75%)	$ 7,125
. Outlet flow gage	$ 1,500	-	-			
. Annual macrophyte surveys	$ 800	-	$ 7,200			
Harvesting	$ 19,250	-	$173,250	$ 192,500[2]	DWPC Clean Lakes (75%)	$129,938
Surveillance	$ 7,500	-	$ 1,500	$ 22,500[3]	DWPC Clean Lakes (75%)	$ 16,875

[1] Initial inspections, first three years of program administration

[2] Town purchase of harvesting equipment may be less costly, depending on future harvesting needs

[3] Based on 3 years consecutive surveillance

* *1984*



L = AREAL PHOSPHORUS LOADING ($g/m^2/yr$)
R = PHOSPHORUS RETENTION COEFFICIENT (DIMENSIONLESS)
T = HYDRAULIC RETENTION TIME (yr)

FIGURE 34 DILLON/RIGLER TROPHIC STATUS (**PROJECTED FUTURE STATUS**)

Table 30. Summary of Recommended Management Program, Costs and Benefits

Program Element	Total Cost	Anticipated Benefit	Comments
Communal Septic Systems	$970,000	• 44% reduction in phosphorus loading; significant improvement in projected trophic status	• requires completion of townwide facilities planning study • funding dependent on future availability of federal/state grant money
Interim Measures for Shoreline Septic Systems Inspection/Maintenance	$195,750	• 8% reduction in phosphorus loading • reduction of projected future increase in phosphorus loading	• requires high level of interaction with shoreline residents
Leachate Interception and Landfill Closure	$250,000	• small reduction in phosphorus loading; reduced contamination of Sucker Brook; reduction in potential for existing/future contamination from micro-nutrients	• landfill presently near capacity
Wetland Enhancement	$ 40,000	• small reduction in phosphorus loading; reduction in sedimentation rate of southern cove	• possible adverse environmental impacts
Wetland Preservation	• determined by assed value of land and negotiation with present owners	• maintenance of existing functions including pollution prevention and maintenance of flow	• supplements protection currently provided under MGL Ch.131, s.40
Stormwater Management and Best Management Practices	• $20,000 for Town-operated programs • Lake Association budget may include Town contributions from beach revenues; private donations; annual dues and membership fees	• small reduction in phosphorus loading; reduction in sedimentation and organic loading	• implementation partly dependent on public interest and voluntary cooperation
Drawdown	• $1500 (outlet flow gage) • $8000 (annual weed surveys) • $2500 (O&M)	• control of nuisance aquatic weeds • small reduction of nutrients by removal of exposed weeds	• may not be attainable every year; weather dependent • limited by downstream environmental constraints
Harvesting	$173,250	• removal of nuisance aquatic vegetation in areas not affected by drawdown	• likely to benefit shoreline residents more than other Lake users
Surveillance	$ 26,550	• documentation of algal blooms and "trigger" conditions	• preservation program for Lake should include ongoing study & future "checkups"

8.2.2 Drawdown

In addition to improving lake shoreline conditions with respect to nuisance weed growth, annual drawdown will allow access to shoreline facilities, such as docks and ramps, for needed repairs and provide some protection from winter ice damage. Fall/winter drawdown should have an overall beneficial effect on in-lake fishery populations. Researchers (Lantz, 1974; Richardson, 1974 and Beard, 1973) have determined that fishes are not adversely affected by overwinter drawdown. In fact, there may be a gradual increase in available size game fish and game fish reproduction during the early years of fluctuation.

Winter recreational opportunities will be somewhat reduced during the years in which the Lake is drawn down. Skating and ice fishing will be viable, however. Public safety concerns center around changes in ice conditions and unstable slippery sediments which could be exposed during drawdown. Due to the favorable substrate types at Lake Massapoag, this should not be of major concern for most shoreline areas. Drawdown of Lake Massapoag would result in short term negative impacts to the aesthetics of the area, through deposition of dessicating weeds along the exposed shoreline. A cooperative program by shoreline residents should be initiated to clear dying vegetation from the shoreline. Removal of vegetation would serve both to reduce nutrient recycling to the Lake; and to make the exposed area more aesthetically pleasing during the drawdown period. Harvesting should have only short term effects on the aesthetics of the area, for all harvested weeds should be transferred to an awaiting vehicle, then transported to a disposal area. There has been some concern expressed that a drawdown of six feet or more would damage shoreline trees. A number of trees along the shoreline were presumed to be dying, following a winter drawdown of at least six feet (Scott Lowry, pers. comm.). Theoretically, a drawdown of this extent should not affect most types of deep rooted vegetation. However, it is recommended that the Town's forester be consulted on the conditions of the trees in question; with subsequent advice on the extent of drawdown (beyond the minimum four foot drawdown desirable).

Concern has been expressed by local residents regarding the impact to Massapoag Brook of seasonal drawdown of the Lake. Due to the relatively high lake area/watershed ratio, storage changes in Lake Massapoag have a greater impact on the downstream flow regime than do other lakes where drawdown is used. Massapoag Brook is stocked annually with trout by the Massachusetts DFW; therefore, minimum flow releases consistent with cold-water fisheries are recommended to mitigate downstream impacts of drawdown.

The U.S. Fish and Wildlife Service regional policy for New England stream flow recommends minimum flows of 0.5 cfsm (cfs per square mile of watershed) during summer; 1.0 cfsm during fall/winter; and 4.0 cfsm during spring. When and where minimum flow releases cannot be met, an "outflow equals inflow" policy is recommended. The development of site-specific guidelines is also permissible.

The USFWS criteria were reviewed in order to determine their compatability with achieving a two-foot refill in Lake Massapoag. Calculations were performed on the assumption that refilling would occur between mid-February and June, using the appropriate winter and spring minimum release values. Average monthly outflows were determined by the same method used in the hydrologic budget calculation for stream outflow, using a 10-year period of record. On the basis of these calculations, it is recommended that flow retention begin mid-February and extend through March, with a minimum release of 2.9 cfs. Retention may continue in April, if needed, with a minimum release of 11.5 cfs. During May and June, outflow should be approxiimately equal to inflow. Average flows to Massapoag Brook under "natural" conditions are below the USFWS spring criterion on 4.0 cfsm. Some evaporative losses will occur, more noticeably during the hotter, drier summer months. (Total evaporative loss for an average year is approximately equivalent to a one foot drop in water level). During the summer months, a minimum release of 1.5 cfs is recommended (mid-June through mid-September).

In order to achieve maximum drawdown through the fall, more water must be released from Lake Massapoag than enters it through streamflow, groundwater, runoff, and precipitation. In order to minimize downstream impacts, a recommended maximum flow release has been established. Under average "natural" conditions, September stream flow in Massapoag Brook is below USFWS criteria for fall/winter. Initiation of drawdown in late September to supplement downstream flows may be desirable; and may also serve to allow more control of downstream releases during wetter fall months by providing some flood storage volume in the Lake. Maximum downstream flows should gradually increase to 10 cfs in October, 13 cfs in November and 16 cfs in December. Gradual increases in flow release through the fall follows the natural pattern of stream flows. This program should allow for full drawdown by mid-December in average or drier-than-average years. However, natural variations in in-flow to the Lake will affect the actual rate and extent of drawdown in any year. The recommendations given here are based on average conditions and are intended to serve as guidelines to a drawdown program which is responsive to downstream concerns. However, operator judgment should be used to make appropriate adjustments under unusual or extreme runoff conditions.

8.2.3 Wetland Enhancement

The proposed wetland enhancement plan for reduction of watershed phosphorus loading to Lake Massapoag is anticipated to have a number of temporary and short-term negative impacts associated with construction and development of new habitat. Increase in noise levels, odors and sedimentation are several temporary negative impacts that could occur during the construction phase of the project. Populations of macroinvertebrates would be expected to decrease during construction as a result of the temporary destruction of habitat. Algal populations would possibly increase due to the creation of the pond.

The creation of the pond may also provide additional habitat for mosquito breeding. A modification to the proposed outlet structure may be to include structural provisions which would allow for periodic drawdown to dry the settling pond. This should be done after the mosquito eggs have been laid (fall/winter) to promote freezing and drying of eggs and/or larvae prior to hatching. It is suggested that the settling basin not be drawn down until it is demonstrated that a mosquito problem is present. The frequency of drawdown should be determined by the severity of the problem, should one arise.

The implementation of the proposed wetland enhancement project would provide long-term improvement in aesthetics, downstream flooding, wetland vegetation, and wildlife populations. The creation of diversity of wetland types with open water enhances wetlands aesthetically as well as enhancing their biological productivity. Opportunities for passive recreational activity, such as nature study and bird watching, would be increased by implementation of this project. See Table 31 for a summary of environmental impacts.

8.3 Permits

The proposed restoration and management program for Lake Massapoag will require filing for several local, state and federal permits. These are summarized below.

Local Permits

Chapter 131, section 40 (The Wetlands Protection Act) of the Massachusetts General Laws requires the filing of a Notice of Intent with the local conservation commission for any activity which will "remove, fill, dredge or alter..." a wetland resource area defined as any bank; vegetated wetlands bordering a stream, river, lake or pond; land under waterbodies and waterways; or land subject to flooding.

The project, as recommended, will require a filing with the Sharon Conservation Commission for construction of the proposed dikes and pond along Inlet 13.

The review procedure consists of a publicized public hearing to be held within 21 days of the filing date. Within 21 days, the Commission is to issue an Order of Conditions, setting forth the conditions under which the project may, or may not, proceed. The Order may be appealed by the Applicant or others. Appeals go to the Massachusetts Department of Environmental Quality Engineering who reviews the project and will issue a Superceding Order which may reaffirm or differ substantially from the original Order. The Superceding Order may be appealed to a DEQE hearing. If resolution is not made, further appeals are taken to the Massachusetts Superior Court.

Harvesting and drawdown of the Pond are likely classified as 'limited projects' under the new Wetlands Regulations, put into effect April 1, 1983. As such, these activities will still require filings with the local

TABLE 31. Environmental Impact Assessment of Proposed Management Program

ENVIRONMENT OF CONCERN / PROGRAM ELEMENT	1. Communal Septic Systems	2. Septic System I/M	3. Landfill Closure	4. Wetland Enhancement	5. Wetland Preservation	6. Best Mgmt. Practices	7. Drawdown	8. Harvesting	COMMENTS
Displacement of local residents	0	0	0	0	0	0	0	0	No adverse impacts
Defacement of local residences	xS	0	0	0	0	0	xS	0	1. Temporary impact during construction. 7. Possible minor short-term impacts to shoreline structures
Changes in land use patterns	0	0	xL	0	xL	0	0	0	3. Relocation; 5. No future development
Agricultural land	0	0	0	0	0	0	0	0	No adverse impacts
Parkland, public land, scenic resources	XL	xS	XL	xL	XL	xL	XL	XL	Improvement in quality of public land and scenic resource
Historic, architect., archael., cultural resources	0	0	0	0	0	0	0	0	No adverse impacts
Aesthetics	xS	0	XL	xL	xL	xL	xS	xL	1,7. Temporary adverse impact during construction and during drawdown; all other impacts positive
Ambient air quality	xS	0	xL	0	0	xL	0	0	1. Temporary increase in dust during construction; 3,6. Improvement in air quality; less dust.
Noise levels	xS	0	xL	xS	0	0	0	xS	1,4,8. Temporary adverse impact during construction/operation; 3. Long term benefit
Odors	0	0	xL	xS	0	0	xS	0	3. Positive long-term benefit; 4. Temporary impacts during construction; 7. Temporary adverse impact possible.
Long range increase in energy demand	xL	xS	xL	0	0	xL	0	0	1. Pumping sewage; 2. Pumping/hauling septage; 3. Increased transportation to new site; 6. Increased use of cleaning and hauling equipment.
Floodplain develop. & effects on flood.	0	0	0	xL	XL	xL	XL	0	4. Minor reduction in flooding; 5. Continued flood protection; 6. Minor flood protection; 7. Increased flood protection during drawdown
Wetlands	0	0	XL	xL	XL	0	xS	xS	3. Long term benefit to downstream wetland; 4. Increased diversity, replacement of one wetland type by another; 5. maximum protection; 7. periodic lowering of water table in uncontrolled shoreline wetlands; 8. maintenance
Public water supplies	0	0	0	0	0	0	0	0	No adverse impacts.
Private water supplies	0	0	0	0	0	0	0	0	No adverse impacts.
Potential increase sediment.	0	0	0	xL	0	xL	0	xS	4. Decreased sediment transport to Lake; 8. Temporary minor disturbance of substrate possible
Com./ind. disruption	0	0	0	0	0	0	0	0	No adverse impacts
Water quality	XL	xS	xL	xL	xL	xL	XL	xS	Major/minor long and short term improvements in Lake water quality; 1,7. Minor adverse impacts to downstream water quality

0 = No adverse impact
X = Major impact
x = Minor impact
L = Long-term or continuous impact
S = Short-term impact

conservation commissions, but would not be subject to as rigorous a review as the dike or pond construction.

Under the new regulations, "...loss of up to 5,000 square feet of bordering vegetated wetland..." (as is found along the stream in question) may be allowed per filing. Should the proposed filling associated with the project result in 5,000 square feet of lost wetland area, multiple filings would be required.

State Permits

The Massachusetts Environmental Policy Act (MGL, Ch.30, ss 62-62H) "...requires review and evaluation of projects so as to describe environmental impact and further requires that agencies find that all feasible means and measures will be used to avoid or minimize damage to the environment." Certain projects are required to submit an Environmental Notification Form (ENF) and possibly a full Environmental Impact Report (EIR) following a review of the ENF. At minimum the fililng of an ENF will be required for the recommended wetland enhancement work. Once final design of the dikes and other structures which might be construed as "impoundments," are finalized, notification to the Division of Waterways is recommended. This state agency may require submission of a filing under Chapter 91.

Under Ch.131, s.48, written notice must be given to the director of the Division of Fisheries and Wildlilfe ten days prior to drawdown of any body of water. The purpose of this section is to allow salvage of any fish within a pond which is to be completely drained. Though this would not be the case at Lake Massapoag, notification to DFW prior to drawdown would be a recommended practice.

Federal Permits

Under section 404 of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500), the U.S. Army Corps of Engineers is required to review, regulate and grant permits for the removal or placement of dredged or fill material. Regulations which clarify the Corps responsibility have expanded its authority to include consideration and protection of all wetland values. Although the Corps may, it appears, become involved in almost any proposed alteration of a wetland, it has limited its involvement to dredge and fill projects or those which are of particular significance. Its policy has been to avoid involvement in routine wetland filings which may be adequately handled by local and state review. Notification to the Corps should be made, however, during the final design phase.

The Federal Emergency Management Agency (FEMA) is responsible for administering the National Flood Insurance Program. As a part of the minimum standards of the Program, adjacent communities and the state coordinating office must be notified and given opportunity to comment on any proposed changes in upstream flow and storage conditions. The Massachusetts Division of Water Resources, the state coordinating agency, should be notified of proposed plans during the final design phase.

Review of the project by federal, state and, regional agencies may also be provided through the A-95 review process. Under this process the project is reviewed for consistency with other ongoing programs. Copies of the federal grant application must be submitted to the regional (Central Massachusetts Regional Planning Commission) and state (Executive Office of Communities and Development) clearinghouse for their review.

Further review may also occur through federal interagency working memoranda of understanding and more formal arrangements wherein project proposals are distributed to a number of agencies for their consideration. Results of these collective reviews would be contained within EPA comments and/or grant conditions, should further federal funding be awarded.

8.4 Project Schedule and Monitoring Program

The extent to which the recommendations contained in this report are implemented will be dependent upon voter approval of funds by the residents of Sharon and continued availability of matching funds through state and federal programs. In order to qualify for federal and state funding for implementation of the sewage disposal measures recommended, Step 1 facilities planning needs to be carried out. This step should also examine long-range septage disposal alternatives; and the feasibility of a septic system inspection maintenance progrm in the remainder of the Lake Massapoag watershed, as well as sewage disposal problem areas throughout the Town. Steps 2 and 3 of the program would consist of engineering design and construction. A 1988 target date for project completion is estimatd, if the process begins immediately. Implementation of the interim septic system I/M program should begin with a request for funding of eligible items through the Chapter 628 Clean Lakes program; and town meeting action on suggested bylaws.

It is recommended that funding be sought through the state's Chapter 628 Clean Lakes Program for implementation of the wetland enhancement projects. The application deadline is October 1, 1983, for 1984 funding. If funding for both design and construction is sought this year, the project could be completed by the end of 1984. Preservation of wetland areas through Town aquirement can be funded under one of the programs, such as the Self Help or Land-Water Conservation Fund, administered by the Massachusetts Division of Conservation Services.

Landfill closure is an ongoing Town project, and should continue regardless of the Lake Massapoag study. Final closure by April 1985 has been specified.

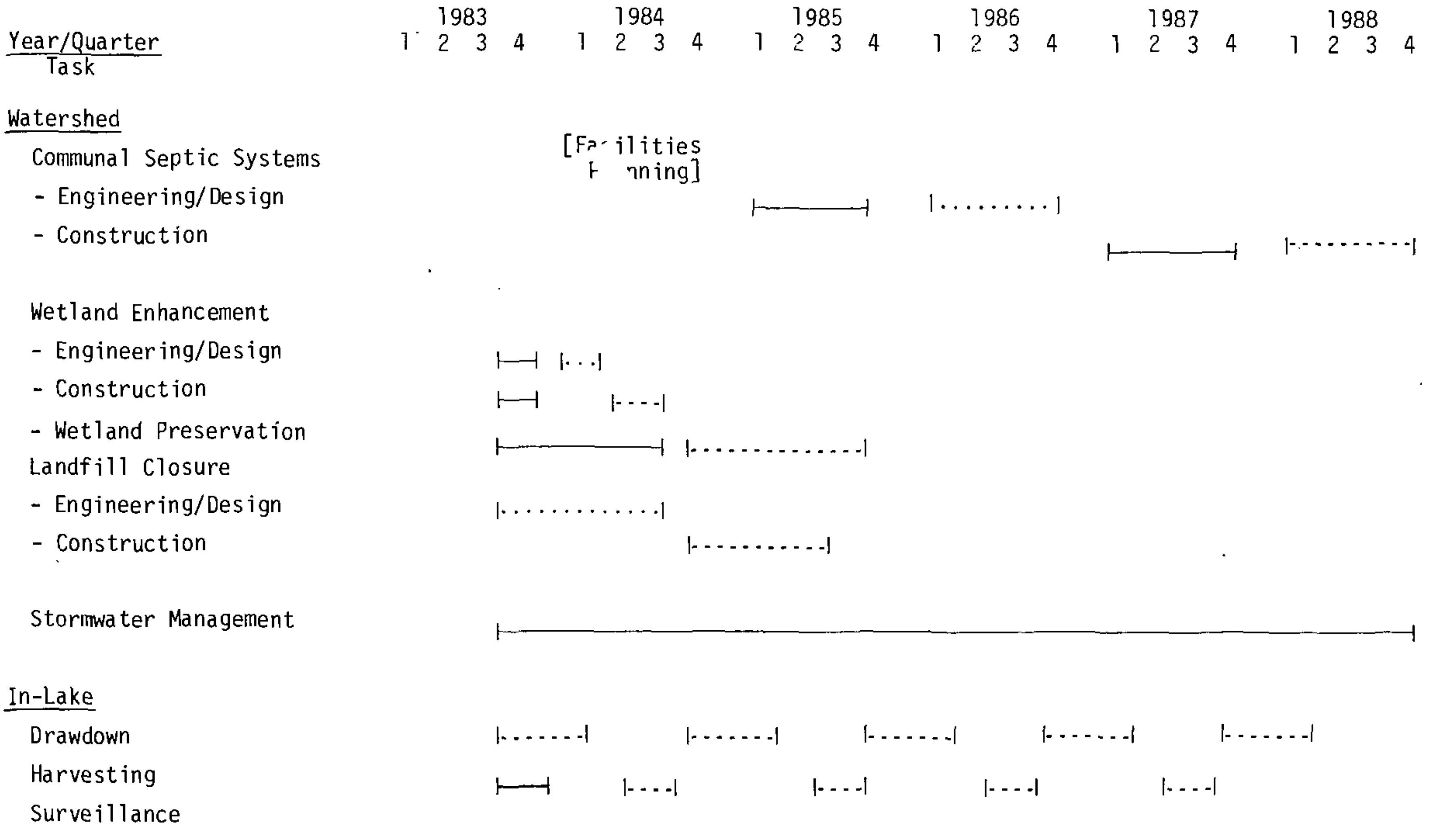
Stormwater management recommendations consist primarily of best management practices. Estimated project costs include an estimated annual O&M cost for additional Town work in the watershed (street sweeping, catchbasin cleaning and curbside leaf/brush pick-up). The implementation of the best management practices recommended in this report should be carried out through a Lake or watershed association. Such a group should be initiated this spring, as interest in outdoor recreational activities picks up.

Drawdown has been an historical management practice at Lake Massapoag. Continuing drawdown has been recommended, and should be implemented again this fall. Outflow during drawdown is limited by sizing of downstream culverts and pond outlets; and maintenance of the channel is a key consideration in implementing drawdown. No funding sources are known to be available for this type of ongoing maintenance. Funding for erection and calibration of a staff gage at the outlet, for mitigation of downstream environmental impacts, should be sought through the Chapter 628 program. It is recommended that shorefront residents be encouraged to remove weeds from exposed shoreline areas in conjunction with this year's drawdown, by means of a public awareness program, and well publicized Town pick-up of collected weeds.

Mechanical harvesting is recommended for the 1984 growing season. Matching funds for contracted harvesting are available through the state program, and should be sought by October 1983 for 1984 implementation. See Table 32.

In order to evaluate the impact of both ongoing and newly implemented Lake water quality improvement measures, a complete monitoring program is necessary. It is recommended that such a program include water quality sampling at the major inlets (7 and 13), the outlet, and the in-lake station on a monthly basis during the spring and summer, and twice during theremainder of the year. Algae sampling in lakes should be conducted at the same time, along with flow measurements of the two major inlets and the outlet. An annual macrophyton survey should be conducted during July or August. Additional water quality sampling should be conducted immediately downstream of the landfill on a quarterly basis, until three years after closure. Sampling upstream of the existing pond at Inlet 13, and upstream of the recommended pond after its construction, should be conducted quarterly to allow an assessment of their water quality functions. See Table 33 for a summary of the recommended monitoring program.

TABLE 32. SUGGESTED PROJECT IMPLEMENTATION SCHEDULE



|———| Grant application submittal, review, award, procure local match.

|. . . . .| Final engineering design work.

|- - - - - - - - - -| Implementation/construction.

TABLE 33: SUGGESTED MONITORING PROGRAM[1]

Year/Quarter	1984				1985				1986				1987			
Task	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Water Quality:																
Inlets (storm drains)		├─┤	├─┤	x	x	├─┤	├─┤	x	x	├─┤	├─┤	x	x	x	x	x
Outlet		├─┤	├─┤	x	x	├─┤	├─┤	x	x	├─┤	├─┤	x	x	x	x	x
In-lake		├─┤	├─┤	x	x	├─┤	├─┤	x	x	├─┤	├─┤	x	x	x	x	x
Sucker Brook at Mountain Street	x	├─┤ x	├─┤ x	x	x	├─┤ x	├─┤ x	x	x	├─┤ x	├─┤ x	x	x	x	x	x
Upstream of Proposed/ Existing Ponds	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Biologic:																
Plankton/Transparency		├─┤	├─┤	x	x	├─┤	├─┤	x	x	├─┤	├─┤	x	x	x	x	x
Macrophyton		├─┤	├─┤ x			├─┤	├─┤ x			├─┤	├─┤ x				x	
Hydrologic:																
(flows)		├─┤	├─┤	x	x	├─┤	x		x	├─┤	├─┤	x	x	x	x	x

x - denotes single sampling/monitoring round or event

├──────┤ - denotes monthly sampling/monitoring round or event

[1]Depending upon implementation date of communal septic systems, program should be extended in time.

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APPENDICES

A. Public Participation and Comments

B. Required Governmental Permits

C. Septic Leachate Detector Survey Results

D. The Effects of Landfill Leachate on Stream Water Quality

E. Recommended Septic System Maintenance Program

F. *Informational Material on Septic Systems*

- What is a Septic System?
- An Owner's Manual for Maintaining A Septic System

Appendix A. Public Participation and Comments

PUBLIC PARTICIPATION

During the course of the study, there has been much review, guidance and direction provided by the Lake Study Committee, particularly Chairman Walter Newman. This process was initiated following the August 8, 1981 letter from the Committee to IEP, indicating acceptance of the IEP proposal. From that time until January 5, 1982, when the Contract was formally signed, numerous telephone conversations and meetings were held with Committee members and/or Joan Beskenis (MDWPC) in order to refine and clarify the project scope. One of these meetings (11/18/81) included a half day session at Town Hall, meeting local officials and learning their perspective of Lake Massapoag, its history and future. That afternoon session was followed by an evening meeting with the Lake Study Committee as well as interested citizens in order to review anticipated scope and findings of the study to date.

On two subsequent occasions, public meetings were held. These included an October 26, 1982 presentation and question and answer session where the preliminary findings of the diagnostic portion of the study were presented and possible in-lake and watershed management measures discussed. Sampling results, hydrologic and nutrient budgets were reviewed in some detail. Approximately 40 people were in attendance at the meeting.

On November 11, 1983, preliminary recommendations of the feasibility portion of the study were presented. These included in-lake as well as watershed management strategies designed to address existing or potential nutrient contributions to Lake Massapoag. Approximately 25 people were in attendance at this meeting.

In the case of both the October 26, 1982 and the November 22, 1983 meetings, draft written reports were subsequently released for public comment. Comments submitted in writing are attached. Numerous questions were addressed at the meetings or in follow-up revisions to the report. This volume includes past revisions as well as those addressing final comments made at the November 22, 1983 public meeting and in subsequent correspondence.

Comments by Ron Gordon
on Lake Massapoag Drafts

6-21-82

WALTER,

HERE ARE MY COMMENTS ON SECTIONS 2.2, 2.4, 2.5 & 3.6.

2.2 Very interesting reading. However, there's not much description related to the purpose listed in the first paragraph "... to determine their influence on watershed hydrologic characteristics ...."

NITS

¶ 1, p 1 "itself" should be plural

¶ 3, p 2 "farily" should be fairly

¶ 4, p 3 I've always seen ~350 acres shown for the Lake, where does 401 acres come from?

2.4 I would think that a classification of "swamp" (or the correct term) should be included. Seems to me that the Great Cedar Swamp, the swamp behind the Community Center and the swamp adjacent to Kiddie Camp are as important (and have as much effect) as, say "agricultural".

2.5 I strenuously object to the third paragraph under the "Bathymetry" heading. It states "... abandoned mine shafts that exist throughout the Lake's bottom." No ~~[illegible]~~ evidence exists to support this statement. Bog iron was obtained by "tonging" from the surface in boats. In all of the diving I did (and continue to do), no "mine shafts" have been found or areas deeper than the one 45' depression. This paragraph should be re-written to be factual.

3.6 ¶3, p.3 I'd like to see some expansion to "Nitella is regarded as one of the most advantageous and ....". It would be worthwhile knowing the reasons why.

Ron [signature]

The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
Department of Environmental Quality Engineering
Division of Water Pollution Control
Technical Services Branch
Westview Building, Lyman School
Westborough, MA 01581

ANTHONY D. CORTESE, Sc. D.
Commissioner

September 23, 1982

Michael Beck
IEP, Inc.
534 Boston Post Road
Wayland, MA 01778

Dear Mike:

I have received a completed copy of the first Progress Report on Lake Massapoag and was very pleased with the results. I am including for your review my comments on these draft sections which are mostly editorial in nature.

2.4 Land Use

page 2 - The lake's use has consequently, increased with two large public beaches... - unnecessary first comma

2.5 Morphometry, Bathymetry and Bottom Sediment Types

page 1 - last paragraph - In many of the values mentioned above, the lake approximates that of a standard measurement. This term is unclear.

page 2 - Massapoag Lake Morphometric Data should read Lake Massapoag Morphometric Data

page 3 - first paragraph - ... St. Francis Retreat Lodge which was acquired....

page 5 - Bottom sediment types - I could not distinguish the symbols on the map for rocks usually submerged from rocks usually exposed.

3.6 Aquatic Vegetation and Plankton

page 1 - Combine paragraphs 2 and 3, they seem redundant at present.

para. 5 - The MDWPC has assigned a trophic status of mesotrophic, or intermediate, to Lake Massapoag. I would suggest that either a statement be included as to how DWPC incorporated aquatic vegetation into this trophic status or include this statement in another section.

page 3 - paragraph 2 - Sediment sampling revealed that water milfoil inhabits primarily sand and gravel substrates. Where is this at Lake Massapoag or in general?

3.61 Phytoplankton, Transparency and Chlorophyll a

page 1 - para. 4 - Chlorophyll a has a direct relationship with phytoplankton densities.... an often close relationship exist between chlorophyll a and phytoplankton densities but the real relationship is chlorophyll a with cell volume not cell count.

page 2 - I suggest that some rewriting be done here. One possibility is: Asterionella, which produces a fishy odor when present in large numbers (Palmer, 1977), was at its peak from April to mid-June 1981. It then declined and was not observed again until March 1982 and at that time in very low densities. Synedra followed a similar trend. This diatom...... Other diatoms such as Navicula and Fragilaria were found in lesser densities at various intervals throughout the monitoring period.

page 3 - Table - Summary of Plankton analysis - What are the units of this table?

Under green algae the spelling should be Phytoconis. I couldn't find Stochoccoccus in our keys. Is this a typo?

General Comments

I would like to see the methodology used in obtaining the data. Possibly this will be covered in Section 1, the Introduction. If not, then I would like to know the type of chlorophyll a extraction used and the method used for algal counts. Under land use, I would like to know where the land use types were obtained. Under aquatic vegetation, I would like to know how the abundance of species was determined.

Sincerely,

Joan Beskenis

Joan Beskenis
Bio-Chemist

JB/dg

November 9, 1983

Lake Study Committee
Town Hall
Sharon, Massachusetts 02067

Attention: Mr. Walter Newman, Chairman

Dear Committee Members:

I have had the occasion to review IEP's draft report of 27 September 1983 entitled "Diagnostic/Feasibility Study. Lake Massapoag, Sharon, Massachusetts". As a result, I have the following comments/questions/concerns to communicate to the Committee. While I have all intention of attending the public meeting at the library on November 22nd, there is a possibility I will be out of town and hence am using this letter as a substitute.

1. Chapter 6, Section 6.1.1., on Zoning implies cluster development in the best interest of the lake in minimizing disturbances to the lake. While the positive reasons given are generally valid, at least two important negative aspects of cluster development are not covered: (1) phosphorous loading to the lake is likely to at least double because of the doubling of dwelling units in the cluster development (as compared to 80,000 sq. ft. lots), and (2) the intensification in location of septic systems (as compared to 80,000 sq. ft. lots) will likely decrease the uptake of phosphorous on the way to the lake. Additionally, a cluster development with a lake view, say off Morse Street, would be particularly disturbing to the lake.

2. Chapter 6, Section 6.2.1, Municipal Sewerage, implies the Town has the possibility of joining the MDC as a member community. This is most unlikely under the present circumstances since the MDC is under court scrutiny to decrease pollution to Boston Harbor and is basically locked out from adding to the situation.

3. Closure of the Sanitary Landfill. The Lake Management Committee report in the 1982 Sharon Annual Town Report (pp. 88-89) recommended that the Town Landfill be closed. This and the Committee's public meetings on the earlier IEP reports, seemed to trigger the citizen petition (by Foreman) to the 1983 Annual Town Meeting to close the Town Landfill. Section 6.3 of the present IEP report estimates the annual contribution of phosphorous to the lake to be only 7 kilograms, an amount that "appears rather insignificant when compared to the total computed annual loadings of

of 312 Kg/year to 617 Kg/year". Town Engineer , William Dowdell, at the last meeting of the Landfill Closure Committee, estimated the capital expenditures related to closure (quite apart from the increased annual expense of disposal) to be about $0.5 million. Thus, the cost effectiveness of this proposal (landfill closure) is about $67,200/Kg of phosphorous removed annually. To put this alternative into proper perspective, it should be included in the first table in the current report (the one in Section 6.2). Reference to this table indicates landfill closure as being the least cost-effective (quite expensive for little gain) of any alternative considered. On this basis, the Town's recent application to the State for grant funding, under the Clean Lakes Program, for assistance with engineering related to landfill closure might not get strong consideration. Perhaps, it can get amended and something else substituted (such as a sanitary survey to track septic system leachate making its way to the lake).

4. Chapter 6, Section 6.2.1, Municipal Sewerage. To put this alternative into perspective, the capital cost per home (based on 110 homes) is nearly $90,000 per home. At this price,one could nearly buy up the homes and relocate the people.

5. The IEP report indicates only 10 detectable plumes were found within the lake during this project. Where were the 10 located? Were they within the recommended communal septic systems zones 1, 2, 9 and 10? Is the fact that only 10 were found significant? Is this an indicator that the phosphorous contributions from lakeside homes might be over-estimated at the present time ?

6. Chapter 7.0, Section 7.1.1, Drawdown. I am increasingly distressed on the amount of effort the Town has spent on lake drawdown considerations, all without consideration of downstream effects. Further, algal blooms in the lake, the primary complaint of the public due to odors, is probably more related to the hydrological cycle (less rain in a year, more liklihood of blooms) than any other immediate management practice. What present control of the lake does do is ruin Massapoag Brook and the distributed ponds (at least four of them) along its length within the Town of Sharon. The State still stocks (one wonders why, or how long they will continue) this brook with trout from the lake outlet to where it crosses North Main Street. Where the ponds were eutrophic prior to 1976 (initiation of Lake Massapoag control), they have become a "real mess" since. Brush now grows in the dried up brooks (at certain times of the year) and the trout are almost forced to crawl on their bellies in the shallow streams. Certainly, the Town can do better in its management of all of its water resources.

7. It appears one of the primary recommendations of the IEP report is for communal septic systems along the northern portion of the lake. To possibly serve 106 homes, it would appear that more than Massapoag Avenue, Beach Street and Beach Road would have to be sewered. Are we talking about all or parts of the following streets: Greenhouse, Cedar, Harding, Lake Ave., East Foxboro, East Massapoag St., Arbor Dr., Franklin Rd., Vine St., Highland Ave.? It is difficult to appraise the estimated construction and maintenance costs without knowing more about the extent of the intended sewering.

   Are pressurized sewers intended for the whole extent? This concept entails storage at each home (say two 55 gallon drums), sewage grinders, and individual home sewage pumps. Will the householders buy such a concept with their owning and maintaining such household equipment? How do you "persuade" the residents to connect to the system? Without failed on-lot systems per "Title 5", there is no "muscle" to do so (phosphorous leaching into the lake via groundwater is not a "failed system" and hence the Board of Health can not force a connection).

   The IEP report indicates that to begin to be considered for any Federal/State aid under the Federal Wastewater Construction Grants Program, a Step I Facilities plan must be completed. That is correct. What needs to be emphasized , however, is that the study requirements for such consideration will require a look at sewering the whole Town, and a look at septage disposal for that part determined not worthy of sewering. Funding, for the present grant program is not likely to be 93% - rather, it is unlikely that much of IEP's proposed program could be constructed with federal money (presently reserved for major interceptor sewers and treatment plants). The construction program might qualify for State money (50%) under Chapter 557, but is likely to be pretty far down the priority list. To begin to qualify will require extensive hydrogeolic studies for subsurface sewage disposal systems.

If there are any questions relative to the above, I will be available after November 28th, and would be glad to meet with the Committee.

Sincerely yours,

Thomas F. Cheyer (Tel. 784-7972)
1 Glenview Road
Sharon, MA. 02067

cc: Board of Selectmen
Conservation Commission
Planning Board
Warrant Committee
Landfill Closure Committee
Town Engineer

ANTHONY D. CORTESE, Sc. D.
Commissioner

The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
Department of Environmental Quality Engineering
Division of Water Pollution Control
Technical Services Branch
Westview Building, Lyman School
Westborough, MA 01581

November 29, 1983

Mr. Walter Newman
Lake Management Committee
175 Bay Road
Sharon, Mass. 02067

Dear Walter:

The consulting firm for the Lake Massapoag project, I.E.P., Inc., informally requested that the Division of Water Pollution Control, Technical Services Branch, review and comment on the draft feasibility report they issued for the town of Sharon. I have enclosed the review comments from personnel at DWPC on this report.

In reviewing the Lake Massapoag draft feasibility report, I noted that there were areas described in the Substate Agreement which still remain to be completed. Therefore, I have included for your consideration a list of what I perceive as unfinished tasks in the Substate Agreement.

If you have any questions or comments, please contact me.

Sincerely,

Joan L Beskenis

Joan L. Beskenis
Biochemist

JLB/lp
Enclosures
cc: J. Ackerman, I.E.P., Inc.
A. Cooperman, DWPC
E. Chesebrough, DWPC
M. Ackerman, DWPC

Specific Comments Relative to the Draft Feasibility Report

In Table Relative Costs and Cost Effectiveness of Various Alternatives are the construction costs for the sewer extension in 1976 dollars? They should be annualized assuming that the rest of the items are current values.

Land Use

1) There are inconsistencies in the developed argument. In this section use of non-phosphate detergents is described as "advisable but not essential." However, page 80 of the Lake Massapoag Diagnostic Report describes a major drop in the average loading factor for phosphorus from 1.6 kg/yr if a person uses phosphate detergents to 0.5 if non-phosphate detergents are used. An educational compaign should be delineated to get more than 50% of the people using non-phosphate detergents and thus reduce the loading of phosphorus to the pond.

2) How much timber is being harvested annually from the watershed? Are there many large land owners and could they be personally contacted to discuss their land use practices? What year was the forested area measured?

Best Management Practices

1) Best Management Practices (BMP) may be "highly recommended," but implementation is not adequately developed in this report. A BMP plan should be included with specific recommendations for an educational program, designed both for watershed residents and town of Sharon residents. The plan should include costs, media approach, etc.

2) Include more description of costs and benefits of vacuum sweepers over mechanical sweepers, include capital and operations and maintenance costs, and propose a schedule for sweeper use which could have an effect on water quality. One reference which may be useful to you is Greeley and Hanson, 1977, Preventative and Corrective Measures of Urban Stormwater Pollution. They describe the ability of vacuum-type street cleaners to pick up the fine particles present on the streets which contribute "one-half of the algal nutrients present in the solids loading from streets."

3) Further description of what an adequate "regular" catch basin cleaning schedule should be made.

4) Town sponsored leaf pickup is advisable, but suitable sites for depositing this material outside of the watershed should be described. (See Philip Kerr report--Growth, Design and Water Quality done by M.I.T. students on the Lake Massapoag watershed.)

Wetland Management

6.5 In this section it is stated that the Sucker Brook wetland between the landfill and the lake should be preserved. A plan should be proposed to purchase or attain a conservation easement on this land.

Wetland Enhancement

In Section 8.2.3, how should the existing wetland area by Inlet 13 be protected so that it will maintain the existing function of pollution prevention?

Proposed Pond--Provisions should be made for removing muck soils and vegetation before area is filled.

Lake Massapoag--Substate Agreement

Still to be Completed

1) Presentation of preliminary engineering drawings and specifications of the recommended alternative.

2) Discussion of the particular benefits and new public water uses expected to result from implementation of this project.

3) Phase II monitoring program and water quality sampling schedule.

4) Description of the relationship of the proposed project to other pollution control programs.

5) Summary of public participation in developing and assessing the project.

6) Copies of all permits.

7) Environmental Evaluation (as described in 40 C.F.R. Part 35, Sub-part H--Appendix A) for the recommended alternatives.

Environmental Assessment

Section 8.2.1 Improved Sewage Disposal

1) Although perhaps taking up reserved capacity in the high school system, the Zone 1 discharge would occur during the summer months. What would be the effect on Massapoag Brook if this tie-in was allowed?

2) What would be the effect on ground water quality from the proposed communal system, particularly the system for Zones 9 and 10?

Section 8.2.2 Drawdown

1) What effects will changes in the drawdown plan have on Massapoag Brook and the lower ponds?

Section 8.2.3 Wetland Enhancement

1) Because the proposed pond would only have a mean depth of 2.5 feet, a permanent population of fish in it is unlikely. The proposed outlet structure would also block the passage of fish from the lake; thus, without an important mosquito predator, a strong possibility exists that this area will be a breeding ground for mosquitoes. What modifications should be considered now to reduce this possibility and what adverse effects would the modifications have?

2) What water quality effects is the proposed pond likely to have on the lake? It is possible that the enhanced wetland (or pond) will function seasonally in removing nutrients and then discharge them after plant die-off (as described in the DWPC-Research and Demonstration Report: Executive Summary-Feasibility Study of Wetland Disposal of Wastewater Treatment Plant Effluent, I.E.P., 1979).

TOWN OF SHARON

MASSACHUSETTS 02067

December 13, 1983

Mike Beck
IEP, Inc.
Northboro, Massachusetts 01532

Dear Mike:

The following are the comments of the Lake Management Committee on the draft diagnostic/feasibility study:

1. Past discussions,reviews and comments from us have indicated the need to draw conclusions on the various aspects of the diagnostic study. That has not been completed to date and must be developed prior to final publication. As an example, numerous past ecological studies have been done on the Lake(FWPCA, 1970; DWPC, several summer snapshots thereafter). These studies provided an ecological baseline. The investigations IEP conducted should be compared with the past studies to provide an ecological continuum. Bottom-line findings, and conclusions on the biology, chemistry, geology, stormwater sampling etc. of the lake and lake watershed should be developed.

2. Section 6.1.1 suggests a Lake front district which would impose restrictions on "the use of non phosphate detergents, minimal lawn fertilization and the like." The report further states "However in view of the extent of development around the Lake, this recommendation must be viewed as advisable but not essential in significantly reducing nutrient loadings." Since other portions of the report stress that the major nutrient input to the Lake is from subsurface disposal and non-point source runoff we would assume that use of non-phosphate detergents and limiting fertilizer use would be major components of a program for preservation of the Lake. In addition, the report acknowledges the difficulties of implementing the proposed sewerage program which further reinforces the importance of non-phosphate detergents.

3. Limiting fertilizer use and non-phosphate detergents whould be set forth in the report as major remedial measures. A continuing public education program should be detailed in the report to achieve this objective.

4. Section 6.3 should further define the impacts and potential or possible impacts of the landfill in the Lake. i.e. micro-nutrients, hazardous wastes etc. Also the wetlands downstream of the landfill should be referenced relating to leachate impact mitigation.

5. The end of Section 6.4 is truncated

6. Section 6.5, Figure Proposed Wetland Enhancement Project the locus map should be clarified so that the reader clearly understands what area is being enlarged on the map.

7. Weed harvesting has been previously considered for portions of the Lake. We doubt that such a program is necessary or would be effective in view of the dispersed weed population and the variable depth of the weeds.

8. A summary table relating nutrient input reductions to proposed program elements would be most helpful and clarifying.

I am also enclosing comments of a concerned citizen, Mr. Tom Cheyer, who is also a practicing consulting engineer.

If you have any questions please contact me.

Sincerely yours,

Walter M. Newman, Chairman
Lake Management Committee

Appendix B. Required Governmental Permits

Form 3

Commonwealth of Massachusetts

DEQE File No. ______ (To be provided by DEQE)

City/Town ______

Applicant ______

Notice of Intent
Under the
Massachusetts Wetlands Protection Act, G.L. c. 131, §40
and
Application for a Department of the Army Permit

Part I: General Information

1. Location: Street Address ______
   Lot Number ______

2. Project: Type ______ Description ______
   ______
   ______
   ______

3. Registry: County ______ Current Book ______ & Page ______
   Certificate (If Registered Land) ______

4. Applicant ______ Tel. ______
   Address ______

5. Property Owner ______ Tel. ______
   Address ______

6. Representative ______ Tel. ______
   Address ______

7. Have the Conservation Commission and the DEQE Regional Office each been sent, by certified mail or hand delivery, 2 copies of completed Notice of Intent, with supporting plans and documents?
   Yes ☐ No ☐

8. Have all obtainable permits, variances and approvals required by local by-law been obtained?
Yes ☐ No ☐

Obtained:	Applied For:	Not Applied For:

9. Is any portion of the site subject to a Wetlands Restriction Order pursuant to G.L. c. 131, §40A or G.L. c. 130, §105? Yes ☐ No ☐

10. List all plans and supporting documents submitted with this Notice of Intent.

Identifying Number/Letter	Title, Date

11. Check those resource areas within which work is proposed:

(a) ☐ Buffer Zone

(b) Inland:

- ☐ Bank*
- ☐ Bordering Vegetated Wetland*
- ☐ Land Under Water Body & Waterway*

Land Subject to Flooding,

- ☐ Bordering
- ☐ Isolated

(c) Coastal:

- ☐ Land Under the Ocean*
- ☐ Coastal Beach*
- ☐ Barrier Beach
- ☐ Rocky Intertidal Shore*
- ☐ Land Under Salt Pond*
- ☐ Fish Run*
- ☐ Designated Port Area*
- ☐ Coastal Dune
- ☐ Coastal Bank
- ☐ Salt Marsh*
- ☐ *Land Containing Shellfish**

* Likely to involve U.S. Army Corps of Engineers concurrent jurisdiction. See General Instructions for Completing Notice of Intent.

Part II: Site Description

Indicate which of the following information has been provided (on a plan, in narrative description or calculations) to clearly, completely and accurately describe existing site conditions.

Identifying Number/Letter (of plan, narrative or calculations)

Natural Features:

__________ *Soils*

__________ Vegetation

__________ Topography

__________ Open water bodies (including ponds and lakes)

__________ Flowing water bodies (including streams and rivers)

__________ Public and private surface water and ground water supplies on or within 100 feet of site

__________ *Maximum annual ground water elevations with dates and location of test*

__________ Boundaries of resource areas checked under Part I, item 11 above

__________ Other

Man-made Features:

__________ Structures (such as buildings, piers, towers and headwalls)

__________ Drainage and flood control facilities at the site and immediately off the site, including culverts and open channels (with inverts), dams and dikes

__________ Subsurface sewage disposal systems

__________ Underground utilities

__________ Roadways and parking areas

__________ Property boundaries, easements and rights-of-way

__________ Other

Part III: Work Description

Indicate which of the following information has been provided (on a plan, in narrative description or calculations) to clearly, completely and accurately describe work proposed within each of the resource areas checked in Part I, item 11 above.

Identifying Number/Letter (of plan, narrative or calculations)

Planview and Cross Section of:

__________ Structures (such as buildings, piers, towers and headwalls)

__________ Drainage and flood control facilities, including culverts and open channels (with inverts), dams and dikes

__________ *Subsurface sewage disposal systems & underground utilities*

__________ Filling, dredging and excavating, indicating volume and composition of material

__________ Compensatory storage areas, where required in accordance with Part III, Section 10:57 (4) of the regulations

__________ Other

Point Source Discharge

__________ Description of characteristics of discharge from point source (both closed and open channel), when point of discharge falls within resource area checked under Part I, item 11 above, as supported by standard engineering calculations, data and plans, including but not limited to the following:

1. Delineation of the drainage area contributing to the point of discharge;
2. Pre- and post-development peak run-off from the drainage area, at the point of discharge, for at least the 10-year and 100-year frequency storm;
3. Pre- and post-development rate of infiltration contributing to the resource area checked under Part I, item 11 above;
4. Estimated water quality characteristics of pre- and post-development run-off at the point of discharge.

Part IV: Mitigating Measures

1. Clearly, completely and accurately describe, with reference to supporting plans and calculations where necessary:
   (a) All measures and designs proposed to meet the performance standards set forth under each resource area specified in Part II or Part III of the regulations; or
   (b) why the presumptions set forth under each resource area specified in Part II or Part III of the regulations do not apply.

☐ Coastal ☐ Inland Resource Area Type:	Identifying number or letter of support documents

☐ Coastal ☐ Inland Resource Area Type:	Identifying number or letter of support documents

☐ Coastal ☐ Inland Resource Area Type:	Identifying number or letter of support documents

2. *Clearly, completely and accurately describe, with reference to supporting plans and calculations where necessary:*

   (a) all measures and designs to regulate work within the Buffer Zone so as to insure that said work does not alter an area specified in Part I, Section 10.02(1) (a) of these regulations; or

   (b) if work in the Buffer Zone will alter such an area, all measures and designs proposed to meet the performance standards established for the adjacent resource area specified in Part II or Part III of these regulations.

☐ Coastal ☐ Inland Resource Area Type Bordered By 100-Foot Discretionary Zone:	Identifying number or letter of support documents

Part V: Additional Information for a Department of the Army Permit

1. COE Application No.__________________ 2.______________________________
   (to be provided by COE) (Name of waterway)

3. Names and addresses of property owners adjoining your property:

4. Document other project alternatives (i.e., other locations and/or construction methods, particularly those that would eliminate the discharge of dredged or fill material into waters or wetlands).

5. 8½" x 11" drawings in planview and cross-section, showing the resource area and the proposed activity within the resource area. Drawings must be to scale and should be clear enough for photocopying.

Certification is required from the Division of Water Pollution Control before the Federal permit can be issued. Certification may be obtained by contacting the Division of Water Pollution Control, 1 Winter Street, Boston, Massachusetts 02108.

Where the activity will take place within the area under the Massachusetts approved Coastal Zone Management Program, the applicant certifies that his proposed activity complies with and will be conducted in a manner that is consistent with the approved program.

Information provided will be used in evaluating the application for a permit and is made a matter of public record through issuance of a public notice. Disclosure of this information is voluntary; however if necessary information is not provided, the application cannot be processed nor can a permit be issued.

I hereby certify under the pains and penalties of perjury that the foregoing Notice of Intent and accompanying plans, documents and supporting data are true and complete, to the best of my knowledge.

____________________________________ ________________
Signature of Applicant Date

____________________________________ ________________
Signature of Applicant's Representative Date

NED FORM 100 (TEST)
1 MAY 82

"Exception to ENG Form 4345 approved by HQUSACE, 6 May 1982".

"This document contains a joint Department of the Army and State of Massachusetts application for a permit to obtain permission to perform activities in United States waters. The Office of Management and Budget (OMB) has approved those questions required by the US Army Corps of Engineers. OMB Number 0702-0036 and expiration date of 30 September 1983 applies". This statement will be set in 6 point type.

10.20: Severability.

(1) If any provision of these regulations (301 CMR 10.00 through 10.99) or the application thereof is held to be invalid by a court of competent jurisdiction, such invalidity shall not affect other provisions or the application of any part of these regulations not specifically held invalid, and to this end the provisions of these regulations thereof are declared to be severable.

(301 CMR 10.21 through 10.29: Reserved)

10.30: Appendix A - Environmental Notification Form

ENVIRONMENTAL NOTIFICATION FORM

I. SUMMARY

A. Project Identification

1. Project Name ____________________

____

2. Project Proponent ____________________

Address ____________________

B. Project Description: (City/Town(s) ____________________

1. Location within city/town or street address ____________________

____

2. Est. Commencement Date: ____________ Est. Completion Date: ____________

Approx. Cost $ ____________ Current Status of Project Design: ______% Complete

C. Narrative Summary of Project

Describe project and give a description of the general project boundaries and the present use of the project area. (If necessary, use back of this page to complete summary).

Copies of this may be obtained from:

Name: ____________________ Firm/Agency: ____________________

Address: ____________________ Phone No. ____________________

1979 · THIS IS AN IMPORTANT NOTICE. COMMENT PERIOD IS LIMITED.

For information, call (617) 727-5830

P. 2

Use This Page to Complete Narrative, if necessary.

This project is one which is categorically included and therefore automatically requires preparation of an Environmental Impact Report: YES_________ NO_________

Scoping (Complete Sections II and III first, before completing this section.)

1. Check those areas which would be important to examine in the event that an EIR is required for this project. This information is important so that significant areas of concern can be identified as early as possible, in order to expedite analysis and review.

	Construction Impacts	Long-Term Impacts		Construction Impacts	Long-Term Impacts
...ace & Recreation	______	______	Mineral Resources	______	______
...al.....................	______	______	Energy Use	______	______
...iogical	______	______	Water Supply & Use............	______	______
...s & Wildlife	______	______	Water Pollution	______	______
...on, Trees	______	______	Air Pollution................	______	______
...ological Systems	______	______	Noise	______	______
...etlands................	______	______	Traffic......................	______	______
...Wetlands or Beaches	______	______	Solid Waste	______	______
...zard Areas.............	______	______	Aesthetics	______	______
...ds, Hazardous Substances,			Wind and Shadow	______	______
...n Risk Operations.......	______	______	Growth Impacts...............	______	______
...ally Unstable Areas.....	______	______	Community/Housing and the Built		
...ural Land	______	______	Environment..............	______	______
...pecify)________________________			....	______	______

2. List the alternatives which you would consider to be feasible in the event an EIR is required.

E. Has this project been filed with EOEA before? Yes _____ No _____
If Yes, EOEA No. __________ EOEA Action? ______________________________

F. Does this project fall under the jurisdiction of NEPA? Yes _____ No _____
If Yes, which Federal Agency? ____________________ NEPA Status? ______________

G. List the State or Federal agencies from which permits will be sought:

Agency Name	Type of Permit

H. Will an Order of Conditions be required under the provisions of the Wetlands Protection Act (Chap. 131, Section 40)?
Yes _____ No _____
DEQE File No., if applicable: __________

I. List the agencies from which the proponent will seek financial assistance for this project:

Agency Name	Funding Amount

II. PROJECT DESCRIPTION

A. Include an original 8½ x 11 inch or larger section of the most recent U.S.G.S. 1:24,000 scale topographic map with the project area location and boundaries clearly shown. Include multiple maps if necessary for large projects. Include other maps, diagrams or aerial photos if the project cannot be clearly shown at U.S.G.S. scale. If available, attach a plan sketch of the proposed project.

B. State total area of project: ______________________________
Estimate the number of acres (to the nearest 1/10 acre) directly affected that are currently:

1. Developed .... ____ acres
2. Open Space/Woodlands/Recreation ____ acres
3. Wetlands .... ____ acres
4. Floodplain .... ____ acres
5. Coastal Area .... ____ acres
6. Productive Resources
   Agriculture .... ____ acres
   Forestry .... ____ acres
   Mineral Products .... ____ acres

C. Provide the following dimensions, if applicable:
Length in miles _____ Number of Housing Units _____ Number of Stories _____

	Existing	Immediate Increase Due to Project
Number of Parking Spaces	_____	_____
Vehicle Trips to Project Site (average daily traffic)	_____	_____
Estimated Vehicle Trips past project site	_____	_____

D. If the proposed project will require any permit for access to local or state highways, please attach a sketch showing the location of the proposed driveway(s) in relation to the highway and to the general development plan; identifying all local and state highways abutting the development site; and indicating the number of lanes, pavement width, median strips and adjacent driveways on each abutting highway; and indicating the distance to the nearest intersection.

I. ASSESSMENT OF POTENTIAL ADVERSE ENVIRONMENTAL IMPACTS

Instructions: Consider direct and indirect adverse impacts, including those arising from general construction and operations. For every answer explain why significant adverse impact is considered likely or unlikely to result.

Also, state the source of information or other basis for the answers supplied. If the source of the information, in part or in full, is not listed in the ENF, the preparing officer will be assumed to be the source of the information. Such environmental information should be acquired at least in part by field inspection.

A. Open Space and Recreation

1. Might the project affect the condition, use or access to any open space and/or recreation area?
   Yes _____ No _____

   Explanation and Source:

B. Historic Resources

1. Might any site or structure of historic significance be affected by the project? Yes _____ No _____

   Explanation and Source:

2. Might any archaeological site be affected by the project? Yes _____ No _____

   Explanation and Source:

C. Ecological Effects

1. Might the project significantly affect fisheries or wildlife, especially any rare or endangered species?
   Yes _____ No _____

   Explanation and Source:

P. 5

2. Might the project significantly affect vegetation, especially any rare or endangered species of plant?
Yes ______ No ______
(Estimate approximate number of mature trees to be removed: ____________)

Explanation and Source:

3. Might the project alter or affect flood hazard areas, inland or coastal wetlands (e.g., estuaries, marshes, sand dunes and beaches, ponds, streams, rivers, fish runs, or shellfish beds)? Yes ______ No ______

Explanation and Source:

4. Might the project affect shoreline erosion or accretion at the project site, downstream or in nearby coastal areas? Yes ______ No ______

Explanation and Source:

5. Might the project involve other geologically unstable areas? Yes ______ No ______

Explanation and Source:

D. Hazardous Substances

1. Might the project involve the use, transportation, storage, release, or disposal of potentially hazardous substances?
Yes ______ No ______

Explanation and Source:

Resource Conservation and Use

1. Might the project affect or eliminate land suitable for agricultural or forestry production?
Yes _____ No _____
(Describe any present agricultural land use and farm units affected.)

Explanation and Source:

2. Might the project directly affect the potential use or extraction of mineral or energy resources (e.g., oil, coal, sand & gravel, ores)? Yes _____ No _____

Explanation and Source:

3. Might the operation of the project result in any increased consumption of energy? Yes _____ No _____

Explanation and Source:
(If applicable, describe plans for conserving energy resources.)

F. Water Quality and Quantity

1. Might the project result in significant changes in drainage patterns? Yes _____ No _____

Explanation and Source:

2. Might the project result in the introduction of pollutants into any of the following:

(a) Marine Waters .... Yes _____ No _____
(b) Surface Fresh Water Body .... Yes _____ No _____
(c) Ground Water .... Yes _____ No _____

Explain types and quantities of pollutants.

10.30: continued

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3. Will the project generate sanitary sewage? Yes ______ No ______
   If Yes, Quantity: ____________ gallons per day
   Disposal by: (a) Onsite septic systems .... Yes ______ No ______
   (b) Public sewerage systems .... Yes ______ No ______
   (c) Other means (describe) ________________________________

4. Might the project result in an increase in paved or impervious surface over an aquifer recognized as an important present or future source of water supply? Yes ______ No ______

   Explanation and Source:

5. Is the project in the watershed of any surface water body used as a drinking water supply?
   Yes ______ No ______
   Are there any public or private drinking water wells within a 1/2-mile radius of the proposed project?
   Yes ______ No ______

   Explanation and Source:

6. Might the operation of the project result in any increased consumption of water? Yes ______ No ______
   Approximate consumption ________ gallons per day. Likely water source(s) ______________ ______________

   Explanation and Source:

7. Does the project involve any dredging? Yes ______ No ______
   If Yes, indicate:
   Quantity of material to be dredged ________________________________
   Quality of material to be dredged ________________________________
   Proposed method of dredging ________________________________
   Proposed disposal sites ________________________________
   Proposed season of year for dredging ________________________________

   Explanation and Source:

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G. Air Quality

1. Might the project affect the air quality in the project area or the immediately adjacent area?
Yes ______ No ______.
Describe type and source of any pollution emission from the project site.______________________________

2. Are there any sensitive receptors (e.g., hospitals, schools, residential areas) which would be affected by any pollution emissions caused by the project, including construction dust? Yes ______ No ______

Explanation and Source:

3. Will access to the project area be primarily by automobile? Yes ______ No ______
Describe any special provisions now planned for pedestrian access, carpooling, buses and other mass transit.

H. Noise

1. Might the project result in the generation of noise? Yes ______ No ______
Explanation and Source:
(Include any source of noise during construction or operation, e.g., engine exhaust, pile driving, traffic.)

2. Are there any sensitive receptors (e.g., hospitals, schools, residential areas) which would be affected by any noise caused by the project? Yes ______ No ______
Explanation and Source:

I. Solid Waste

1. Might the project generate solid waste? Yes ______ No ______

Explanation and Source:
(Estimate types and approximate amounts of waste materials generated, e.g., industrial, domestic, hospital, sewage sludge, construction debris from demolished structures.)

J. Aesthetics

1. Might the project cause a change in the visual character of the project area or its environs?
Yes ______ No ______

Explanation and Source:

2. Are there any proposed structures which might be considered incompatible with existing adjacent structures in the vicinity in terms of size, physical proportion and scale, or significant differences in land use?
Yes ______ No ______

Explanation and Source:

3. Might the project impair visual access to waterfront or other scenic areas? Yes ______ No ______

Explanation and Source:

K. Wind and Shadow

1. Might the project cause wind and shadow impacts on adjacent properties? Yes ______ No ______

Explanation and Source:

IV. CONSISTENCY WITH PRESENT PLANNING

A. Describe any known conflicts or inconsistencies with current federal, state and local land use, transportation, open space, recreation and environmental plans and policies. Consult with local or regional planning authorities where appropriate.

V. FINDINGS AND CERTIFICATION

A. The notice of intent to file this form has been/will be published in the following newspaper(s):

(Name) ______________________ (Date) ______________________

______________________ ______________________

______________________ ______________________

B. This form has been circulated to all agencies and persons as required by Appendix B.

______________ Date	______________ Signature of Responsible Officer or Project Proponent
	______________ Name (print or type)
	Address ______________
	______________
	Telephone Number ______________
______________ Date	______________ Signature of person preparing ENF (if different from above)
	______________ Name (print or type)
	Address ______________
	______________
	Telephone Number ______________

Appendix C. Septic Leachate Detector Survey Results

A summary and description of potential plume locations and their subsequent Septic Leachate Detector readings are presented below. The readings are demonstrated as follows:

$$\frac{x}{x} = \frac{\text{organic channel}}{\text{inorganic channel}} = \frac{\text{fluorescence}}{\text{conductivity}}$$

Plume 1 - 60/10 - Plume 1 was sampled 25' from shore in front of the southern end of a large, grey stucco house with dark grey shutters. The house has a chimney and large TV antenna.

Plume 2 - 80/40 - Potential Plume 2 caused a quick deflection on both panel meters. The sample was taken 15' from shore in front of a concrete bench and 2 small red maples. Set back slightly from the shore is a redwood house with white trim.

Plume 3 - 100/40 - Plume 3 was sampled at the mouth of a small tributary located between the forementioned redwood house and their neighbor to the west.

Plume 4 - 80/50 - Plume 4 was sampled 300' east of the westernmost corner of this cove. The sample was taken 10' offshore and 8' east of a large cement block in the water.

Plume 5 - 100/40 - This sample was taken 25' from shore in front of a brick BBQ pit at the southern end of a yellow clapboard house with white trim.

Plume 6 - 100/20 - This potential plume was located and sampled 20' from shore across from #145 Beach Rd. The plume was located between 2 rock walls at a sand beach.

Plume 7 - 100/20 - This plume was sampled 8' from shore in front of a shingled house with green shutters and a boat dock. The plume was located in the southernmost of the 2 westerly coves.

Plume 8 - 100/15 - Plume 8 was sampled at the end of the southernmost westerly cove.

Plume 9 - 100/25 - This sample was taken 15' from shore at the southern end of the cove which is just north of the summer camp.

Plume 10 - 100/40 - This plume was sampled 15' from shore approximately 100' from the western corner of the cove. A tributary stream with substantial flow enters the pond 20' south of this sampling point.

Plume 11 - 100/40 - Sampling for Plume 11 was done under a small wooden bridge over the entrance to minor Massapoag Lake.

Plume 12 - 100/100 - Plume 12 was sampled at the mouth of Sucker Brook. The sample was taken 75' lakeward of the 2 discharge culverts.

Plume 13 - Plume 13 was located and sampled directly in front of the protruding storm drain on the western side of the Towns public beach.

Backgrounds A & B - Background Samples A and B were located slightly off-center in the northern section of Massapoag.

Background C - Background C was located in the southern section of Massapoag, just outside the entrance to the large, southernmost cove.

Grab #1 - Grab Sample 1 was located 20' south of Plume 10. It was taken at the mouth of a tributary exhibiting substantial flow, dark brown color and an unpleasant odor.

Appendix D. The Effects of Landfill Leachate on Stream Water Quality:

Fitchburg Landfill and Flag Brook*

*The following data have been published by the Massachusetts DEQE in a report entitled, Nashua River Basin: Flag Brook Water Quality Survey 1980-1981, prepared by the Division of Water Pollution Control Technical Services Branch in June 1983.

1980-1981 FLAG BROOK SURVEY
LOCATION OF SAMPLING STATIONS

STATION NUMBER	LOCATION	RIVER MILE
1	Below spillway dam at outlet of Crocker Pond, Westminster	2.7
2	Approximately 10 m upstream from landfill discharge, Westminster	2.1
3	Ambrose Lane, directly downstream from landfill discharge, Westminster	2.1
4	Approximately 40 m downstream from landfill discharge, Westminster	2.1
5	Directly upstream of inlet to Sawmill Pond, Westminster	1.6
6	Outlet of Sawmill Pond above spillway dam, Fitchburg	0.9
7	5th Street Bridge, Fitchburg	0.5
8	Directly upstream from railroad crossing, Fitchburg	0.2

FITCHBURG LANDFILL TREATMENT LAGOON EFFLUENT

RESULTS OF LABORATORY ANALYSES

PARAMETER*	1980 6/3	1981 5/26	6/2	7/22	9/1
Temperature (^{o}C)	--	--	19.0	21.0	20.0
Dissolved Oxygen	--	--	0.0	0.0	0.0
BOD_5	--	1,200	523	870	456
COD	2,850	1,310	2,309	1,176	762
pH (Standard Units)	6.4	5.7	6.3	6.9	6.4
Total Alkalinity ($CaCO_3$)	135	417	394	395	223
Turbidity (NTU)	--	28	34	100	110
Suspended Solids	370	172	236	160	168
Total Solids	3,142	1,768	1,808	1,644	1,460
Total Volatile Solids	36	740	754	722	532
Total Hardness	914	--	503	447	449
Specific Conductance (μmhos/cm)	3,000	1,700	1,650	1,300	1,400
Total Kjeldahl-Nitrogen	32	26	41	21	19
Ammonia-Nitrogen	30	19	36	20	18
Nitrate-Nitrogen	0.2	0.1	0.0	0.0	0.1
Total Phosphorus	1.5	0.87	0.44	0.50	0.65
Chloride	7.0	**	**	**	**
Cadmium (Cd)	0.00	0.00	0.00	0.01	0.00
Copper (Cu)	0.00	0.01	0.18	0.01	0.00
Iron (Fe)	650	270	315	170	110
Manganese (Mn)	8.0	3.6	4.0	3.0	2.2
Nickel (Ni)	0.04	0.00	0.15	0.00	0.00
Lead (Pb)	0.00	0.01	0.05	0.02	0.00
Zinc (Zn)	0.03	0.01	0.06	0.02	0.00
Cyanide	--	0.00	--	--	--
Total Coliform (No. per 100 ml)	--	<36	<36	<36	<36
Fecal Coliform (No. per 100 ml)	--	<36	<36	<36	<36

* Units are mg/l unless otherwise specified
** Color Interference

1980-1981 FLAG BROOK SURVEY

RESULTS OF STREAM SAMPLING

June 3, 1980

PARAMETER*	STATION 2	4	6	8
Temperature (°C)	--	15.5	19.4	20.0
Dissolved Oxygen	--	1.0	7.0	8.3
BOD_5	4.8	--	6.9	1.8
COD	42	700	4.7	--
pH (Standard Units)	7.1	6.6	7.2	7.5
Total Alkalinity ($CaCO_3$)	22	47	17	--
Turbidity (NTU)	--	--	--	6.7
Suspended Solids	12	54	6.0	5.0
Total Solids	70	198	64	74
Total Volatile Solids	37	39	31	--
Total Hardness	20	51	18	--
Specific Conductance (μmhos/cm)	74	212	96	--
Total Kjeldahl-Nitrogen	1.4	4.4	1.1	1.3
Ammonia-Nitrogen	0.26	1.7	0.48	0.23
Nitrate-Nitrogen	0.0	0.0	0.1	0.1
Total Phosphorus	0.70	0.70	0.13	0.10
Chloride	--	--	12	--
Cadmium (Cd)	0.00	0.00	0.00	--
Copper (Cu)	0.00	0.00	0.00	--
Iron (Fe)	5.5	25	1.1	--
Manganese (Mn)	0.15	0.55	0.05	--
Nickel (Ni)	0.00	0.05	0.00	--
Lead (Pb)	0.00	0.00	0.00	--
Zinc (Zn)	0.00	0.03	0.00	--
Total Coliform (No. per 100 ml)	--	100	250,000	1,500
Fecal Coliform (No. per 100 ml)	--	<5	30,000	660

* Units are mg/l unless otherwise specified

1980-1981 FLAG BROOK SURVEY

RESULTS OF STREAM SAMPLING

May 26, 1981

PARAMETER*	STATION 1	STATION 4	STATION 6
BOD_5	1.5	38	1.8
COD	18	54	36
pH (Standard Units)	5.4	5.7	6.3
Total Alkalinity ($CaCO_3$)	6.0	31	14
Turbidity (NTU)	1.4	5.2	3.7
Suspended Solids	3.0	28	0.5
Total Solids	34	134	64
Total Volatile Solids	10	58	26
Specific Conductance (μmhos/cm)	47	130	88
Total Kjeldahl-Nitrogen	0.85	2.9	1.2
Ammonia-Nitrogen	0.40	1.6	0.90
Nitrate-Nitrogen	0.1	0.1	0.2
Total Phosphorus	0.15	0.25	0.15
Chloride	6.0	10	11
Cadmium (Cd)	0.00	0.00	0.00
Copper (Cu)	0.01	0.00	0.00
Iron (Fe)	0.19	15	1.6
Manganese (Mn)	0.07	0.32	0.05
Nickel (Ni)	0.00	0.00	0.00
Lead (Pb)	0.00	0.01	0.00
Zinc (Zn)	0.01	0.00	0.01
Cyanide	0.00	0.00	--
Total Coliform (No. per 100 ml)	72	150	<36
Fecal Coliform (No. per 100 ml)	72	150	<36

* Units are mg/l unless otherwise specified

1980-1981 FLAG BROOK SURVEY

RESULTS OF STREAM SAMPLING

June 2, 1981

PARAMETER*	STATION 1	4	5	6	7	8
Temperature (°C)	20.0	17.0	16.5	19.0	19.0	19.0
Dissolved Oxygen	8.3	5.2	8.4	7.3	6.9	8.1
BOD_5	2.4	42	31	1.2	0.6	0.9
COD	23	44	46	29	12	12
pH (Standard Units)	5.4	6.5	6.6	6.4	6.3	6.4
Total Alkalinity ($CaCO_3$)	3.0	20	20	12	7.0	14
Turbidity (NTU)	1.1	4.3	8.4	3.0	2.1	2.3
Suspended Solids	3.5	52	32	1.5	0.5	2.5
Total Solids	48	148	144	70	164	124
Total Volatile Solids	16	64	54	22	42	26
Total Hardness	9.0	33	36	20	18	20
Specific Conductance (μmhos/cm)	47	130	115	90	90	100
Total Kjeldahl-Nitrogen	0.42	1.8	3.1	0.61	0.47	0.37
Ammonia-Nitrogen	0.09	1.2	2.6	0.37	0.25	0.18
Nitrate-Nitrogen	0.0	0.0	0.2	0.1	0.1	0.2
Total Phosphorus	0.02	0.05	0.04	0.01	0.01	0.01
Chloride	7.0	**	**	7.0	11	12
Cadmium (Cd)	0.0	0.0	0.0	0.0	0.0	0.0
Copper (Cu)	0.00	0.00	0.02	0.02	0.03	0.02
Iron (Fe)	0.38	18	14	2.0	2.4	2.4
Manganese (Mn)	0.10	0.25	0.39	0.10	0.12	0.26
Nickel (Ni)	0.00	0.00	0.00	0.00	0.00	0.00
Lead (Pb)	0.00	0.00	0.00	0.00	0.00	0.00
Zinc (Zn)	0.02	0.02	0.05	0.05	0.03	0.03
Total Coliform (No. per 100 ml)	80	71	91	100	90	100
Fecal Coliform (No. per 100 ml)	10	<36	91	65	30	<5

* Units are mg/l unless otherwise specified

**Color interference

1980-1981 FLAG BROOK SURVEY

RESULTS OF STREAM SAMPLING

July 22, 1981

PARAMETER*	STATION 1	4	5	6	7	8
Temperature (°C)	23.0	20.0	19.0	24.0	23.0	22.5
Dissolved Oxygen	7.0	5.5	7.3	7.9	5.3	7.5
BOD_5	2.7	31	12	2.1	2.4	2.1
COD	27	59	--	16	11	21
pH (Standard Units)	5.2	5.6	6.4	6.8	6.1	6.8
Total Alkalinity ($CaCO_3$)	5.0	13	23	16	16	21
Turbidity (NTU)	2.3	8.8	6.5	1.9	2.2	2.5
Suspended Solids	5.5	3.5	8.0	0.0	0.5	2.0
Total Solids	42	112	90	64	66	76
Total Volatile Solids	26	64	36	22	24	32
Total Hardness	9.2	320	29	16	19	23
Specific Conductance (μmhos/cm)	4.5	110	94	74	84	90
Total Kjeldahl-Nitrogen	1.2	1.1	0.98	0.38	0.30	0.15
Ammonia-Nitrogen	0.01	0.85	0.62	0.19	0.13	0.11
Nitrate-Nitrogen	0.0	0.0	0.1	0.1	0.1	0.1
Total Phosphorus	0.05	0.02	0.02	0.02	0.02	0.02
Chloride	6.0	13	10	13	12	11
Cadmium (Cd)	0.01	0.01	0.00	0.02	0.00	0.00
Copper (Cu)	0.01	0.00	0.00	0.00	0.00	0.00
Iron (Fe)	0.51	7.9	6.3	0.95	1.1	1.2
Manganese (Mn)	0.09	0.26	0.31	0.05	0.08	0.12
Nickel (Ni)	0.00	0.00	0.00	0.00	0.00	0.00
Lead (Pb)	0.00	0.01	0.00	0.00	0.00	0.00
Zinc (Zn)	0.02	0.01	0.00	0.00	0.00	0.00
Total Coliform (No. per 100 ml)	12,000	400	700	140	220	320
Fecal Coliform (No. per 100 ml)	<10	80	100	50	50	<10

* Units are mg/l unless otherwise specified

1980-1981 FLAG BROOK SURVEY

RESULTS OF STREAM SAMPLING

September 1, 1981

PARAMETER*	STATION 1	4	5	6	7	8
Temperature (°C)	20.0	17.0	17.0	20.0	20.0	19.0
Dissolved Oxygen	7.6	6.8	8.3	7.3	6.9	8.3
BOD_5	0.9	13	2.4	1.5	1.5	3.0
COD	24	40	32	24	24	48
pH (Standard Units)	5.5	6.0	6.9	6.1	6.1	6.8
Total Alkalinity ($CaCO_3$)	2.0	18	30	19	16	60
Turbidity (NTU)	2.6	13	6.7	5.6	2.4	10
Suspended Solids	7.0	12	2.0	5.0	3.0	2.0
Total Solids	108	118	106	84	82	278
Total Volatile Solids	8.0	22	24	28	8.0	36
Total Hardness	9.0	39	37	21	21	60
Specific Conductance (μmhos/cm)	48	130	125	100	100	190
Total Kjeldahl-Nitrogen	0.51	1.2	0.84	0.44	0.21	0.13
Ammonia-Nitrogen	0.50	1.0	0.77	0.08	0.04	0.04
Nitrate-Nitrogen	0.1	0.2	0.1	0.1	0.1	0.1
Total Phosphorus	0.04	0.09	0.05	0.05	0.04	0.04
Chloride	3.0	13	12	13	13	16
Cadmium (Cd)	0.00	0.00	0.00	0.00	0.00	0.00
Copper (Cu)	0.00	0.00	0.00	0.00	0.00	0.01
Iron (Fe)	0.33	4.0	3.0	2.0	0.92	2.6
Manganese (Mn)	0.07	0.26	0.27	0.25	0.07	1.1
Nickel (Ni)	0.00	0.00	0.00	0.00	0.00	0.02
Lead (Pb)	0.00	0.00	0.00	0.00	0.00	0.00
Zinc (Zn)	0.02	0.01	0.00	0.00	0.00	0.00
Total Coliform (No. per 100 ml)	140	300	110	180	10	160
Fecal Coliform (No. per 100 ml)	20	110	90	80	<5	70

* Units are mg/l unless otherwise specified

Appendix E. Recommended Septic System Maintenance Program

RECOMMENDED SEPTIC SYSTEM MAINTENANCE PROGRAM

TOWN OF SHARON, MASSACHUSETTS

A. ADMINISTRATIVE AUTHORITY

Statutory Authority of Boards of Health - Municipal Boards of Health are authorized by the Massachusetts General Laws (MGL Chapter 111, Sections 31, 127 and 127A) to adopt and enforce reasonable health regulations. Such regulations may include provisions to meet the minimum requirements for septic system maintenance of the State Environmental Code (MGL 21A:13 - State Environmental Code - Title V - "Minimum Requirements for the Subsurface Disposal of Sanitary Sewage").

It is suggested that Section 2.19 of Title V be adopted into the rules and regulations of the Sharon Board of Health, by a majority vote of the Board and publication in a local newspaper.

> Title V - (Section 2.19) - "Maintenance - Every owner or agent of premises in which there are any private sewers, individual sewage disposal systems, or other means of sewage disposal, shall keep the sewers and disposal systems in proper operational conditions and shall have such works cleaned or repaired at such time as ordered by the Board of Health. If the owner or agent of the premises fails to comply with such order, the Board of Health may cause the works to be cleaned or repaired and all expenses incurred to be paid by the owner. Sewage disposal works shall be maintained in a manner that will not create objectionable conditions or cause the works to become a source of pollution to any of the waters of the Commonwealth."

By-Law Authority of the Board of Health - Septic system inspections and periodic maintenance pumping may be authorized by a municipal by-law as a public service similar to regular trash and solid waste collection from private property. Adopting such a by-law is authorized by the General Laws (MGL, Chapter 40, Section 21). The by-law should contain a purpose statement which includes the identification, prevention and removal of public and private nuisances by the Board of Health, as well as functional public service activities which might be performed by other municipal agencies. Assigning such a charge upon the Board of Health would support the Board's statutory authority as an enforcement agency.

The general by-law must be adopted by a majority vote of the Sharon town meeting. It should provide the imposition of a duty upon the Board of Health, and impose penalties for violations.

Before such by-law takes effect, it must be approved by the Attorney General or ninety (90) days shall have elapsed without such approval. Notice by publication at least two (2) times is required (see MGL, Chapter 40, Sections 31 and 32).

Approval of such a by-law would:

1. Authorize the establishment of the septic system maintenance service as a municipal function;

2. Establish improper maintenance as a defined nuisance; and,

3. Authorize the Sharon Board of Health to adopt and enforce the regulations necessary to carry out the purposes of the by-law, including fees and penalties.

Examples of suggested by-laws are included in Section C. It is recommended that the Town of Sharon consider adoption of either Example B (Municipal Inspection and Private Maintenance) or Example C (Private Inspection and Private Maintenance).

Authority from Rules and Regulations of the Board of Health - Following adoption of an appropriate by-law, the Sharon Board of Health - as the municipal agency charged with enforcing and implementing the septic system maintenance program - should adopt rules and regulations to carry out these duties. The by-law could be adopted for the entire Town of Sharon or just for homes within the Lake Massapoag Watershed.

Regulations may require revisions from time to time to meet special unforeseen or changing conditions. It is suggested that the enabling by-law contain general rather than specific provisions. This would avoid the necessity of special town meetings and Attorney General approval for procedural and administrative concerns which would be covered through Board of Health regulations. Suggested Board of Health rules and regulations for each of the three example by-laws are included in Section C.

B. ELEMENTS OF A SEPTIC SYSTEM MAINTENANCE PROGRAM

Administrative Requirements - It is suggested that the Town of Sharon (or the Lake Massapoag Watershed) be divided into three (3) maintenance districts of approximately the same number of residences and then further subdivided to establish inspection and pumping schedules. One maintenance district should be completed each year, or each system inspected and pumped as required once every three (3) years. Certain problem systems will require more frequent attention.

Proper septic system inspection may require complete pumping of the contents in order to determine structural conditions, excessive water flows, and the buildup of solid matter. Thus the statutory public health function of the Board of Health will be combined with the public service pumping functions authorized by the local by-law.

Central Records - Central records should be kept by the Sharon Board of Health. Records maintained on property location cards should show the location of the on-site sewage disposal system and means of access, street address, lot number, owner's name and pumping and maintenance information. An example of the suggested record card follows.

The cards are designed so that, when folded, the property location information is uppermost for ease of filing and retrieval. The inspector should not remove the record cards from the Board of Health files, but instead carry a copy of the card into the field. Maintenance record information, system location information, notes and comments recorded on the field copy by the inspector are later transcribed onto the original card so that a complete record of all systems is always available in the Board of Health office.

The Town of Sharon may appropriate money to exercise its corporate powers, including the performance of statutory and other duties of the Board of Health. Funds for the maintenance program should be included in the Sharon Board of Health's annual budget.

Location Plan

System description ______________________________

____

____

____

____

____

______________________________ Street & Number

______________________________ Owner

______________________________ Assessors plan no. & lot

Maint. Record

date	comments	inspector

TOWN OF SHARON

SEPTIC SYSTEM MAINT.

Record Card

BOARD OF HEALTH
TOWN OF SHARON, MASSACHUSETTS

Suggested Rules and Regulations
Septic System Maintenance Program
Municipal Inspection/Municipal Maintenance

Section 1 - Authority

1.1. These rules and regulations are adopted by the Board of Health of the Town of Sharon acting under the authority of Chapter 111 of the General Laws and Section ____ of the By-Laws of the Town of Sharon for the purposes of a program of inspection and maintenance of cesspools and septic tank systems and the collection and disposal of the contents of such systems.

1.2 To ensure compliance with the requirements of Title V of the State Environmental Code, every owner, agent or occupant of premises in which there are private sewage disposal systems shall keep such systems in proper operational order including means of access for inspection and pumping, and shall have such systems cleaned or repaired at such times as ordered by the Board of Health.

Failure to comply with such orders, or to maintain such a system in a manner which will prevent objectionable conditions may be deemed a nuisance injurious to the public health.

2.0 Inspection of Premises

2.1. For the purpose of determining the proper operation of on-site sewage disposal systems within the Town of Sharon (or within the Lake Massapoag Watershed), such systems shall be subject to inspection by the Board of Health at intervals of not more than three years.

2.2 The Board of Health shall maintain a record of each system inspected, including the address of the premises, name and address of the owner/occupant, description, and shall keep a record of the condition of any system or component thereof on the inspection date.

2.3 The Board of Health shall report to the owner/occupant any system found to require improvement, repair, alteration or replacement and may make recommendations as to the appropriate type and size of system required.

3.0 Pumping and Disposal of Contents

3.1 The contents of on-site sewage disposal systems within the Town of Sharon (or within the Lake Massapoaq Watershed) shall be inspected and pumped as conditions require within three (3) years of the effective date of these regulations, and every three (3) years thereafter. Such pumping shall be made by municipal employees or private operators duly authorized by the Board of Health. A system will not be pumped if the volume of sludge, solids and scum is found to be less than one-third (1/3) of the tank volume.

Additional pumpings may be made as deemed necessary by the Board of Health for the proper operation of a septic tank system.

3.2 Contents pumped from cesspools and septic tank systems shall be discharged at suitable septage treatment/disposal facilities as designated by the Town of Sharon Board of Health.

4.0 Enforcement

4.1 Compliance with Title V of the State Environmental Code, and with these Rules and Regulations may be enforced by the Board of Health or by its duly authorized agents.

5.0 Fees

5.1 As authorized by Section _____ of the Sharon By-Laws, an annual fee of $_____ shall be paid by all owners of property within the Town of Sharon included in the program of inspection, collection and disposal of contents of septic systems.

Such charge shall constitute a debt due to the town upon the rendering of an account thereof to the owner, his authorized agent or the occupant.

Septage Collection and Disposal - The fundamental basis of the septic system maintenance program is regular pumping and removal of septage, solids and floating scum from the cesspools and septic tanks. This task could be accomplished by town or privately-owned and operated septage pumping and collection vehicles. Pumpings throughout the town (or just within the Lake Massapoag Watershed) would be scheduled so that all individually-owned sewage disposal facilities would be inspected and pumped as required once every three (3) years. The schedule would also be organized to allow for additional emergency pumpings - especially during spring high groundwater periods - and provide flexibility during winter months when frozen ground may prevent opening systems.

For the recommended Sharon program, the inspector/operator should be a town employee trained in septic disposal system construction and operation and capable of performing the required inspection and maintenance tasks. The designated individual should also be an appointed health agent by the Sharon Board of Health. The inspector should be a Registered Sanitarian in the Commonwealth of Massachusetts.

C. MODEL BY-LAWS AND SUGGESTED BOARD OF HEALTH RULES AND REGULATIONS

Example A: Municipal Inspection and Municipal Maintenance - A general by-law, adopted by majority town meeting vote, should contain the following provisions:

1. Authority and direction to the Board of Health to implement a program of septic system inspection and maintenance, and a brief purpose statement including the statutory authority of the Board of Health under Title V of the State Environmental Code that septic systems be kept in proper working order.

2. Provision that failure to maintain a proper system would be deemed a nuisance, and authority of the Board of Health to make inspections and to require that an improperly maintained system be cleaned or repaired at the expense of the property owner.

3. Requirement that the Board of Health adopt rules and regulations to provide for:

   - the issuance of necessary permits;
   - necessary inspections;
   - maintenance of systems;
   - pumpings and disposal of the contents; and,
   - the establishment of reasonable fees to be paid by the owners of properties included in the program.

A suggested general by-law and suggested Board of Health rules and regulations for a septic system maintenance program which allows for municipal inspection and municipal maintenance follow:

TOWN OF SHARON, MASSACHUSETTS

Suggested General By-Law
Septic System Maintenance Program
Municipal Inspection/Municipal Maintenance

1. For the purpose of ensuring compliance with minimum standards for the health and safety of the inhabitants of Sharon , and to provide for the pumping and disposal of the contents of privies, cesspools and septic tanks as a public service, it shall be the duty of the Board of Health to examine, remove or prevent nuisances due to improper on-site sewage disposal systems, and the Board of Health is directed and authorized to implement a program of septic system inspection and maintenance, and disposal of the contents of such septic systems as an alternative to the system of common sewers and for the protection of surface and groundwater resources of the town from pollution.

2. The Board of Health shall adopt and enforce rules and regulations relative to such a program of inspection, maintenance and disposal of the contents of privies, cesspools, and septic tanks within the town, to issue necessary permits, and to establish reasonable fees to defray the costs of such program - such fees to be paid by the owners of properties included in the program.

3. The Board of Health shall have express authority under this by-law to make inspections of on-site sewage disposal systems, failure to maintain a proper system may be deemed a nuisance, and the Board of Health may require such system to be cleaned or repaired at the expense of the property owner.

Example B: Municipal Inspection and Private Maintenance - In this approach, the Board of Health would inspect each septic system at least once every three (3) years. If the health agent finds the system is not working properly, the Sharon Board of Health would require that it be remedied.

Each septic tank would be inspected and pumped as deemed necessary by the Board of Health's agent at least once every three years - or more frequently, if necessary, to keep the system functioning properly.

Licensed septic tank pumpers would be responsible for issuing a receipt to owners showing the name, address and date of pumping. The owner would sign the receipt. The pumper would submit a copy to the Board of Health. These records would be used to show compliance with the program. The record-keeping may be similar to the one presented previously. Records would be maintained to keep track of which systems were inspected or pumped and when.

The suggested rules and regulations which follow are based entirely on the authority of Chapter 111 and Title V of the State Environmental Code. Prior to adoption of these suggested rules and regulations specific reference to the authority of Chapter 111 and Title V should be made in a general by-law rather than just establishing a septic tank maintenance program through Sharon Board of Health regulations.

Without local acceptance and support of the program evidenced by adoption of a by-law, the Board of Health may find it lacks funds to enforce its regulations because there is no general recognition of the problem. This method (municipal inspection and private maintenance) does not provide for a fee system to cover costs. Instead, each individual would be responsible for paying for pumping the septic tank or cesspool.

Suggested Board of Health rules and regulations for a septic tank maintenance program which allows for municipal inspection and private maintenance follow:

BOARD OF HEALTH
TOWN OF SHARON, MASSACHUSETTS

Suggested Rules and Regulations
Septic System Maintenance Program
Municipal Inspection/Private Maintenance

Section 1. Inspection of Systems

All on-site sewage disposal systems within the Town of Sharon (or within the Lake Massapoag Watershed) shall be inspected by the Board of Health within three years of the effective date of this ordinance and every three years thereafter to determine whether all components of the system are operating properly and are not malfunctioning.

Section 2. Malfunctioning Systems

Any system or component thereof which is found to be malfunctioning or a nuisance to public health, safety and welfare or to the quality or surface waters or groundwaters shall be ordered remedied in accordance with Title V of the State Environmental Code.

Section 3. Septic Tank Pumping

The septic tanks of all on-site sewage disposal systems within the boundaries of the Town of Sharon (or within the limits of the Lake Massapoag Watershed) shall be pumped as required within three years of the effective date of this ordinance, and every third year thereafter. A system shall be pumped whenever the volume of sludge, solids and scum is found to be greater than one-third (1/3) of the tank volume. The Board of Health may require more frequent inspections and pumpings of any septic tank wherever it may find such additional pumping necessary to the proper operation of the septic tank system.

Section 4. Proof of Compliance

All septic tank pumpers must be licensed in accordance with Title V of the State Environmental Code. Septic tank pumpers shall issue to owners of the septic tanks which they pump out a signed receipt showing the date of pumping, the name and address of the septic tank owner and a description of the location and size of the septic tank. The owner shall sign the receipt, and the pumper shall submit a copy to the Board of Health. The receipt shall serve as proof of compliance with this Article.

Section 5. Site Investigation

For any system which is serving an existing dwelling or structure and which must be upgraded, altered or replaced, a site investigation to determine the appropriate type and size of system in accordance with Title V of the State Environmental Code shall be conducted.

Section 6. Health Board Report

The Board of Health shall prepare a report for each system inspected, including the name and address of the on-site sewage disposal system owner, a description of the location and type of system, and whether or not the system or any of its components is operating improperly. For any system found to be operating improperly, the report shall also include a copy of the site investigation report as described in Section 5.

Section 7. Enforcement

All violations of municipal and state health regulations and the State Plumbing and Environmental Code discovered during on-site sewage disposal system inspections shall be reported, and appropriate corrective and enforcement actions shall be taken by the municipality. In absence of local enforcement, the State Department of Environmental Quality Engineering may take any action which the Board of Health is authorized to take.

Example C: Private Inspection and Private Maintenance - This approach is based on a septic system maintenance permit issued by the Sharon Board of Health. The process would be authorized by acceptance of a town by-law by majority vote at a Sharon town meeting.

The owner of any building served by a septic system would apply for a permit from the Board of Health. The application form would include the owner's name and address and would indicate that an authorized licensed septic system pumper inspected the septic system. The form would also indicate whether the system was pumped or not. If the sludge volume is less than one-third the tank volume, pumping would not be necessary. One original septic system permit should be enough. As occupants change, no new permits should be needed.

The Board of Health through its designated health agent has the duty to make inspections. This authority cannot be delegated to persons who are not agents of the Board of Health.

A septic tank pumper's permit does not provide authority to make a judgment on the conditions of a septic system. In fact, the private person who has just been paid a fee to perform a private service is the wrong person to make such an inspection.

TOWN OF SHARON, MASSACHUSETTS

Suggested By-Law
Septic System Maintenance Program
Private Inspection/Private Maintenance

Section 1. Purpose

It is recognized that proper maintenance of septic tanks will increase the useful life of all on-site sewage disposal systems which rely on soil absorption of septic tank effluent. To further the purpose of increased life of such on-site sewage disposal systems and to protect the health, safety and welfare of the inhabitants of the Town of Sharon, the Town of Sharon hereby establishes a septic system maintenance permit program.

Section 2. Permit Required

No owner may occupy, rent, lease, live in or reside in, either seasonally or permanently, any building, residence or other structure serviced by a private domestic sewage treatment and disposal system unless the owner has a valid septic system maintenance permit for that system issued in his/her name by the Board of Health. Owner is defined to mean a natural person, corporation, the state or any subdivision thereof.

Section 3. Fee

A fee of $________ shall accompany each application for a septic system maintenance permit.

Section 4. Permit Application

Application for a septic system maintenance permit shall be made to the Board of Health on forms supplied at the Board of Health's office. All applications shall state the owner's name and address, the address or location of the private sewer system and shall contain the following statement:

I certify that on ________ day of ________, 19__, I inspected the septic system located at the address stated on this application, and I (check one):

_____ pumped all sludge and scum out of the septic tank, <u>or</u>

_____ found that the volume of sludge and scum was less than 1/3 of the tank volume, and I did not pump the septic tank.

____
Signature

____
Sanitary License Number

Section 5. Issuance

The Board of Health shall issue a permit to the applicant upon receipt of the fee and a completed application, properly signed by a person licensed to service septic systems and stating his sanitary license number. The permit shall include on its face all information contained in the application and shall contain the date of issuance.

Section 6. Validity

The permit issued under this section shall be valid for a period of three years from the date of issuance.

Section 7. Sale of Property

When property containing a private domestic sewer system is sold, the new property owner, prior to occupying, renting, leasing or residing in the building, residence or structure served by the system, shall make application for and receive a septic tank maintenance permit. However, the system may be used for a period not to exceed 30 days after making application for a permit.

Appendix F. Informational Material on Septic Systems

(Suggested Educational Brochures)

- What is a Septic System?
- An Owner's Manual for Maintaining a Septic System

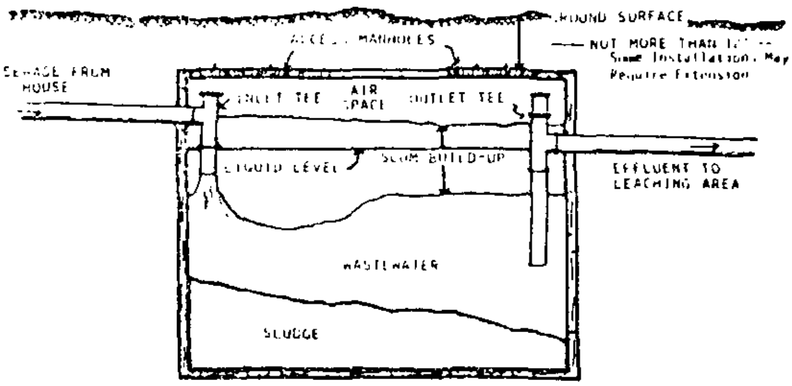
What Is A Septic System?

Cesspool Large (6 feet) diameter concrete or brick pit with open-jointed lining in the bottom portions. Raw sewage enters the cesspool, with the liquid portions seeping into the soil. According to State regulation, the installation of cesspools is not permitted.

Septic Tank Water-tight box in which all household sewage is stored for one to three days. During this period, some of the solid components of the sewage (septage) have time to separate from the liquid portion. Septic tanks remove about 40% of the solids in raw sewage. Liquid from the septic tank flows to the leaching system.

Leaching System Large concrete pit with holes or a series of perforated pipes in trenches, or in "beds" of washed stone.

The Septic Tank



Why Do They Fail?

EXCESSIVE BUILDUP OF SOLIDS in the Septic Tank with resultant overflow of solids.

POOR DESIGN - Too small for present uses.

CARELESS INSTALLATION - Septic Tank not level or drain pipes not properly graded.

POOR LOCATION - Wet soil, high groundwater, or poor soil percolation.

ROOTS in the Leaching Area - Drain pipes may become clogged.

DO YOU KNOW WHERE YOUR SEPTIC TANK IS LOCATED?

For assistance on any septic tank or cesspool problems, call the Board of Health.

To have your septic tank pumped, call a licensed septic tank pumper, listed in the phone book under "Cesspools - Cleaning".

AN OWNER'S MANUAL FOR
MAINTAINING A SEPTIC SYSTEM

* Understanding Your Septic System
* How to Locate Your Septic Tank or Cesspool
* How to Inspect Your Septic Tank or Cesspool
* Causes of Septic System Failure
* Preventing System Failure

AN OWNER'S MANUAL FOR MAINTAINING A SEPTIC SYSTEM

Understanding Your Septic System

On-site subsurface wastewater disposal systems (septic systems), or cesspools in older homes, provide for the treatment and disposal of sewage or wastewater. Cesspools and septic systems have been known, with proper maintenance, to perform effectively for many years. Surveys in various areas have found septic tank/leaching area system half-lives of 27 years in one Connecticut community and a 90 percent survival after 20 years of service in Fairfax County, Virginia.

Your septic system is just as important to you as your furnace. A new system of any type or repairs to the old one are very costly. Cost variation is due to the type of failure, soil conditions, water table characteristics and lot size. Proper maintenance is the least expensive method to prevent repair or replacement costs.

Cesspools are no longer allowed in new construction, but a large number of the older homes in the Central Massachusetts area are still using them. From these older homes the building sewer (pipe) goes directly to the cesspool. A cesspool is a large pit with sidewalls typically constructed with either concrete block or fieldstone and an earth bottom. The lighter solids, grease and scum float at the top and the heavier solids and sludge settle to the bottom. The liquid seeps through the perforated blocks or the irregular stones. A cesspool's life span is usually limited, although with proper maintenance they could function effectively for many, many years. Should your cesspool overflow, it is usually because the pores in the sidewall and/or the surrounding soil have become clogged with solids. Normally, this occurs from lack of periodic inspections and infrequent pumping out of accumulated quantities of scum and sludge. It is highly recommended that you inspect your cesspool at least once every year. A cesspool should be pumped whenever the accumulation of solids is greater than one-third (1/3) of the available volume (approximate pumping frequency of once every year).

The most common septic system is made up of two (2) components; a septic tank and a leaching area. This system functions by allowing wastewater to flow from its source (usually a house) into a septic tank, where settling and initial bacterial purification occur. A schematic of a typical on-site septic tank/leaching area system is shown on the following page. From the septic tank, portions of the wastewater flow into a leaching area where final purification of the liquid portion of the waste is accomplished by ground absorption. The function of a leaching area is to spread the septic tank effluent over a large area, so that infiltration through the soil can occur. Leaching systems are constructed underground and are surrounded by a layer of clean stone, which separates the distribution part of the leaching system from the natural ground.

How to Inspect Your Septic Tank or Cesspool

Once your system has been located, the system should be inspected on an annual basis in accordance with the following procedure:

1. Remove the cover or covers. Care should be taken to avoid allowing soil or other materials to fall into the opening(s).

2. With a rod or a stick, measure the scum and sludge layers. If they total more than one-third (1/3) the liquid depth of the septic tank or cesspool, it should be pumped out. Approximately 1 - 2 inches of sludge should be left in the bottom of the septic tank by the pumper in order to provide bacteria for the decomposition of future wastes. Septic tank or cesspool pumpers can be found in the yellow pages of the telephone book or by contacting the board of health for recommended pumpers servicing your town.

3. Inlet and outlet tees, if present, should be checked to insure that they are in place and free of solids.

4. For additional assistance on any cesspool or septic tank problem, call your local board of health. The board of health's agent is usually available to assist you. For additional professional assistance, you can contact a private consulting sanitary engineer.

Causes of Septic System Failures

There are many causes of septic system failures. A few of the major causes are discussed below:

1. Lack of Maintenance - If your septic system is not checked regularly and serviced as required, the sludge or scum layers in the septic tank or cesspool may pass through to the leaching system. The result may be elimination of the ground's absorption capabilities through clogging of the leaching area, causing septic system failure.

2. Uneven Distribution of Effluent - If the wastewater flowing from the septic tank is concentrated in one area of the leaching system, that part of the system will become overloaded. Surface ponding of the wastewater may then result; ponding is an indication of septic system failure.

3. High Water Table - During the wet seasons of the year (normally early spring and late fall), if the groundwater level of the soil is at or near the bottom of the leaching system, clogging of the soil can result due to certain chemical/biological reactions. Expensive replacement of the system to allow adequate movement of wastewater through the soil may be necessary in this instance. Prior to construction of a new system, deep hole observation tests must be conducted in order to determine maximum groundwater elevations in the exact location of the proposed system. These tests should only be completed during the wet season period. A minimum of 4 feet should be maintained between the maximum groundwater elevation and the bottom of the leaching system.

4. Roots - Trees or shrubs which are planted too near the leaching system may send roots to feed on water and useable nutrients. These roots may eventually find their way into the distribution system, and may block it.

5. Heavy Equipment - Trucks, automobiles, and tractors should not be allowed to drive over the leaching system, as they may crush components of the system, resulting in an uneven distribution of the effluent as noted above in paragraph 2.

6. Inappropriate Design - The design of a septic system is based on expected wastewater flows, natural ground conditions, and the type of wastes to be treated. Flows may exceed original design calculations if the system is, for example, used year-round when designed for seasonal use, or if a large family purchases a house with a waste disposal system initially designed for two people. Natural ground conditions may differ

from those observed at the time original ground determinations were made or they may be inaccurately assessed, if not performed by a trained observer. Deep-hole observation tests should be completed only when groundwater elevations are known to be at a maximum.

7. Faulty Construction Practices - Several investigations have shown that the greatest chance of system failure occurs within the first 3 years of operation and that most of these failures are due to faulty construction practices. Improper use of construction equipment can compact the leaching area and reduce the soil's liquid absorption capability. This situation is further compounded during periods of excess soil moisture. Additional problems of shearing of soil absorption faces have been noted when rainfall or excessive silt-laden wind occurred while trenches were open during construction.

8. Inappropriate Use - Steps should be taken to conserve water and to refrain from permitting certain substances from entering the system. The following section discusses appropriate use practices.

Preventing System Failure

A properly designed, located, constructed and operated septic system will remove over ninety (90) percent of the pollutants in domestic wastewaters, equalling the treatment level provided by secondary treatment plants. Several uncontrollable variables, including rainfall, groundwater levels, and temperature influence the quality of treatment achieved. In addition, there are other variables, which can be controlled by people living with a septic system, to help assure maximum treatment levels and long-term reliable service. The amount of wastewater flowing into the system, and the type of waste accompanying this flow are two of the most important factors.

The use of "convenience" appliances may severely effect septic system operations. Garbage disposals add massive amounts of solids to the septic tank, making pumpouts more frequent. New homes with garbage disposals must have 1500 gallon capacity septic tanks installed. Dishwashers may add excess food remnants and grease if dishes are not prewiped (assuming food remnants are not allowed to go down the sink drain). Washing machines may add substantial amounts of detergents, exceeding the capacity for ground purification, or may add large quantities of lint. Substances which should not be flushed down the toilet or emptied into drains include:

COARSE ORGANICS - Vegetable trimmings, ground-up garbage, lint, sanitary napkins, coffee grounds, cigarettes, or paper towels.

OIL AND GREASE - Automotive oil, excess cooking oil or bacon grease.

CHEMICALS - Pesticides, disinfectants, acids, medicine, paint, paint thinner or any other petroleum based substances.

The use of commercially sold enzymes and other miracle septic system additives does not take the place of regular maintenance and should not be practiced. Annual inspection and periodic pumping is the recommended maintenance program.

The quantity of wastewater flow to the septic tank is also very important to proper operation of the overall system. By reducing water use in the home, effluent from the septic tank to the leaching area will be reduced. This will give bacteria in the septic tank more time to digest and assist in the settling of solids. Fewer of these solids will then flow to the leaching system, placing less stress on the natural soils ability to absorb and remove potential pollutants.

Suggested low-cost (or no-cost) water conservation practices which can be easily employed in your home include:

* Place a weighted plastic bottle in the reservoir of your toilet.

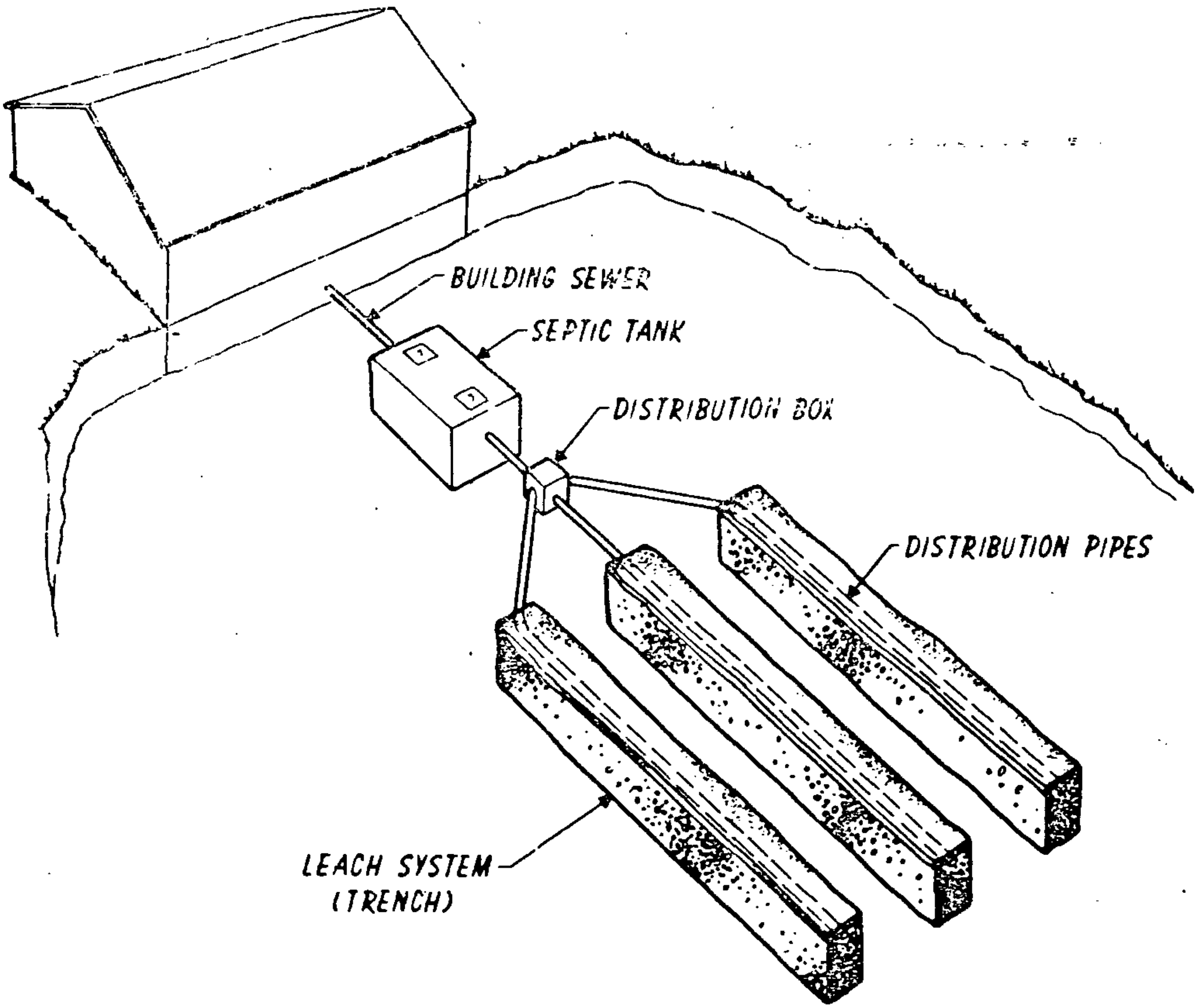
* Turn water off while brushing teeth, scrubbing hands, etc.

* Don't operate the clothes washer or the dishwasher without a full load.

* Install a flow reduction showerhead.

A septic tank/leaching system is the preferred type of subsurface sewage disposal system. A properly designed, located, installed and operated on-site subsurface wastewater disposal system is viewed as the most cost effective and environmentally sound method for the disposal of domestic sewage.

TYPICAL ON-SITE SEPTIC TANK/LEACHING AREA SUBSURFACE SEWAGE DISPOSAL SYSTEM



How to Locate Your Septic Tank or Cesspool

Yearly inspection of your disposal system can save the owner potentially large amounts of money, as well as eliminate possible inconveniences. However, the location of your septic system must first be determined. This is not always an easy task, especially if you own an older home. The septic system owner should follow the inspection procedure as outlined below:

1. Contact your board of health to see if they have a plan on file.

2. Contact the previous owner and/or builder to try to identify the individual or company which constructed the septic system in order to obtain a copy of the plan or information on the type and location of your system.

3. If your plan is not on file and no other information on your system is available:

    a. Attempt to locate an access manhole cover to the septic tank or cesspool. These are usually concrete or metal and are usually found in an area of fast growing, green grass, or where there is a depression where the grass does not grow, or where there is rapid melting of snow.

    b. If a ground surface inspection is of no help, locate the building sewer in the cellar and observe where and in what direction it leaves the house. Measure 5 or 10 feet from the foundation in the direction of the building sewer (prior to 1976, the State Health Code required only a 5 foot distance from the foundation). Probe the soil with a thin metal rod. The septic tank or cesspool cover should be 12" or less below the surface (older homes could be more than 12" below the ground surface).

    c. If probing of the soil proves to be unsuccessful, start digging at the foundation at the point from which the building sewer located in the cellar leaves the house. Locate the building sewer and continue digging until the building sewer connects to the cesspool or septic tank.

    d. Once the location has been verified by excavating the area and removing the cover, record the exact location and give a copy to your local board of health for their files.

4. If all attempts to locate your system fail, contact your board of health for assistance or consult with a sanitary engineer.

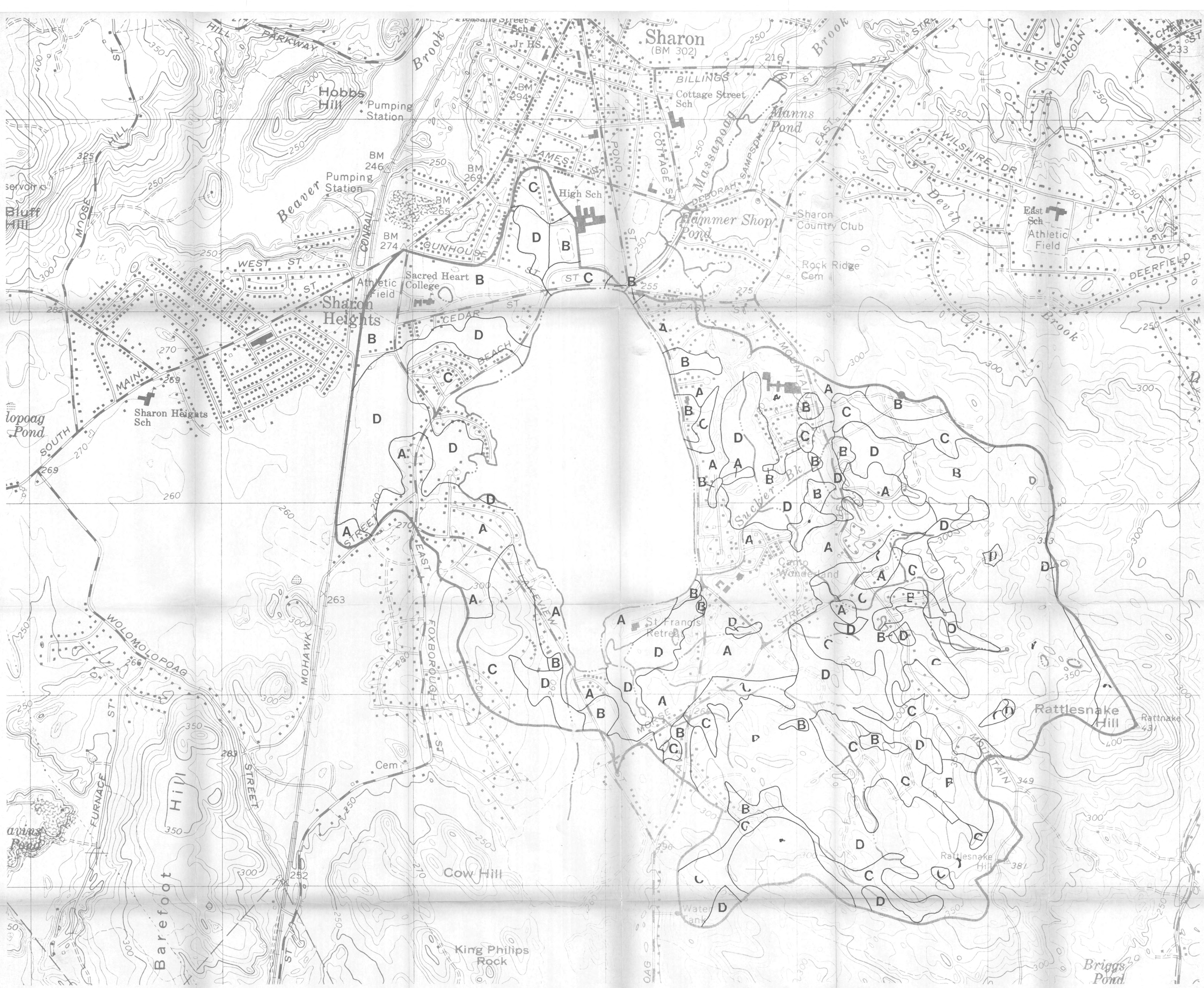


FIGURE 2
HYDROLOGIC SOILS GROUPS

LAKE MASSAPOAG DIAGNOSTIC / FEASIBILITY STUDY
TOWN OF SHARON, MASSACHUSETTS

KEY

A	VERY WELL DRAINED
B	MODERATELY WELL DRAINED
C	POORLY DRAINED
D	VERY POORLY DRAINED

N

1000 0 500
SCALE (FEET)

PREPARED BY IEP, Inc.

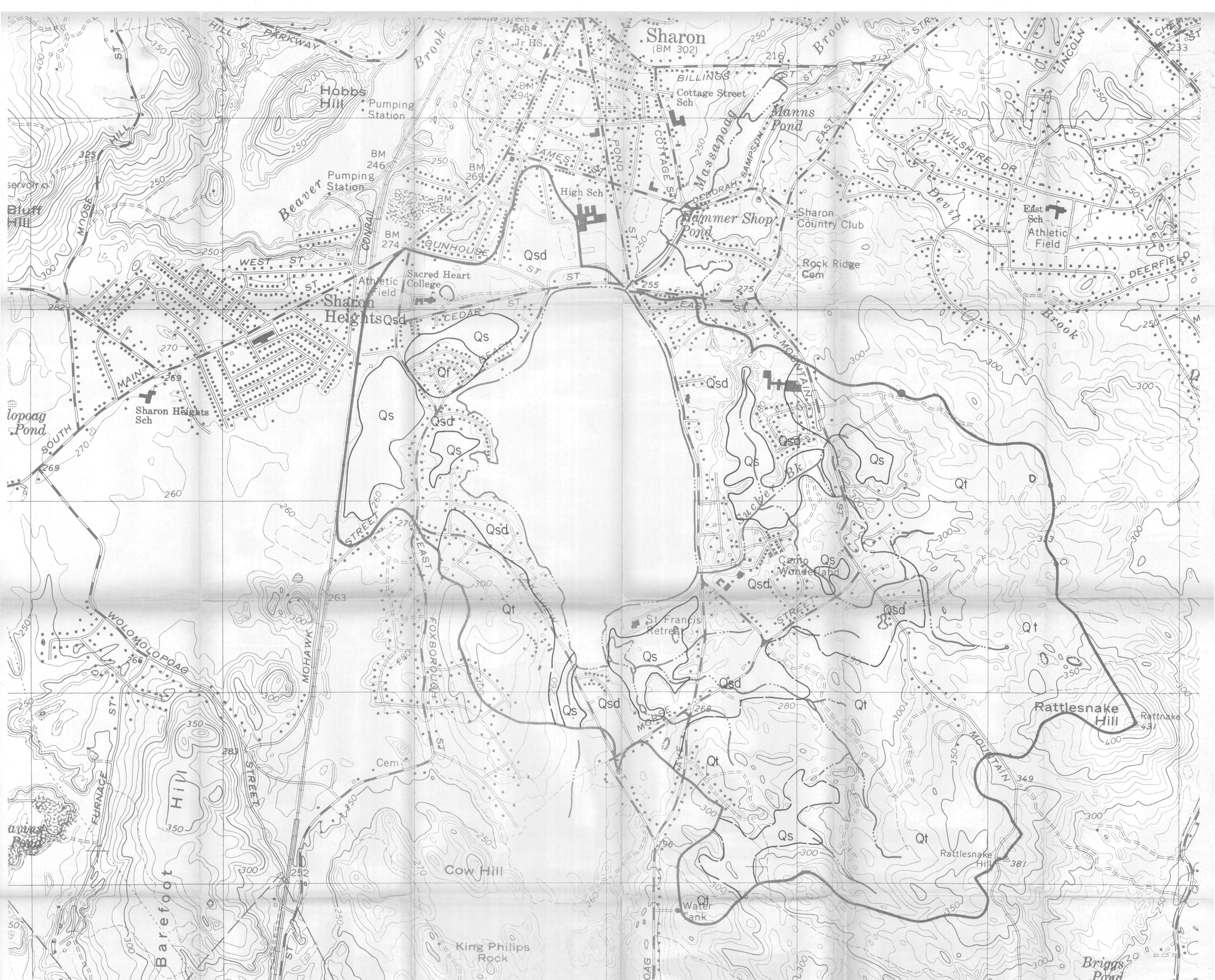


FIGURE 1
SURFICIAL GEOLOGY

LAKE MASSAPOAG
DIAGNOSTIC / FEASIBILITY STUDY
TOWN OF SHARON, MASSACHUSETTS

KEY

Qs
SWAMP DEPOSITS
FINE SAND, SILT AND CLAY WITH <50% ORGANIC MATTER

Qsd
STRATIFIED DRIFT
WELL SORTED, WELL STRATIFIED SANDS AND GRAVELS DEPOSITED BY GLACIAL MELTWATER STREAMS

Qt
TILL
UNSORTED, UNSTRATIFIED MIXTURE OF BOULDERS, COBBLES, GRAVEL, SAND, SILT AND CLAY DEPOSITED DIRECTLY BY THE GLACIAL ICE

CONTACT
DASHED WHERE INFERRED

N

1000 0 500
SCALE (FEET)

PREPARED BY IEP, Inc.

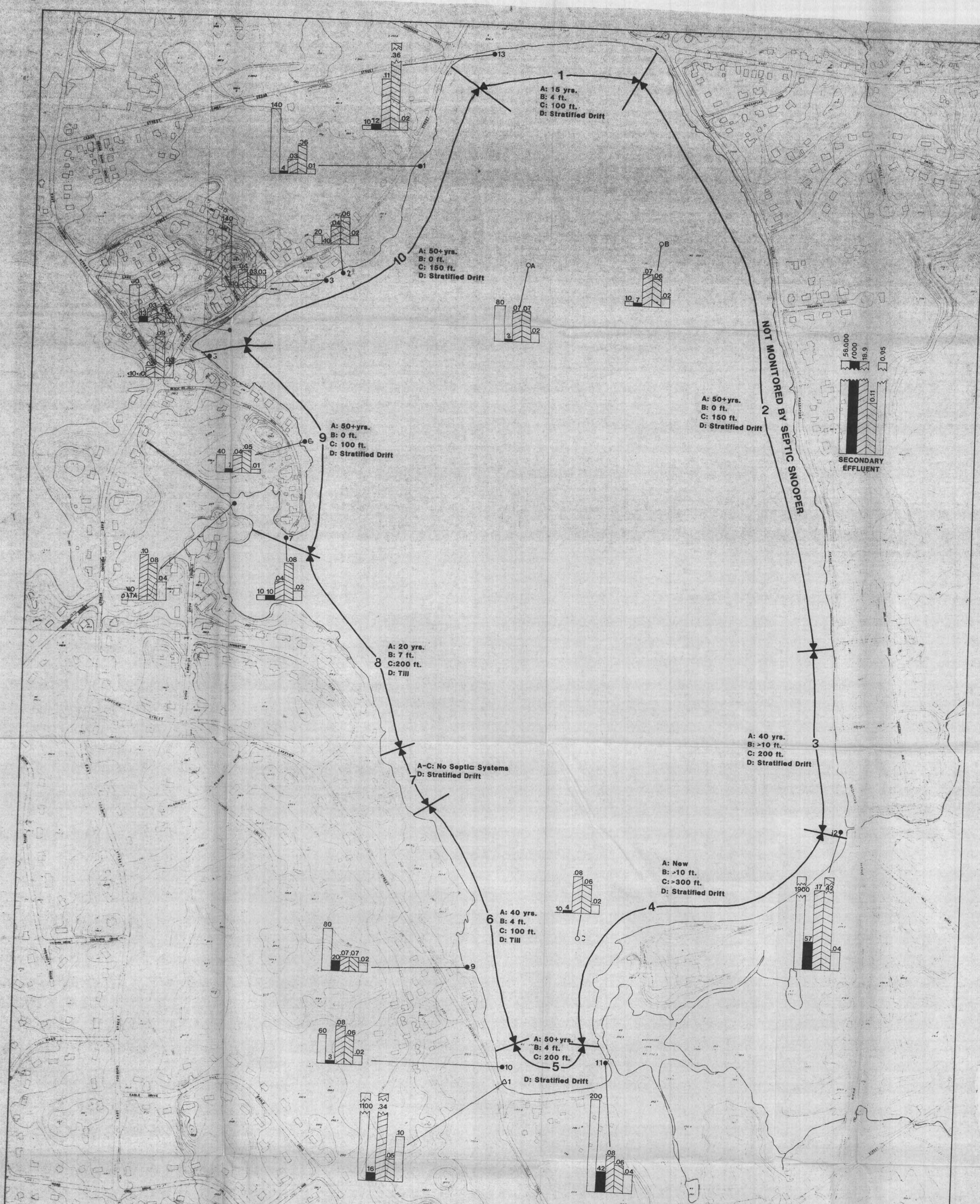


FIGURE 22
SEPTIC LEACHATE DETECTOR SURVEY AND LOCATIONS OF CEM ZONES

LAKE MASSAPOAG DIAGNOSTIC/FEASIBILITY STUDY SHARON, MASSACHUSETTS

EXPLANATION

- ● POTENTIAL PLUME SAMPLE
- ○ BACKGROUND SAMPLE
- △ GRAB SAMPLE

TOTAL COLIFORM BACTERIA (org/100 ml)
FECAL COLIFORM BACTERIA (org/100 ml)
AMMONIA-N (mg/l)
NITRATE-N (mg/l)
TOTAL PHOSPHORUS (mg/l)

CEM SHORELINE SEPTIC ZONES
- A: AGE OF SEPTIC SYSTEM
- B: DEPTH TO WATER TABLE
- C: DISTANCE FROM LAKE
- D: SOIL TYPE

SCALE (FEET)
500 0 300

PREPARED BY IEP, Inc.

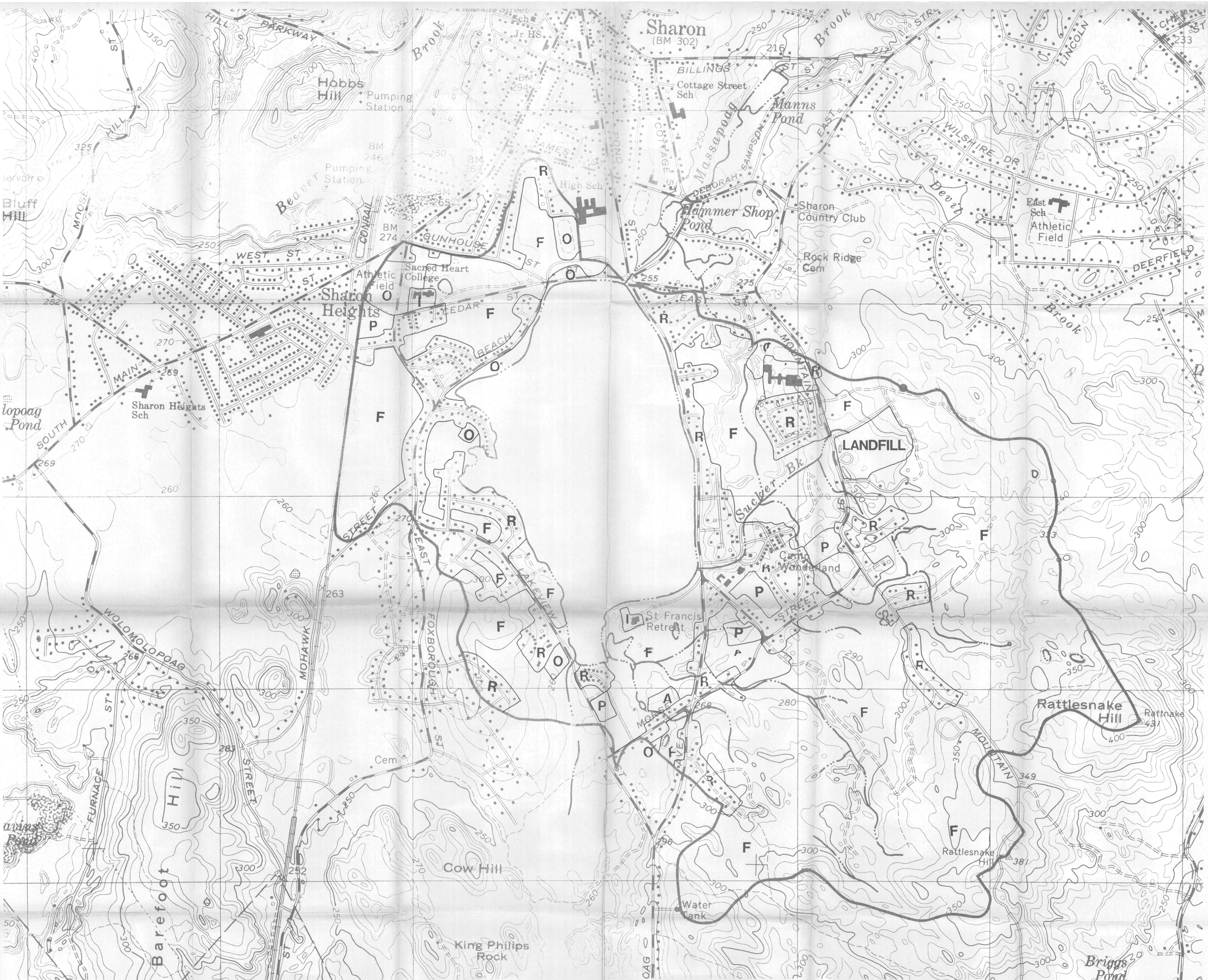


FIGURE 4
LAND USE

KEY

F	FOREST
O	OPEN SPACE (MAINTAINED)
P	PASTURE
A	AGRICULTURE
R	RESIDENTIAL
I	INSTITUTIONAL

LAKE MASSAPOAG DIAGNOSTIC / FEASIBILITY STUDY

TOWN OF SHARON, MASSACHUSETTS

PREPARED BY IEP, Inc.

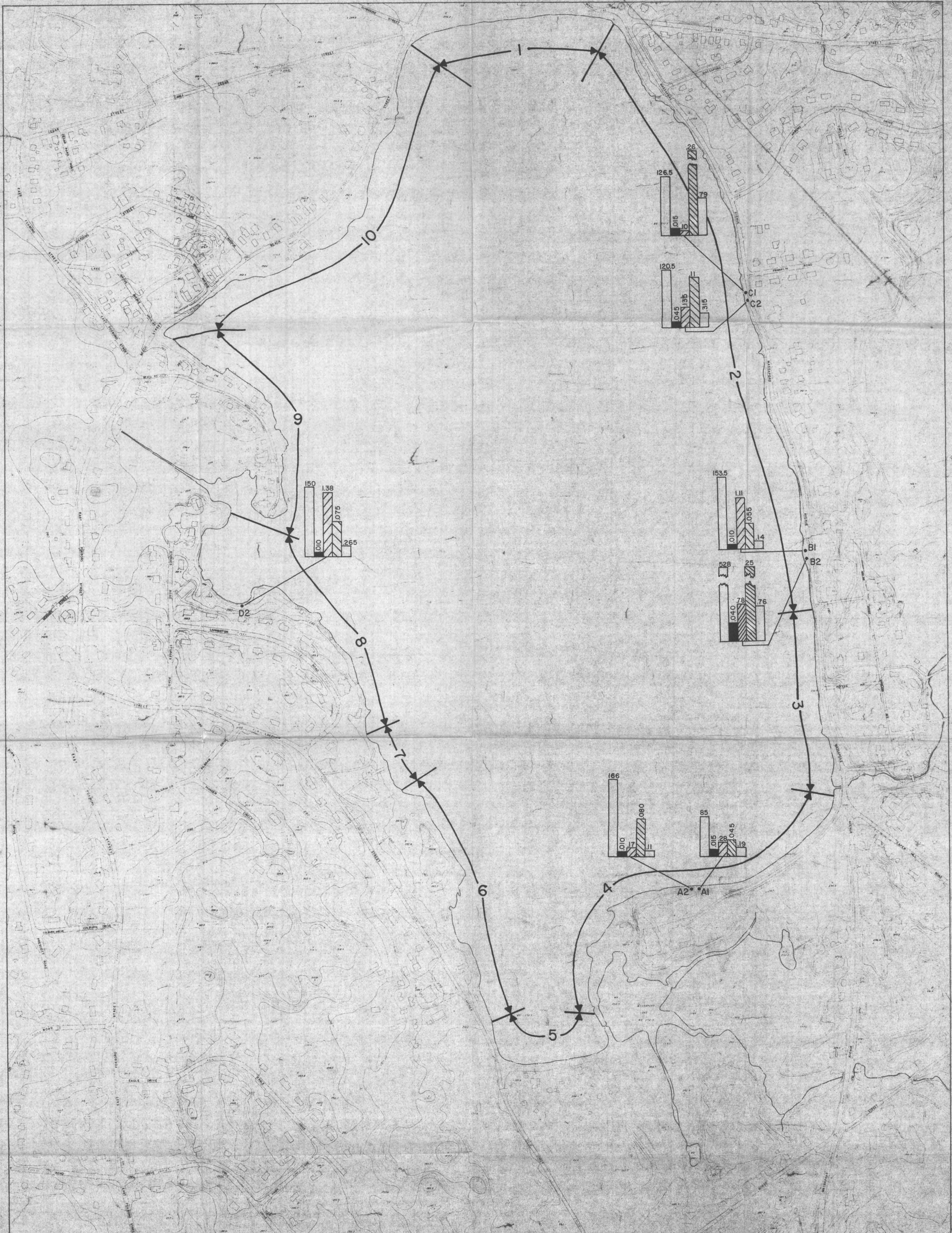
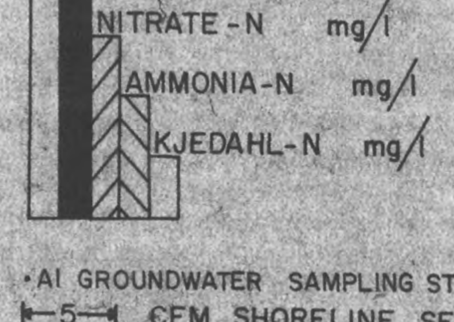


FIGURE 20

GROUNDWATER QUALITY RESULTS

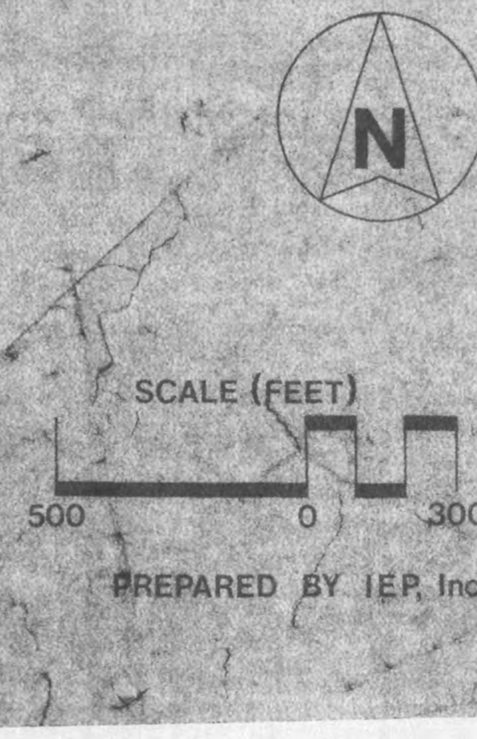
LAKE MASSAPOAG DIAGNOSTIC / FEASIBILITY STUDY SHARON, MASSACHUSETTS

EXPLANATION



• A1 GROUNDWATER SAMPLING STATION

├─5─┤ CEM SHORELINE SEPTIC ZONES



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