DIAGNOSTIC/FEASIBILITY STUDY FOR THE MANAGEMENT OF GREAT POND EASTHAM, MASSACHUSETTS

BAYSTATE ENVIRONMENTAL CONSULTANTS INC.

DIAGNOSTIC/FEASIBILITY STUDY
FOR THE MANAGEMENT OF
GREAT POND

PREPARED FOR
THE
TOWN OF EASTHAM
AND THE
MASSACHUSETTS DIVISION OF WATER POLLUTION CONTROL

UNDER
MGL CHAP. 628
MASSACHUSETTS CLEAN LAKES PROGRAM

BY
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FINAL REPORT

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DIAGNOSTIC EVALUATION

INTRODUCTION

The establishment of the Massachusetts Clean Lakes Program under Chapter 628 of the Acts of 1981 enabled many municipalities and lake associations to acquire funding for study and restoration of their lakes. As an environmentally aware and concerned community, the Town of Eastham applied for a grant for a Phase I diagnostic/feasibility study of Great Pond, the largest fresh water body in the town and the focal point of fresh water recreation in this summer resort community. After being awarded the grant, the town contracted Baystate Environmental Consultants, Inc. to conduct the study.

Rapid development of available land in Eastham and elsewhere on Cape Cod has raised questions regarding the carrying capacity of the land with respect to waste disposal, particularly as it affects water resources (lakes and ground water). Deterioration of historically pristine conditions in many area lakes represents both a decline in the quality of life on Cape Cod and a potential economic loss, as water-based recreation is a major element of tourism on the Cape. Lakes represent an often welcome alternative to the cold salt water and crashing waves of the ocean, and add diversity to the water resources of Cape Cod.

Concern over the present [illegible] status of Great Pond and [illegible] study. The water [illegible] quality impacts of man's activities [illegible] were largely unknown, and the condition of Great Pond was perceived to be deteriorating, although it was still a very popular recreational facility. Mitigation of any current negative influences on the pond and prevention of major degradation of this water resource in the future were desired.

DATA COLLECTION METHODS

Previous studies of Great Pond and related Cape Cod lakes were reviewed, and locally collected water quality data were also evaluated. Maps and reports prepared by the United States Geological Survey (USGS) and Soil Conservation Services (SCS) were used to initially assess watershed characteristics. Of particular use were the USGS (1974) Orleans Quadrangle Sheet from the 7.5 minute series, the USGS-Massachusetts Department of Public Works Bedrock Geologic Map (Zen, 1983), and the unpublished Barnstable County soil survey report prepared by SCS (1986). Areal measurements were made with a Planix Electronic Planimeter. Determinations made from maps were verified by field inspection by staff engineers, biologists, and a geo-hydrologist wherever possible.

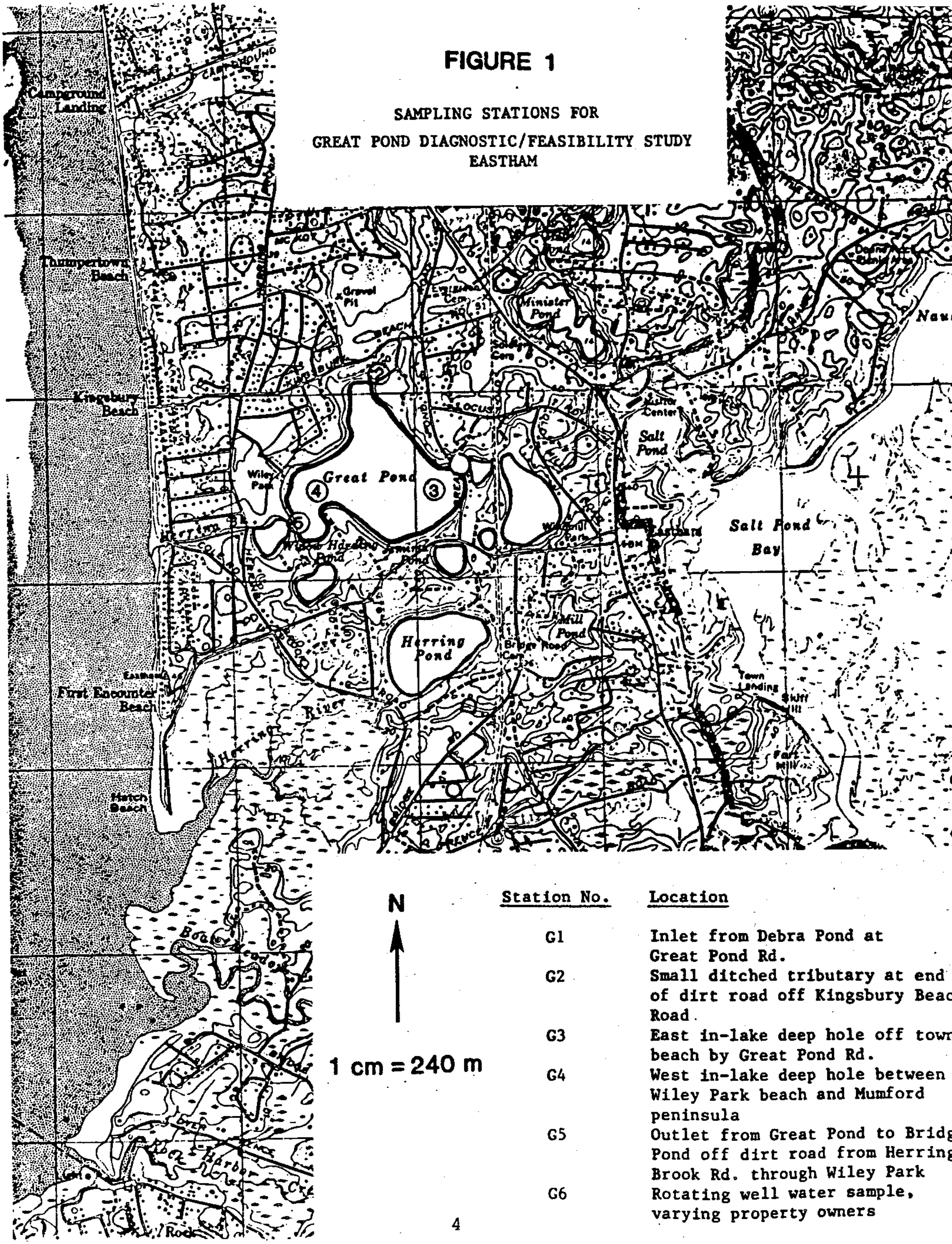
Historical lake and land use were investigated through conversations with watershed residents, newspaper and technical articles, previous reports and maps, state agency correspondence, and field inspection. Old and recent aerial photographs made available by Mr. Robert Mumford of Eastham, a 1946 USGS map provided by the Eastham Board of Selectmen, and the records of Mr. Henry Lind, Town Natural Resources Officer, provided valuable insights. Conversations with Mr. Howard Quinn, former Chairman of the Board of Selectmen, and Mr. John Ullman, editor of the Cape Codder, were particularly helpful. Mr. Don Sander kept detailed rainfall and water level records during the study. Discussions with Dr. Joseph Moran of Cape Cod Community College were also very helpful. The assistance of Mr. Wallace Ruckert, a former Selectman, in locating people and information was extremely valuable. Assistance by Ms. Cae Barton, Mr. David Humphrey, Mr. Ralph Earle, and Ms. Rusty Gifford is also gratefully acknowledged.

The Great Pond bathymetric map prepared by the Massachusetts Division of Water Pollution Control (Duerring and Rojko 1984a) was verified by plumb-lining along cross-lake transects and through visual inspection by a SCUBA diver; modifications were made as appropriate. Soft sediment depth was assessed by driving a probe to first refusal; these measurements were also performed by a diver in conjunction with the bathymetric check.

A comprehensive monitoring and investigative research program was instituted to assess the physical, chemical, and biological characteristics of Great Pond. Sampling stations were selected from topographic maps and field inspection. These stations are described and shown in Figure 1. The two in-lake stations were sampled with a Van Dorn bottle at three vertical levels (surface, thermocline, and bottom) during statification and at the surface and bottom during mixis. All stations were

FIGURE 1

SAMPLING STATIONS FOR
GREAT POND DIAGNOSTIC/FEASIBILITY STUDY
EASTHAM



Station No.	Location
G1	Inlet from Debra Pond at Great Pond Rd.
G2	Small ditched tributary at end of dirt road off Kingsbury Beac.. Road
G3	East in-lake deep hole off town beach by Great Pond Rd.
G4	West in-lake deep hole between Wiley Park beach and Mumford peninsula
G5	Outlet from Great Pond to Bridge Pond off dirt road from Herring Brook Rd. through Wiley Park
G6	Rotating well water sample, varying property owners

sampled approximately biweekly between spring and fall turnovers and monthly thereafter until the following spring.

Fifteen parameters were routinely assessed at all sampling locations. Temperature and dissolved oxygen levels were measured with a YSI model 57 meter, with vertical profiles obtained at the in-lake stations (0.3 to 1.0 m intervals). The pH was measured on-site with a Hach colorimetric kit and conductivity was assessed with a Horizon model 1484-10 meter. A four liter water sample was taken at each sampling location and transported to Arnold Greene Testing Laboratories in Natick, MA for analysis of suspended solids, dissolved solids, total alkalinity, chlorides, total Kjeldahl nitrogen, nitrate nitrogen, ammonia nitrogen, total phosphorus, and orthophosphorus by accepted standard methods (e.g., Kopp and McKee, 1979; APHA et al., 1985). Separate bacterial samples were collected for fecal coliform and fecal streptococci analyses, also performed by Arnold Greene Testing Laboratories by standard methods (membrane filter technique).

Flow was assessed at all stream stations, using either the float method, a Gurley Standard flow meter, or a pipe/weir equation (SCS, 1975) where appropriate. A 20 cm Secchi disk was lowered on the shady side of the boat to evaluate water transparency at the in-lake stations. Analyses of chlorophyll concentration and features of the phytoplankton and zooplankton communities were made for those locations as well. Phytoplankton samples were obtained from a depth integrated epilimnetic composite sample, while zooplankton samples were collected by oblique tow of an 80 micron mesh net. Phytoplankton samples were preserved with Lugol's solution and zooplankton samples were preserved with a formalin solution. Plankton samples were analyzed microscopically for species composition, relative abundance and biomass. The size distribution of the zooplankton was also assessed, and all data were recorded and tallied using a microcomputer routine developed by BEC and Cornell University personnel.

Sediment samples were obtained from the in-lake stations with a manual coring device (5 cm diameter lucite tube) operated by a SCUBA diver, providing a cross section of bottom sediment strata. Samples were analyzed by Arnold Greene Testing Laboratories for total Kjeldahl and nitrate nitrogen, total phosphorus, organic/inorganic fraction, heavy metals (As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, V, Zn), PCB's, oil and grease, and sodium.

Macrophyte species composition and areal extent of cover were assessed by visual inspection from a boat and by a SCUBA diver. The distribution of summer bottom cover was mapped, noting dominant species in each area. Qualitative notes were made on the subsurface density, composition, and distribution of macrophyte stands by the diver. Macroinvertebrate composition and density were also assessed at that time through dredge and net samples.

A shoreline conductivity survey was conducted in August to locate any major input points for dissolved substances. The probe for the conductivity meter was trailed behind a slow-moving boat, with readings made approximately every 50 meters. Any changes in water temperature or appearance were also noted.

Domestic wells within the Great Pond watershed were sampled for thirteen of the fifteen water quality parameters routinely assessed in surface waters (temperature and dissolved oxygen excluded). One well was sampled on each of the first 13 sampling trips, and 12 well samplings were made on the final sampling trip. Two wells were sampled twice for comparison. Samples were handled and processed in the same manner as the surface water samples.

A questionnaire survey was performed to assess the preferences and practices of watershed residents. Questionaires were prepared by BEC and distributed and collected by the Eastham Conservation Commission. Emphasis was placed on properties near the lake, but residences up to 1000 m from Great Pond were surveyed. Responses were tallied and interpreted by BEC personnel.

LAKE AND WATERSHED DESCRIPTION AND HISTORY

Lake Description

Great Pond is located in the Town of Eastham, Barnstable County, Massachusetts. It lies on Cape Cod at latitude 41°50'00" and longitude 69°59'25", encompassing an area of 44.7 ha (Table 1). Great Pond has a deformed triangular shape (Figure 2) with depth contours forming depressions near two of the three "corners" of the pond. The hypsograph for Great Pond (Figure 3) indicates a rather even partitioning of pond area among possible depths, down to 8 m. The mean depth of the pond is 3.6 m and the maximum depth is 11 m, allowing thermal stratification in the two deep holes during summer. On average, a total volume of 1.62 million cu.m of water is impounded. The detention time for water in Great Pond ranges from 0.26 to 0.77 yr on an annual basis, with a predicted long-term mean of 0.41 yr.

Great Pond is fed primarily by ground water, but there is a small tributary leading from Deborah Pond on the east and a small ditch which allows drainage from the swampy area to the north of the pond. Precipitation represents the only other detectable source of water; area soils are too porous to allow substantial runoff even during major events. Outflow is also primarily via ground water, although there is a constant flow of surface water into Bridge Pond to the west and then out to the bay via Herring Run.

There are developed beaches on the east and west sides of Great Pond, with a devcloped boat ramp adjac[illegible] beach (Figure 2). The eastern beach is known locally as the Town Beach, while the western one is referred to as Wiley Park Beach. Along with the woodland associated with Wiley Park to the west, these beaches afford excellent public access to Great Pond.

Great Pond is one of 151 Cape Cod lakes with an area greater than 4 ha (10 ac) (Strahler 1972), and exceeds the mean area of 24.3 ha (60 ac). Shoreline development has destroyed the pristine nature of many of these lakes, but Great Pond remains one of the visually most appealing lakes. Great Pond is the largest and deepest lake in Eastham, and is subject to the most intense recreational use.

Watershed Description

The watershed of Great Pond is not well defined, given the importance of ground water flow to the pond and uncertainty regarding ground water flow paths in Eastham. Based on surface topography (Figure 1) and interpretation of a ground water elevation map prepared by the Cape Cod Planning and Economic Development Commission (CCPEDC) (Figure 4), the surface and ground water drainage basins were delineated as shown in Figure 5. The area of the potential surface water drainage is 132.1 ha,

TABLE 1

CHARACTERISTICS OF GREAT POND AND ITS WATERSHED

Lake Measures

Location: Barnstable County, Town of Eastham, 41o50'00" lat. 69o59'25" long.

Area:	44.7 ha	(110.5 acres)
Depth: Mean	3.6 m	(11.8 ft.)
Maximum	11.0 m	(36.1 ft.)
Volume:	1.62 million m3	(1315 acre-ft.)
Detention Time: Mean	0.41 yr	(148 days)
Range (annual means)	0.26-0.77 yr	(95-281 days)
Longest Fetch	880 km	(2887 ft)
Greatest Distance Perpendicular To Fetch	800 km	(2624 ft)
Shoreline Length	3095 km	(10154 ft)
Shoreline Development	1.31	

[illegible]s

Area (Excluding Great Pond):		
Surface Water Drainage	132.1 ha	(326.5 acres)
Probable Ground Water Drainage	200.1 ha	(494.5 acres)
Combined Surface and Ground Water Drainage Areas (Some Overlap)	275.5 ha	(680.8 acres)
Watershed Area/Lake Area	6.2	
Land Use: % Residential	67.7	
% Residential/Commercial	13.0	
% Forest	7.6	
% Water (Excludes Great Pond)	5.3	
% Open (Landfill/Gravel Pit)	4.3	
% Cemetery	2.1	

FIGURE 2

BATHYMETRIC MAP OF GREAT POND, EASTHAM

(Intervals in meters)

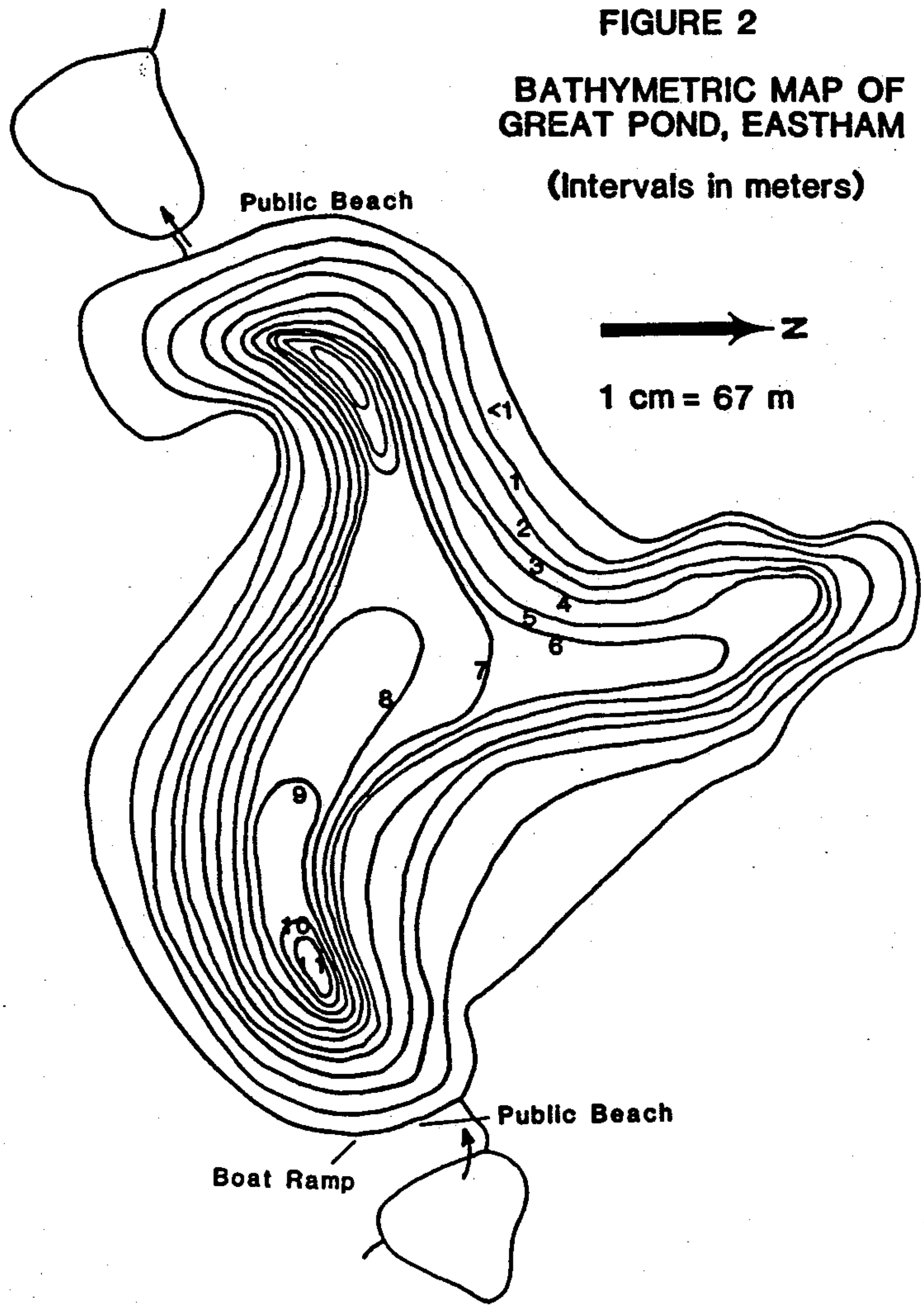
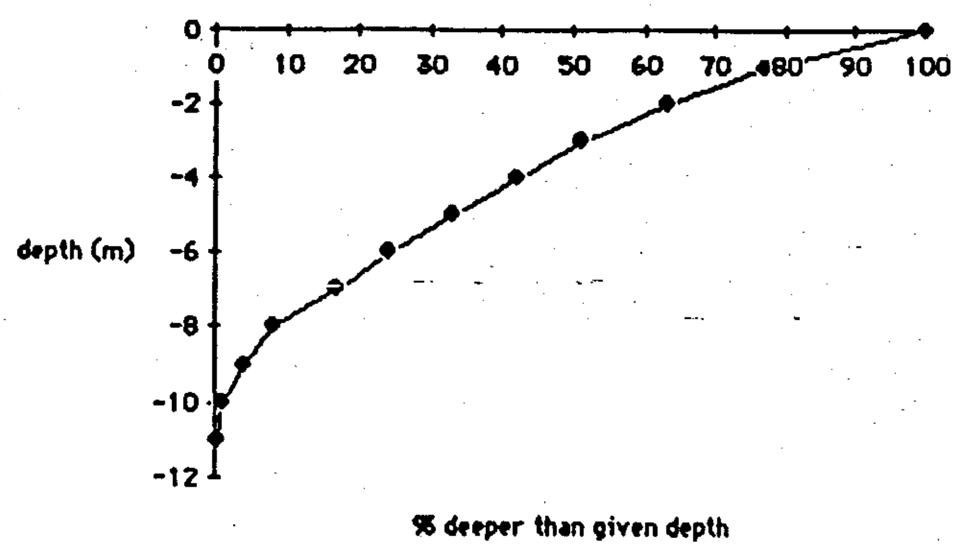


FIGURE 3

Great Pond Hypsographic Curve



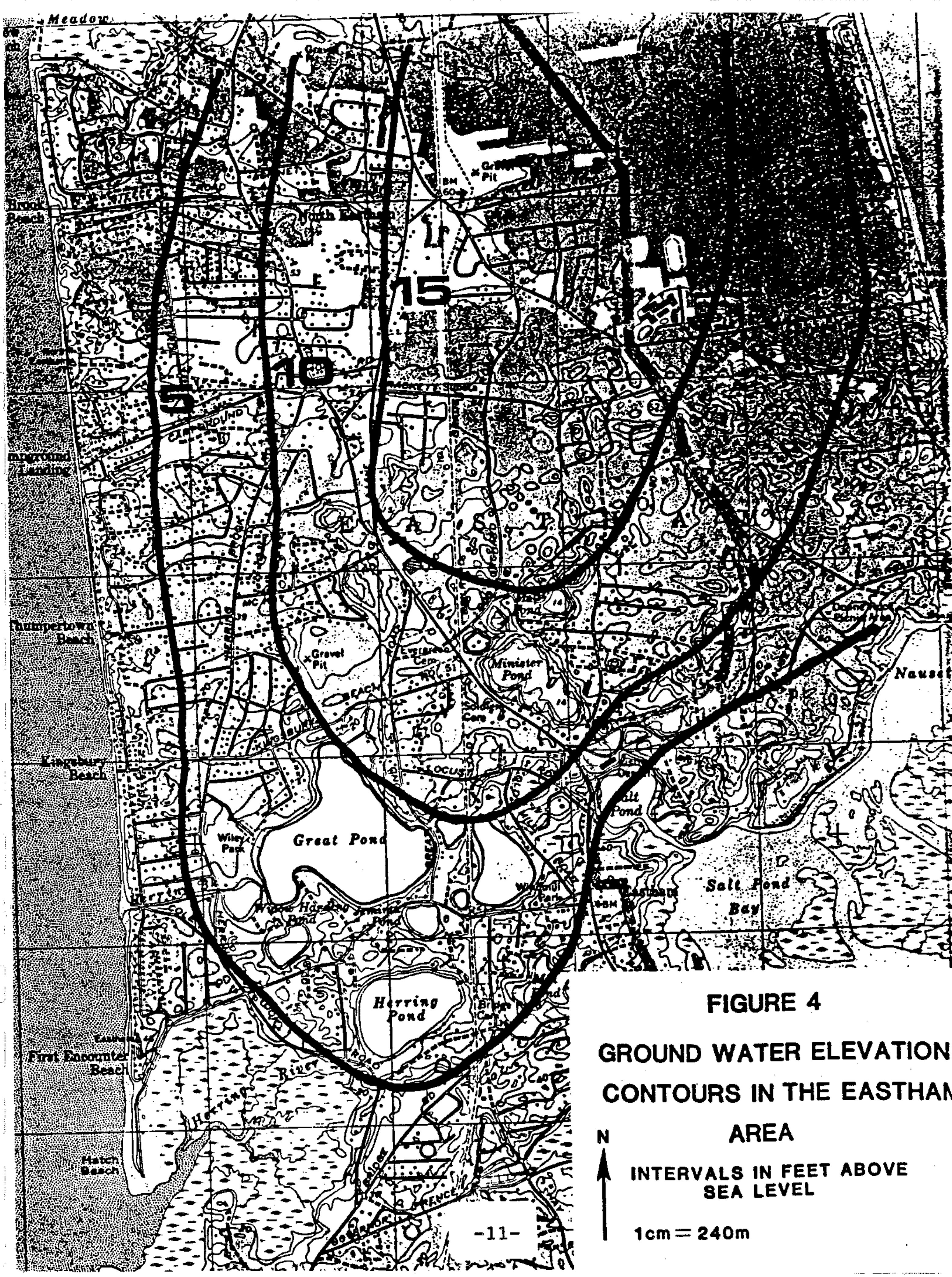
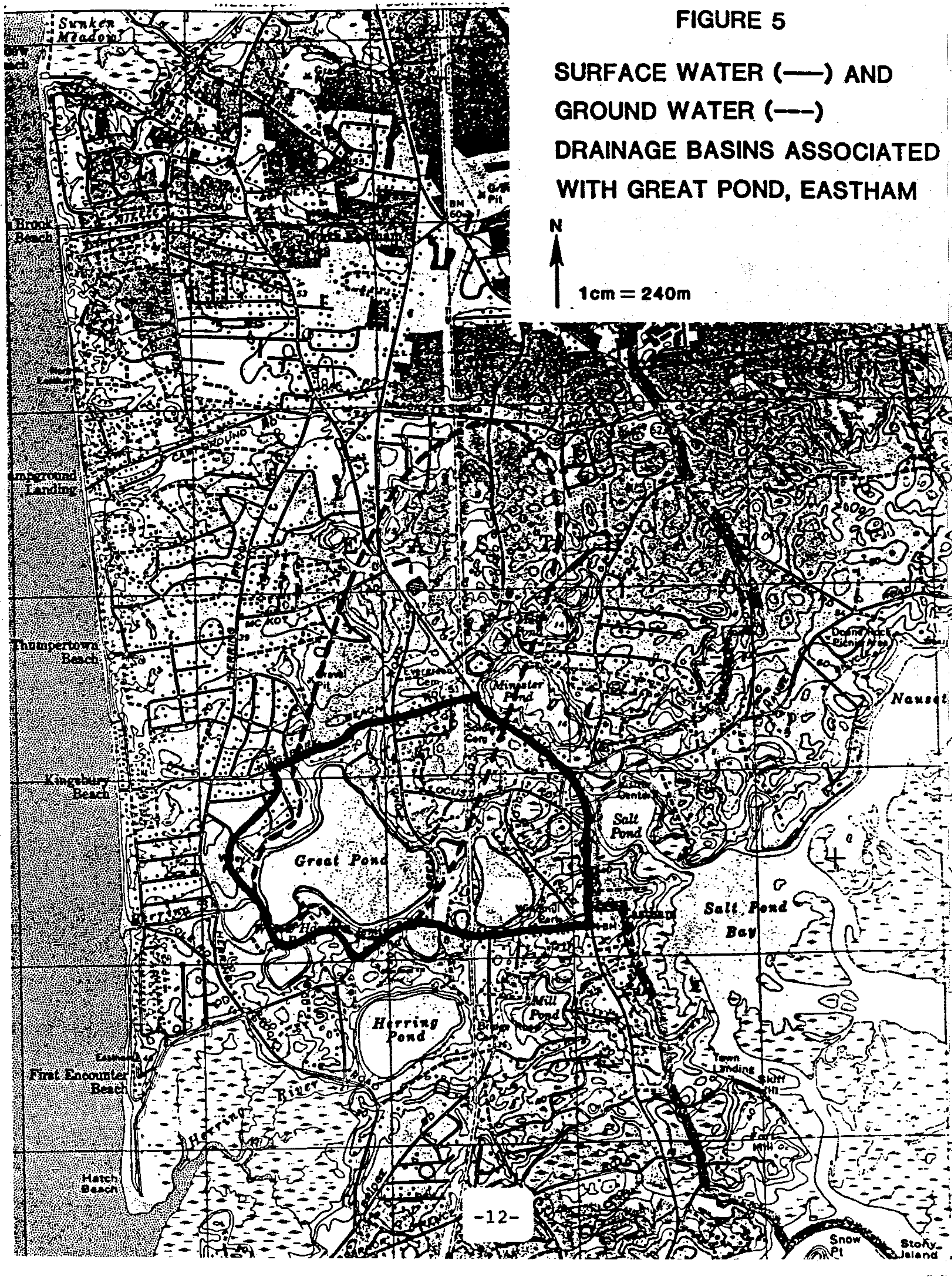


FIGURE 4

GROUND WATER ELEVATION CONTOURS IN THE EASTHAM AREA

FIGURE 5

SURFACE WATER (——) AND
GROUND WATER (– – –)
DRAINAGE BASINS ASSOCIATED
WITH GREAT POND, EASTHAM



while that of the postulated ground water basin is 200.1 ha. The total estimated watershed area (excluding overlap in ground and surface water contribution zones) is 275.5 ha (Table 1).

The small watershed to lake area ratio of 6.2 suggests great potential for the control of pollutants in the watershed and successful management of Great Pond water quality. At ratios of 10 or more such management becomes more difficult, while at ratios higher than 50 it becomes almost impossible to economically control water quality at all times. Watershed geology, soils, and land use greatly affect the relationship between watershed:lake area ratio and water quality, but most sources of pollution can be effectively managed when the watershed is small in both the absolute and relative senses.

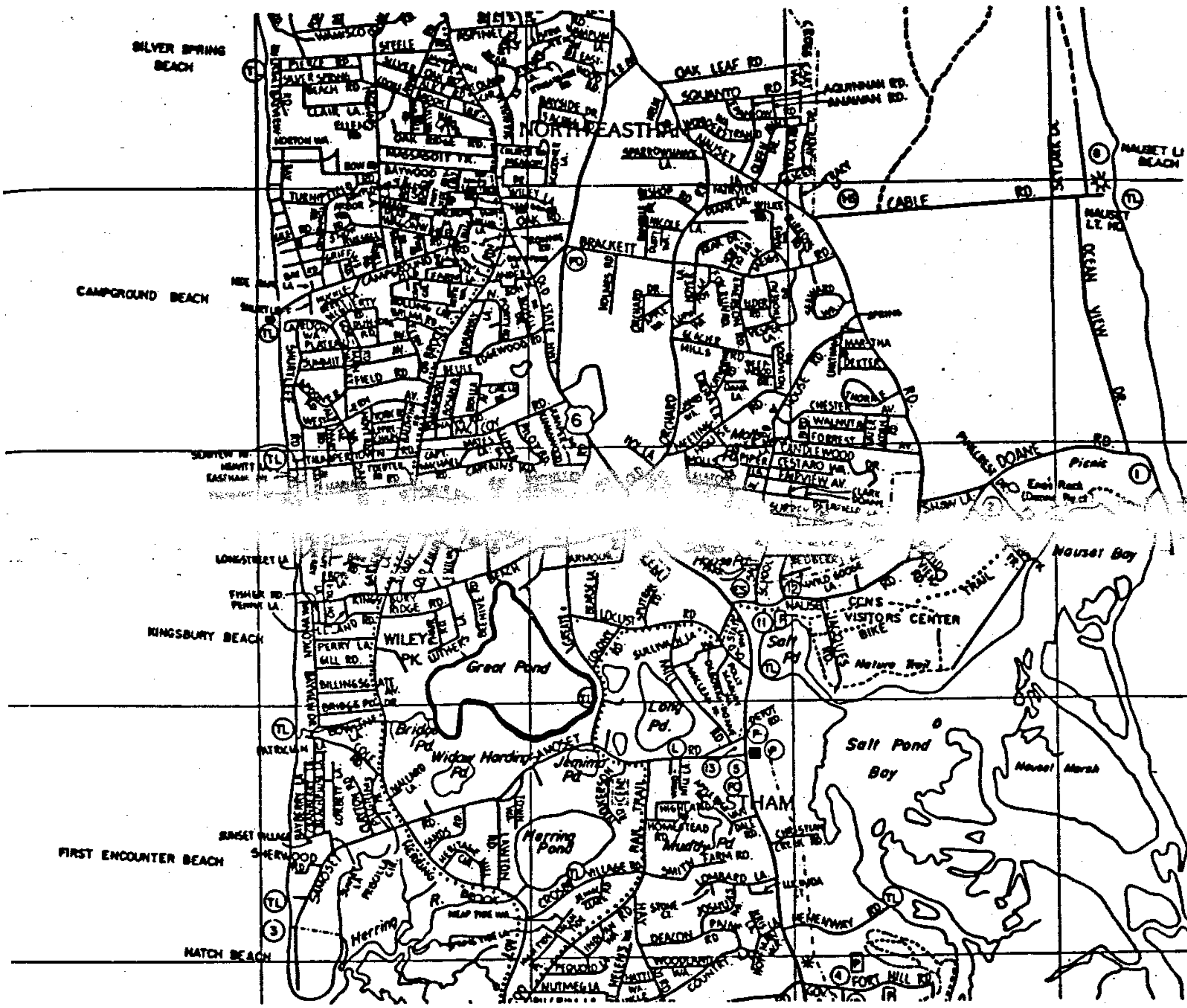
Land use in the Great Pond watershed consists mainly of low density residential housing, although the density is rapidly increasing as a consequence of minimal zoning regulation and perceived desirability of the area. The reticulate pattern of streets (Figure 6) indicates the developed, residential nature of the watershed. Over two-thirds of the land in the watershed (ground and surface water drainage, Figure 7) is specifically residential, while an additional 13% is residential/commercial. Residential/commercial lands are mostly associated with the highly developed Route 6 corridor. Open land, such as gravel pits and the town's landfill, and cemeteries comprise about 6.4% of all land in the watershed. Less than 8% of the land remains totally wooded, although most residences are built on lots with considerable tree cover.

The remaining land in the watershed (5.3%) is occupied by water bodies other than Great Pond (Figure 8). Deborah, Depot, Long, and Minister Ponds are all within the Great Pond watershed, although only Long and Deborah Ponds have a surface water connection with Great Pond. Bridge Pond is also connected to Great Pond by a surface water channel, but receives flow from Great Pond and is technically not part of the Great Pond watershed. Nearby Widow Harding, Jemima, and Herring Ponds are not considered to be within the Great Pond watershed, but may be influenced by ground water associated with the Great Pond watershed.

The porous nature of the soil in Eastham and lack of an extensive storm sewer system (only some leaching pit drains are used) results in percolation of most precipitation. The ground therefore acts as a filter for waterborn pollutants, removing susceptible contaminants from much of the flow into Great Pond. Of particular concern in Eastham are on-site domestic wastewater disposal systems, the town landfill, and road salting operations. All constitute potential threats to the integrity of the ground water supply, which provides water for domestic consumption as

FIGURE 6

STREET LAYOUT IN THE VICINITY OF GREAT POND, EASTHAM



N

1cm = 310m

FIGURE 7

LAND USE IN THE GREAT POND WATERSHED

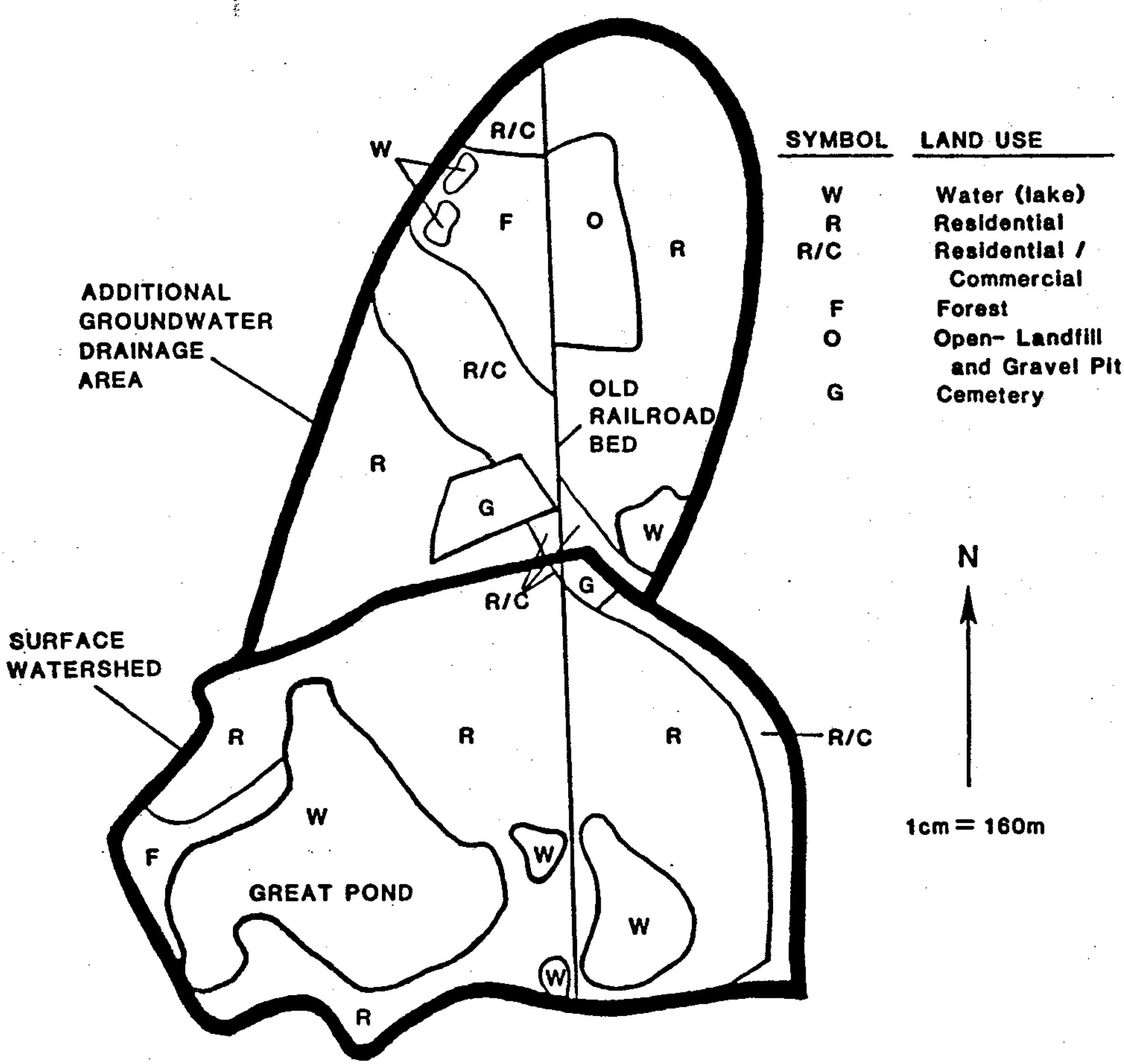
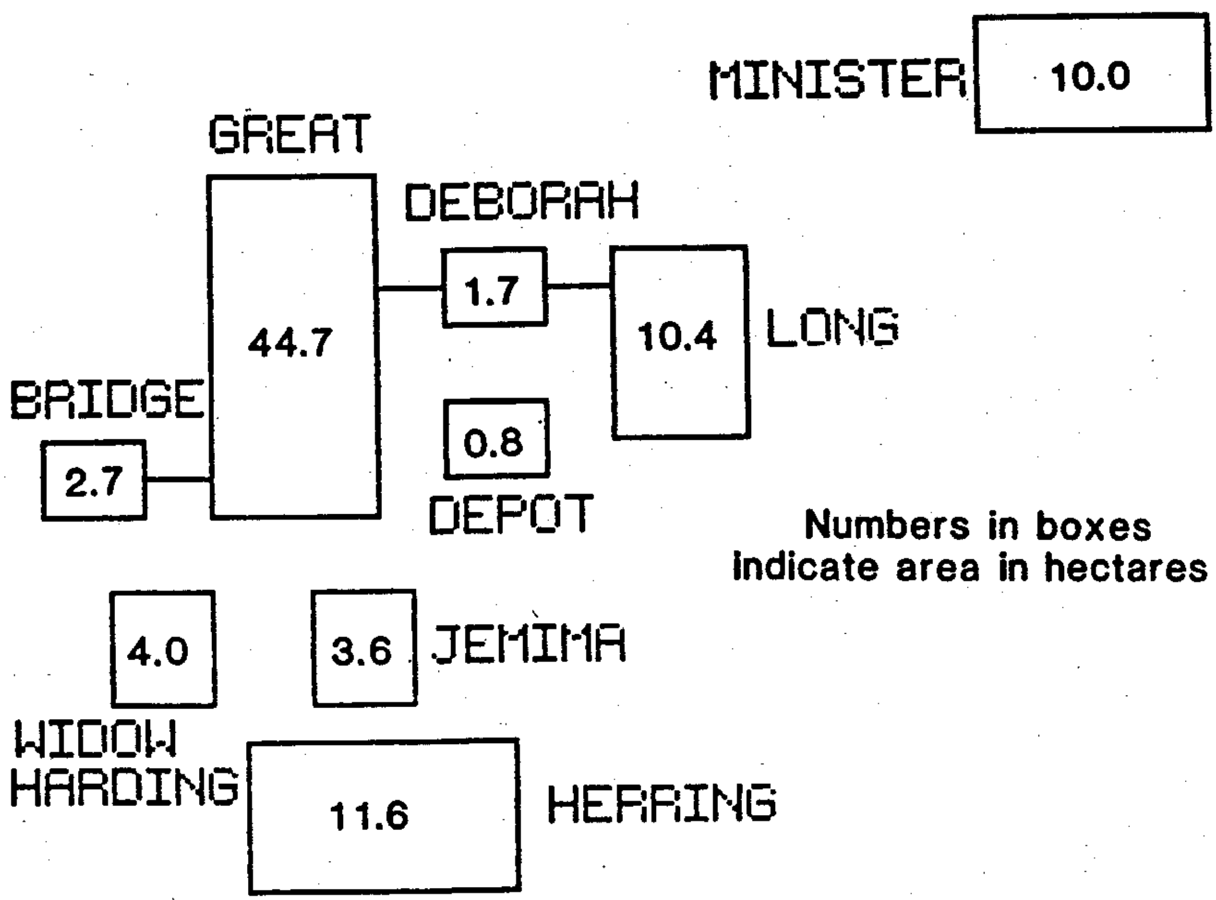


FIGURE 8

SCHEMATIC OF SELECTED EASTHAM PONDS



well as for the maintenance of Great Pond. There are no known industrial or agricultural activities of any consequence to water quality in the Great Pond watershed. Direct precipitation is the only source of water and pollutants not subjected to ground filtration. While acidic precipitation constitutes a threat to poorly buffered aquatic systems, most lakes on Cape Cod are naturally acidic. The nutrient load deposited atmospherically is usually only a minor part of the total load received by lakes, and is rarely a cause for concern.

Watershed Geology and Soils

The Generalized Geologic Map of Cape Cod (Oldale 1985) shows most of Eastham and all of the Great Pond watershed as Eastham Plain Deposits, defined as mostly gravelly sand deposited as glacial outwash. Stone counts in Eastham Plain Deposits are dominated by felsic volcanic rock, and these deposits represent the youngest glacial drift on the Cape. Sites of ice-contact with the drift are marked by deposits of silt and clay, which today complicate the flow of subsurface water in Eastham. Melting blocks of ice embedded in the countryside, left behind by the melting glacier, created lakes known as kettleholes. All the Eastham Lakes were formed in this manner.

The soils which have developed in the Eastham area are predominantly coarse sands of the Carver and Eastchop Series (Figure 9). Permeability of these soils is very rapid, and they allow minimal runoff. Subsoils are sometimes of a finer nature in the Eastchop Series, but these soils have poor filtering capabilities associated with their use in waste disposal systems. They support growths of scrub oak and pine in most cases, and have associated slopes ranging from 0 to 15%.

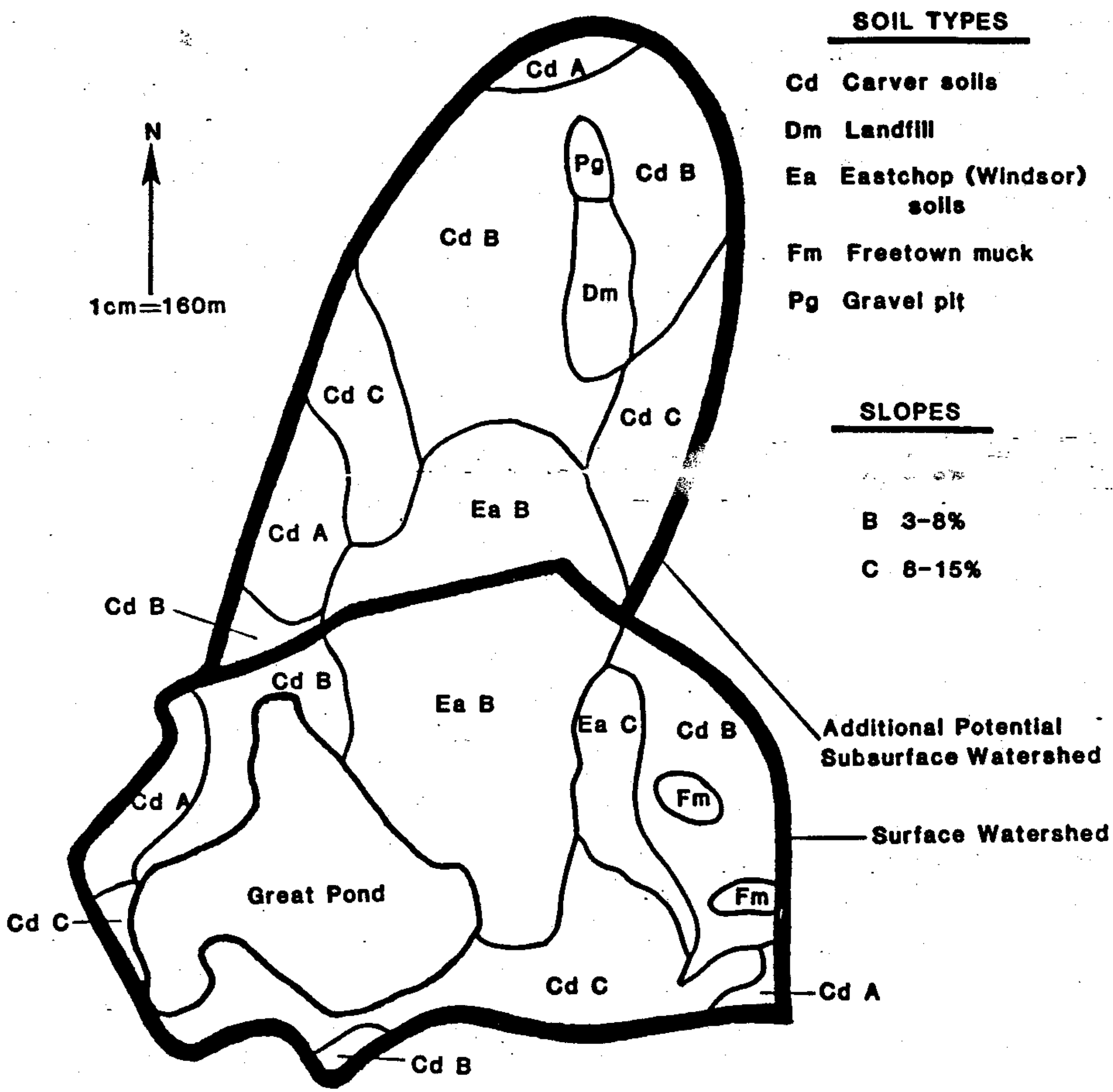
The only other actual soil found in the Great Pond watershed is Freetown Muck, an organically derived material with poor drainage characteristics. It is most often associated with low lying wetlands, and is rather rare in this watershed. Two other soil type designations, Landfill and Gravel Pit, are more appropriately land use categories. These designations indicate that the original soil has been stripped or modified in such a way as to preclude characterization by the standard soil series names. The dominant features of areas so designated are obvious from their names.

Historical Lake and Land Use

Eastham was incorporated in 1651, and included parts of five other towns at the time. Previously the area was inhabited by Wampanoag indians, with a few white settlers beginning in the 1640's. The topsoil which had accumulated since the last glaciation supported a rich forest, but the gradual settlement by white men led to almost complete deforestation by the mid-1800's. Clearing for agriculture and the collection of firewood for salt

FIGURE 9

CLASSIFICATION OF SOILS IN THE WATERSHED OF GREAT POND, EASTHAM



production by evaporation of seawater were the major influences on area vegetation and soil. A 1920's aerial photograph provided by Mr. Robert Mumford shows considerable open land in the Great Pond area even then. Only in the last 50 years has Eastham regained an appreciable tree cover.

Agriculture was the mainstay of the Cape Cod economy until the early 1900's, when tourism began to increase dramatically. Although much of the topsoil was lost after deforestation, farming activity persisted. Most of the Great Pond watershed was part of a large granary, which fed the Union troops during the Civil War. Agricultural activities gradually shifted from grains to other crops during the 1800's, with several orchards located near Great Pond around 1850. The land south of Great Pond became a large asparagus farm run by the Clarks. An asparagus farm was also established to the north of the pond by the Smith family, and the Hatches grew potatoes immediately east of the pond. Asparagus grown in the area was marketed as Beehive brand and served in the best Boston hotels. These farms persisted until about the time of the Depression.

In 1872 a railroad was built through the watershed, passing just east of Great Pond and separating Long Pond from Depot and Deborah Ponds. A station was built off Samoset Road east of Great Pond. Nearby a general store was constructed, and a fish processing plant was erected on Depot Pond by the Nickerson family. A leather tannery was constructed on the south shore of Great Pond; it was gone by 1920, but a few timbers from that structure are still visible near the shoreline in that area. [illegible] saltworks in the nearby tidal marsh made use of the railroad until they were put out of business by the discovery of salt near Syracuse, NY around 1900.

From about 1910 to 1930 there was a commercial ice operation on Great Pond, with an ice house on the south shore. Two-foot ice blocks were cut, which is interesting in light of the slight to non-existent ice cover now experienced by the pond. The sheltering action of relatively recent tree cover may be responsible, as it restricts wind-mediated cooling of pond waters.

In the very early 1900's Mr. Quincy Shaw started the Great Pond Trust, which purchased most of the north, west, and south shoreline and used the lake to hunt waterfowl. Members included Mr. R. Mumford, who purchased the former Richardson estate on the south peninsula in the 1920's and bought out the other Trust members. He sold much of the land during the 1930's, but turned the estate over to his son, who lives there now.

Land use changed rapidly from the 1930's until recently. Much of the shoreline of area ponds was inaccessible to all but the hardiest nature enthusiasts in 1930, and there were very few shoreline residences. In addition to land sales by Mr. Mumford, the Hatch family (which still lives near Great Pond) sold much of its land in the 1930's. The town purchsed a parcel which included the site of the present town beach. Land around Deborah Pond was subdivided into house lots and sold. Rental units appeared adjacent to Great Pond. The former asparagus farm to the north of Great Pond was used to grow gladiolas for some time, but it too was eventually subdivided and sold as house lots.

The demise of the railroad between 1936 and 1948 and increased emphasis on travel by motorized vehicles led to considerable road construction in Eastham and throughout Cape Cod. Recreational use of the Cape expanded dramatically, and a building boom began. In 1851 there were only six homes within 300 m of Great Pond and only a few dozen in the watershed. Over the next century there was only slight development, resulting in the housing and road density shown in Figure 10. Comparison of Figure 10 with Figure 5 demonstrates the great extent of development between 1946 and 1974. Since 1974 the population of Eastham has grown by almost 70% (Boston Globe 1986), and it continues to grow.

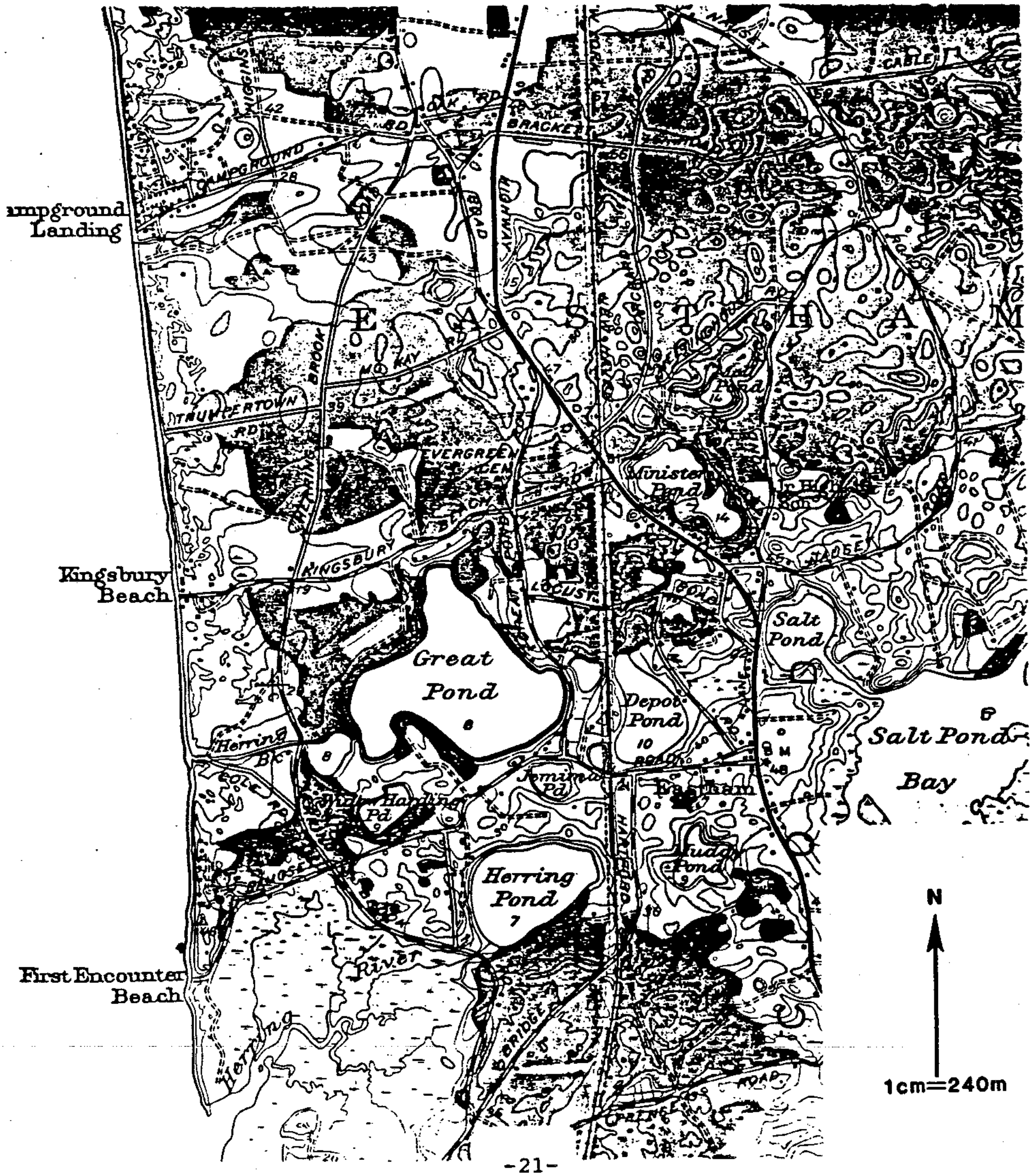
Prior to World War II, the largest population in Eastham was 966 in 1830 (Eastham Open Space Committee 1986). The population was only 430 in 1920, and rose to only 600 by 1946. In 1980 the [illegible] ...er peak population of [illegible] ...e permanent population at 4,043 and the peak at 20,447. Population density now ranges from about 300 to 1,435 people per square mile over the course of the year.

The increasing demand for housing has led to a 600% increase in urban land in Eastham since 1951 (Eastham Open Space Committee 1986). Preserving undeveloped land has become quite a chore, aided only by the Massachusetts Wetland Protection Act and town purchase of land. Subdivision of the present Wiley Park into about 70 house lots was proposed prior to its purchase by the town in 1971. The current and long-standing zoning regulation of 20,000 sq.ft per house is inadequate to preserve the character of the landscape. Almost miraculously, there are less than a dozen lakefront homes at Great Pond, although there are 27 parcels of land which include shoreline property.

Increases in permanent residences and the seasonal peak population have raised the volume of traffic and waste generated in Eastham. The average annual traffic volume for Eastham in 1983 was between 10,000 and 15,000 vehicles per day (Eastham Open Space Committee). Wastewater disposal is by on-site systems, many of which are very old cesspools. Solid waste (trash) and pumped septic wastes are deposited in the town landfill, which

FIGURE 10

MAP OF THE GREAT POND, EASTHAM AREA IN 1946



lies at the northeast (upgradient) end of the Great Pond watershed. This area was established as a town dump site in 1935, and has been in operation as a landfill since about 1970.

Transformation of Cape Cod into a summer resort area has greatly boosted the economy of that region, and recreational opportunities and support facilities are numerous. Along Route 6 in Eastham there are many hotels, motels, and guest houses, several of which lie in the Great Pond watershed. Restaurants, gas stations, and assorted stores also line this corridor. Recreation centers on water-based activities involving the ocean, bay, area lakes, and motel swimming pools.

Great Pond is the largest and most popular of Eastham's ponds, and affords opportunities for swimming, snorkeling, scuba diving, windsurfing, canoeing, rowing, power boating, waterskiing, fishing, bird watching, and other more passive uses. One lakefront resident even lands his seaplane on the lake. The town maintains two beaches and a boat ramp for the use of the public, and Wiley Park provides shoreline trails in a wooded setting.

With many users and multiple uses, there has been an increasing need for "people management" at Great Pond. The town has adopted, and periodically modifies, a series of regulations intended to manage the use of Great Pond for the greatest benefit of both users and the environment. A policy of every-other-day motor use has been adopted, allowing swimmers, windsurfers, canoeists, fishermen, and those seeking [illegible] opportunity to enjoy this relatively small lake without interference. Supervised swimming is restricted to roped areas at each beach. Registration of motorboats is required, and engines larger than 50 horsepower are prohibited. In each of the last two years there have been 50 motorboats registered for use on Great Pond. Guidelines for waterskiing have been promulgated in an effort to promote safety and minimize effects on the lake (e.g., no shallow water starts).

Fishing was augmented by the construction of Herring Run, an artificial channel connecting the bay with Bridge, Great, and Deborah Ponds, sometime in the late 1800's. Alewife, known locally as herring (they are members of the herring family), run up this channel each spring and spawn in the ponds. After several months of growth, young alewife rejoin their older relatives in the ocean, where they form a valuable link in the marine food web. To encourage this cycle, the town has maintained Herring Run since 1968, building gates and weirs to ensure adequate water depth for the run. Alewife may be netted only at the bay end of the run.

Great Pond has received some recreational use as far back as records go, but there is no question that its recreational use peak is occurring now and may continue indefinitely. The time is right to examine pond condition and potential threats to its recreational utility, and to take remedial action before substantial damage is done to the environment and economy of the area.

Limnological data were collected for one year in an effort to assess pond condition and evaluate temporal and spatial variability in physical, chemical, and biological features. Through this data collection effort we attempt to learn how the system functions and which factors are important to its well-being. Considerable information is generated, and one must sort out the critical items from those of general interest or minimal utility in the management of the system. Therefore, in the interest of brevity, most raw data have been incorporated into a technical appendix which serves as a support document to this report. Calculation sheets which detail the derivation of useful values and other information of secondary importance have also been included in the technical appendix.

Water Chemistry

The chemical nature of Great Pond influences biological characteristics, and is itself greatly influenced by the rate of transfer of substances into and out of the water column. Flow characteristics are therefore of major potential importance in the system. Inflow from tributaries is slight; the two small streams entering Great Pond have mean flows of 0.11 and 0.15 cu.m/min (Table 2). Flows from these sources rarely exceed 0.5 cu.m/min. Yet the outlet exhibits a mean flow of 1.65 cu.m/min, with a minimum flow in excess of the sum of the mean tributary values. Clearly ground water inflow is important in this system, as it is in most kettlehole lakes. Flow from [illegible] addressed in more detail in the Hydrologic Budget section of this report.

Phosphorus is usually viewed as the key plant nutrient in aquatic (and often terrestrial) systems. It is most often the element in shortest supply in relation to the needs of plants, and is more easily controlled than most other essential plant nutrients. The level of phosphorus in a lake is therefore of critical importance to the condition of the system.

Mean, maximum, and minimum total phosphorus values are relatively stable over the nine regularly sampled stations. Means range from 30 ug/l at the outlet to 52 ug/l at station 2 (Figure 1, Table 1). There is no discernible vertical or horizontal gradient of total phosphorus concentration in Great Pond. The maximum value for all but three stations exceeded 100 ug/l, while the minimum values were less than 20 ug/l. There was no strong seasonal pattern associated with the total phosphorus data.

The total phosphorus data suggest moderate to high fertility for Great Pond, but the bio-availability of much of the

TABLE 2

VALUES OF MONITORED PARAMETERS THE GREAT POND SYSTEM

PARAMETER	UNITS	VALUE TYPE	G-1		G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
FLOW	CU.M/MIN	MEAN	0.11								1.65
		MAXIMUM	0.68								3.74
		MINIMUM	0								0.34
TOTAL PHOSPHORUS	UG/L	MEAN	41		35	35	37	44	37	30	30
		MAXIMUM	100		100	80	100	290	75	70	100
		MINIMUM	10		10	13	15	10	18	10	5
ORTHOPHOSPHORUS	UG/L	MEAN	12		10	10	10	10	10	10	12
		MAXIMUM	20		20	10	13	20	13	13	35
		MINIMUM	10		5	10	10	5	10	5	5
AMMONIA NITROGEN	MG/L	MEAN	0.02		0.02	0.02	0.21	0.01	0.01	0.27	0.02
		MAXIMUM	0.04		0.07	0.04	1.70	0.03	0.02	2.10	0.12
		MINIMUM	0.01		0.01	0.01	0.01	0.01	0.01	0.01	0.01
NITRATE NITROGEN	MG/L	MEAN	0.03		0.04	0.05	0.06	0.04	0.03	0.04	0.04
		MAXIMUM	0.12		0.16	0.11	0.29	0.14	0.11	0.21	0.20
		MINIMUM	0.01		0.01	0.01	0.01	0.01	0.01	0.01	0.01
TOTAL KJELDAHL NITROGEN	MG/L	MEAN	0.59		0.43	0.46	0.60	0.47	0.75	0.76	0.48
		MAXIMUM	1.20		0.81	0.58	2.10	1.00	2.80	1.90	0.99
		MINIMUM	0.32		0.18	0.31	0.12	0.25	0.28	0.23	0.22
NITROGEN:PHOSPHORUS RATIO	NONE	MEAN	34.8		31.0	33.0	40.6	27.0	48.2	54.3	40.6
		MAXIMUM	75.4		44.3	56.3	54.6	59.4	88.7	53.7	105.6
		MINIMUM	30.2		22.2	19.7	19.8	9.0	36.8	48.2	27.2
TEMPERATURE	CELSIUS	MAXIMUM	19.9	[illegible]	24.8	24.1	17.1	24.8	23.2	18.2	24.8
		MINIMUM	1.0	[illegible]	0	16.0	0.2	0.1	15.4	2.2	0.2
DISSOLVED OXYGEN	MG/L	MEAN	9.7	[illegible]	10.0	5.9	4.1	9.7	5.8	2.3	9.4
		MAXIMUM	12.6	[illegible]	14.1	9.8	13.6	14.2	9.5	9.2	14.6
		MINIMUM	4.4	[illegible]	7.8	2.3	0	7.2	1.7	0	6.2
D.O. SATURATION	%	MEAN	81.1	[illegible]	97.1	64.8	32.0	94.7	63.2	18.6	89.5
		MAXIMUM	108.2	[illegible]	109.2	99.3	106.9	105.8	95.0	73.0	109.0
		MINIMUM	44.6	[illegible]	84.2	26.2	0	77.1	18.7	0	74.8

TABLE 2 CONTINUED

TOTAL SUSPENDED SOLIDS	MG/L	MEAN	4.2	5.3	4.3	3.8	8.8	2.1	3.6	11.0	2.4
		MAXIMUM	15.0	20.0	19.0	6.8	44.0	4.8	8.0	46.0	6.8
		MINIMUM	0.8	0.8	0.4	0.8	1.2	0.4	0.4	0.4	0.4
TOTAL DISSOLVED SOLIDS	MG/L	MEAN	72	96	73	61	84	67	57	69	58
		MAXIMUM	116	152	116	80	244	115	83	104	109
		MINIMUM	29	57	31	21	21	15	24	44	21
CONDUCTIVITY	UMHOS/CM	MEAN	140	152	158	154	163	155	153	164	157
		MAXIMUM	192	200	202	180	208	201	185	210	210
		MINIMUM	118	127	140	142	139	139	139	140	132
PH	S.U.	MAXIMUM	6.7	6.3	7.1	7.0	6.9	7.1	7.1	6.9	7.0
		MINIMUM	5.8	5.0	6.7	6.4	6.3	6.9	6.6	6.3	6.3
TOTAL ALKALINITY	MG/L	MEAN	5.6	5.2	8.8	9.1	11.7	8.9	9.4	12.7	8.9
		MAXIMUM	7.7	9.0	11.0	11.0	28.0	11.0	11.0	31.0	10.0
		MINIMUM	3.2	1.1	7.1	8.1	7.2	7.9	7.7	8.6	7.5
CHLORIDE	MG/L	MEAN	25	26	28	2	26	25	24	26	27
		MAXIMUM	32	32	43	27	42	32	37	35	33
		MINIMUM	17	20	19	20	18	20	19	21	21
FECAL COLIFORM	N/100ML	MEAN*	5	5	1			1			1
		MAXIMUM	338	150	5			6			14
		MINIMUM	0	0	0			0			0
FECAL STREPTOCOCCI	N/100ML	MEAN*	7	12	4			2			2
		MAXIMUM	380	460	165			37			263
		MINIMUM	0	0	0			0			0
FC:FS RATIO	NONE	MEAN	0.3	2.8	0.4			0.6			0
		MAXIMUM	1.4	18.8	3.0			4.0			0
		MINIMUM	0	0	0			0			0
CHLOROPHYLL A	UG/L	MEAN			7.8			8.4			
		MAXIMUM			28.0			21.0			
		MINIMUM			1.6			2.5			
SECCHI DISK TRANSPARENCY	METERS	MEAN			3.4			3.2			
		MAXIMUM			4.8			4.5			
		MINIMUM			2.5			2.1			

* GEOMETRIC MEAN APPLIED INSTEAD OF ARITHMETIC MEAN.

phosphorus is questionable, as a large fraction of total phosphorus may be bound in forms unusable by plants. Orthophosphorus represents the other end of the availability scale, functioning as an estimator of minimum available phosphorus. Mean values (Table 2) ranged from 10 to 14 ug/l, but many of the individual values obtained were below the lower detection limit of 10 ug/l for orthophosphorus. Extrapolation of the standard curve allowed the laboratory to calculate values as low as 5 ug/l for some samples. Available phosphorus would therefore appear to be in short supply in this system.

Maximum orthophosphorus values ranged from 10 to 43 ug/l, with no in-lake values over 20 ug/l. Since some phosphorus can be scavenged from particulate matter, the available phosphorus fraction is probably somewhat larger than the orthophosphorus portion, and available phosphorus may be cycled rapidly. The rate of plant production may therefore be fairly high, but the standing crop of plants dependent on phosphorus in the water column is unlikely to be very large. Algal blooms should therefore be fairly rare, and one might expect moderately clear water and a sizeable crop of rooted aquatic plants in Great Pond.

Nitrogen is another important plant nutrient, and occurs in three major forms in aquatic systems: ammonia, nitrate, and organic compounds. Ammonia and nitrate can be measured directly, while organic nitrogen is assessed as the difference between the total Kjeldahl nitrogen (a digestion-based test result) and ammonia nitrogen. Ammonia and nitrate are readily available for uptake by plants, and the former can be toxic to most animals, depending on the temperature, pH, and dissolved solids level. Nitrogen inputs to aquatic systems are very difficult to control as a consequence of the high nitrogen concentration in the atmosphere and the high mobility of nitrate in soil.

Mean ammonia nitrogen values ranged from 0.02 to 0.27 mg/l for the nine locations sampled, with the higher values occurring at the bottom locations for stations 3 and 4. Ammonia is rapidly converted to nitrite and then nitrate in the presence of oxygen by naturally occurring bacteria, but the lack of oxygen during summer in the deep parts of Great Pond promote the build-up of ammonia through decay processes. There is a potential ammonia toxicity problem in the summer anoxic zone, but the lack of oxygen there precludes the presence of most animal life anyway. At this time, ammonia represents no threat to aquatic life in Great Pond.

Nitrate nitrogen was found at mean concentrations ranging from 0.03 to 0.17 mg/l, with only the mean at station 2 higher than 0.06 mg/l. Maximum values exceeded 0.30 mg/l (an unofficial standard for an acceptable concentration when low algal density is desired) at only station 2, the small tributary on the north side of the pond. Minimum values were all below the detection limit of 0.01 mg/l.

Total Kjeldahl nitrogen (TKN) exhibited mean values ranging from 0.43 to 0.86 mg/l, with maximum values between 0.81 and 2.80 mg/l. Except at stations 3B and 4B, where ammonia levels were occasionally high, most of the TKN was organically bound nitrogen. The values obtained suggest low to moderate quantities of organic matter in the waters of the Great Pond system.

The nitrogen:phosphorus ratio, calculated as [(TKN + nitrate nitrogen)/total phosphorus]x2.21, indicated phosphorus to be in relatively shorter supply than nitrogen at all stations nearly all of the time. This is typical of aquatic systems not grossly disturbed by man's activities, and suggests that phosphorus would be a more appropriate target for control than nitrogen. The ratio does not prove that phosphorus is the limiting factor for growth in the system, however, as influences such as light and other elements have not been considered. Yet in most cases it is easier to create a phosphorus limitation than to attempt to control the other possible influences.

The temperature of water at the sampled stations demonstrated a typical temperate zone seasonal pattern of variation. The surface of Great Pond freezes during the winter, but not to any great ice depth. The ice supported human weight only a small portion of the time it was present, and ice cover was lost and reformed several times during the winter of 1985-86. The bottom waters of Great Pond never got as cold as might be expected in a lake with less ground water influence; ground water temperature varies only slightly from a mean around 12^{o}C and moderates the temperature of Great Pond. Additionally, heat generated from the decay of organic matter produced in preceeding seasons may elevate the water temperature.

Dissolved oxygen levels varied appreciably over time and space, with values lower than 4.0 mg/l detected at station 2 and at the mid-depth and bottom locations at stations 3 and 4. The mean value was below 4.0 mg/l at only station 4B, but the mean at station 3B was only 4.1 mg/l. Water from the swampy area draining into the lake at station 2 is affected by both decay processes and upwelling of oxygen-poor ground water. Water below about 5 m of depth in Great Pond is affected by thermal stratification during summer.

Stratification separates a lower layer of water from the surface layer, eliminating atmospheric inputs of oxygen to the lower layer (hypolimnion). The hypolimnion is rather dark, so there is little oxygen generated by photosynthesis. Decay processes continue to consume oxygen in the hypolimnion, however, resulting in a decline in oxygen concentration. If the oxygen demand is greater than the supply, the oxygen reserves may be depleted and anoxia occurs. Chemical reactions can occur in the absence of oxygen that release phosphorus from the sediment into the water column. Hypolimnetic anoxia is therefore a problem in terms of supporting aquatic life and controlling system fertility.

The range of in-lake oxygen regimes observed during this study is shown in Figure 11. The effect of air temperature and wind on the pond results in minimal vertical variation in oxygen or temperature in early spring, while by mid-summer there is pronounced stratification and hypolimnetic anoxia. The prevailing wind direction is from the southwest, mixing the more exposed eastern basin to a greater extent, but stratification and anoxia occur there as well as in the west basin.

The temporal sequence of thermal stratification can be interrupted by heavy winds, resulting in a rather thick metalimnion (Technical Appendix). Oxygen depletion is also affected by wind action, making the onset and duration of anoxia difficult to predict. By mid-July there is little oxygen below the 6 or 7 m depth level, but the progression to that point is not steady. Stratification is broken in September, with only the deepest waters exhibiting low oxygen values by October.

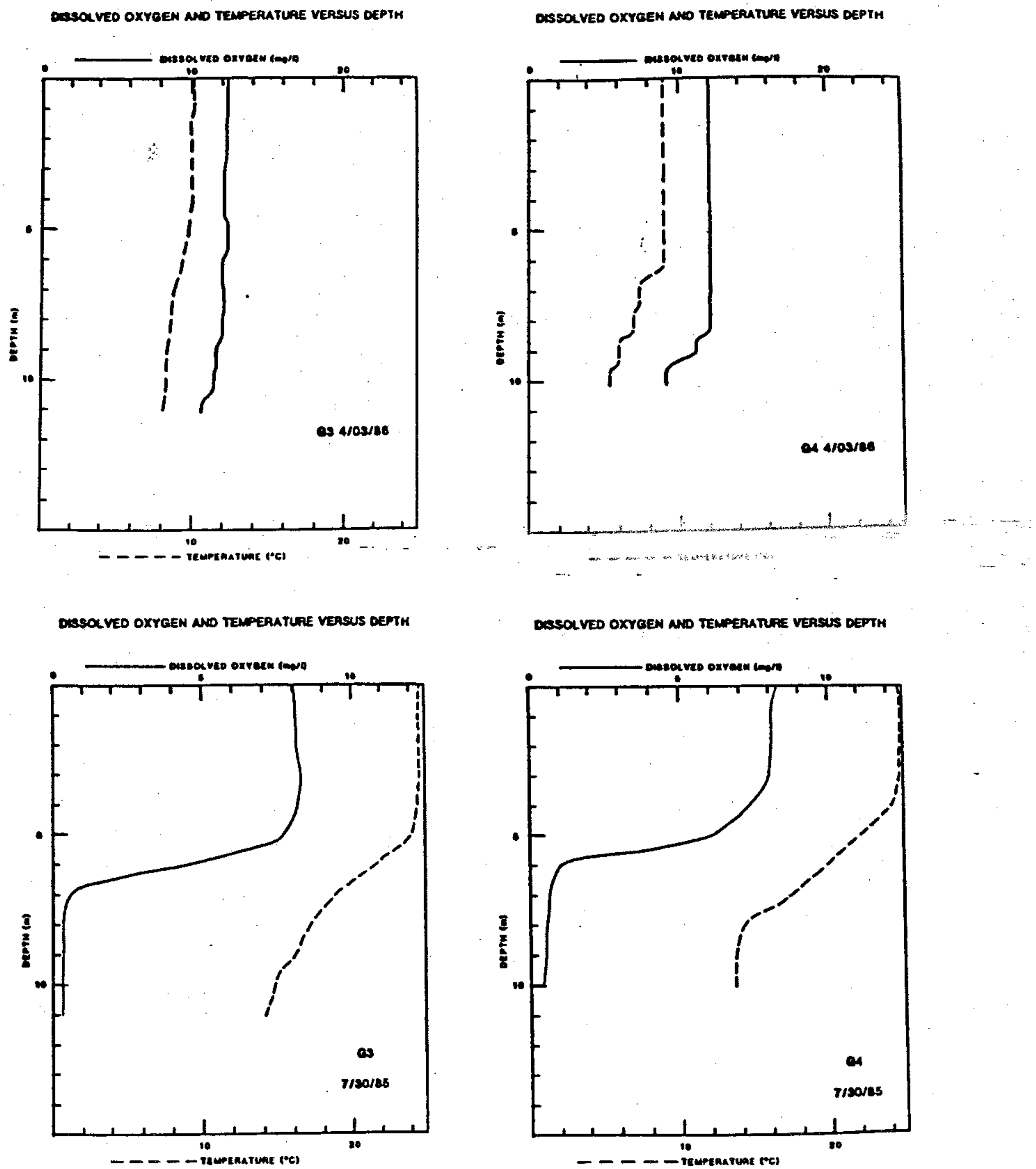
Increases in certain parameters measured at the bottom of a lake are often linked to thermal stratification and oxygen depletion. Few such trends are discernible [illegible] however (Technical Appendix). The effects of wind, ground water introduction, and diffusion appear to override the forces which typically promote the accumulation of phosphorus, ammonia, and dissolved solids in the hypolimnion. Despite detectable thermal stratification and anoxia, the system is not divided into chemically distinct upper and lower water layers.

The amount of oxygen that will dissolve in water is dependent on temperature, dissolved substances, and atmospheric pressure. The relation of the actual oxygen level to the maximum possible concentration is termed the percent saturation, and reveals much about the processes at work in a given system. In the Great Pond system saturation and even supersaturation occur as a consequence of wind action, temperature changes, and photosynthesis, while subsaturation is taken as evidence of an oxygen demand in excess of oxygen inputs.

The surface of the pond and its outlet do not appear to experience any substantial subsaturation (Table 2), but all other stations are subjected to considerable oxygen demands which result in rather low percent saturation levels at times. The lower percent saturation levels are considered undesirable from a

FIGURE 11

REPRESENTATIVE TEMPERATURE - DISSOLVED OXYGEN PROFILES



recreational management viewpoint, but only a small portion of the total pond volume is detectably affected.

Total suspended solids concentrations are generally low (Table 2), although a few moderately high values were observed. Total dissolved solids levels and conductivity readings, both indicative of overall system fertility, averaged near the upper end of the observed range for Cape Cod lakes (Duerring and Rojko 1984a, 1984b), although they were appreciably lower than in many other Massachusetts lakes. Chloride levels were moderate and indicative of human influence; effects from both wastewater disposal systems and road salting operations are likely.

Mean total alkalinity ranged from 5.2 to 12.7 mg/l, with minimum values between 1.1 and 8.6 mg/l. With such slight buffering capacity one might expect low pH values, as is often the case for Cape Cod lakes (Duerring and Rojko 1984a, 1984b). However, biological buffering capacity appears to be substantial in Great Pond, and the minimum in-lake pH was 6.3 standard units (Table 2). Maximum pH was 7.1 units, which is very nearly neutral. The removal of carbon dioxide from the water column by rooted aquatic vegetation during the process of photosynthesis appears to effectively control the pH in the pond. The pH in the tributaries ranged from 5.0 to 6.7, which is normal to slightly high for ground water.

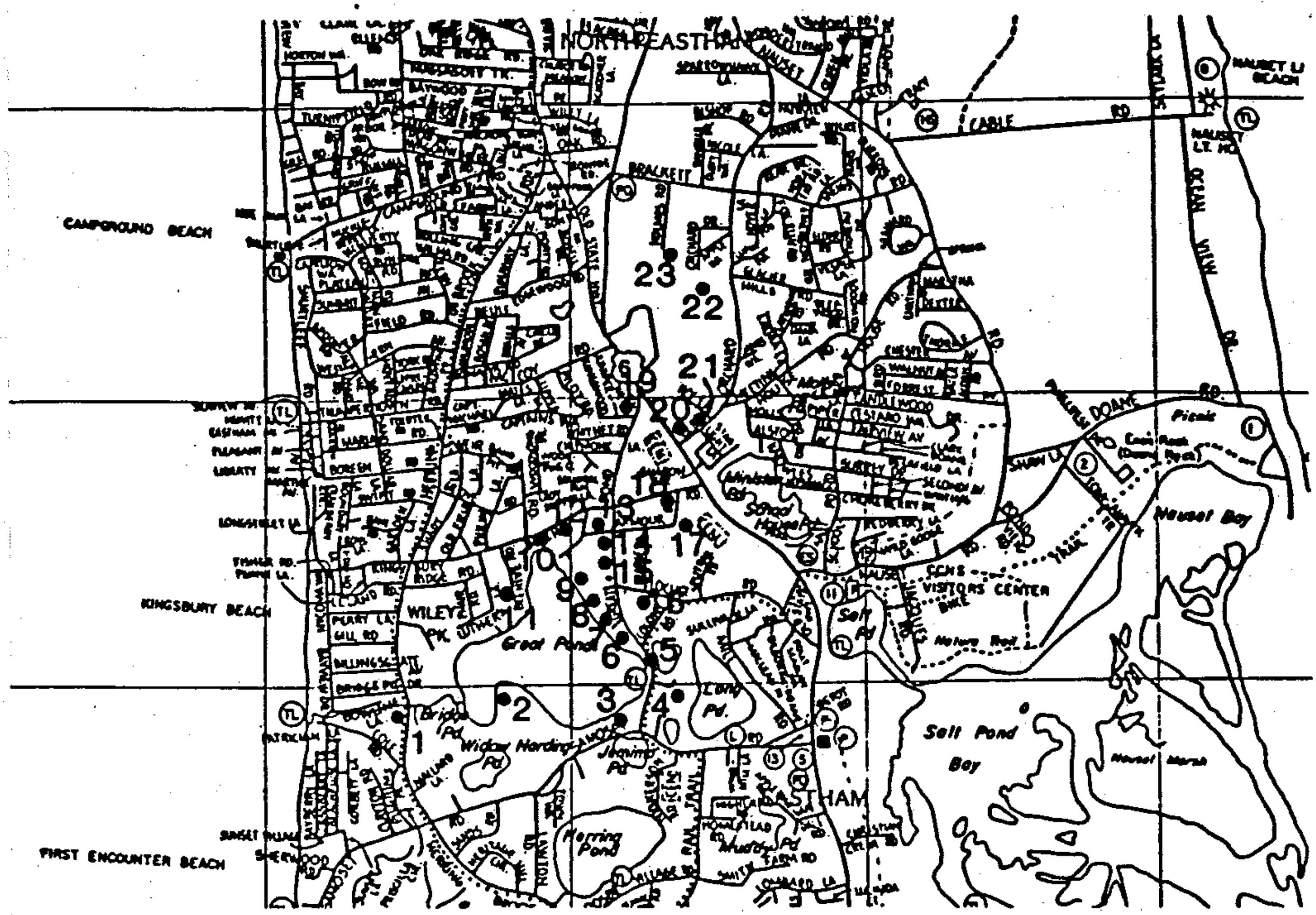
Domestic wells with [illegible] watershed were sampled [illegible] nt of ground water quality, particularly near the [illegible]. As residents rarely know the precise depth of their wells, and the detailed path of water flow throughout the watershed is unknown, interpretation of the results is somewhat speculative. Coupled with the data collected by Dr. Joseph Moran, however, they form the best available data base in the area. The general locations of wells sampled during this study are given in Figure 12; owners and addresses are omitted to preserve the privacy of participating parties.

No problems related to fecal coliform or streptococci bacteria were encountered in the wells (Table 3), but several high nitrate nitrogen values were recorded. Values for nitrate nitrogen over 0.5 mg/l rarely occur in the absence of man's influence (Martin and Goff 1972), and values greater than 10 mg/l represent a definite health hazard. Agricultural activities and the disposal of human wastes are the most likely sources of nitrate, with only the latter likely in Eastham.

Inadequate treatment of wastes and the high mobility of nitrate in sandy soil leads to elevated nitrate nitrogen concentrations in water emanating from on-site wastewater disposal systems. All disposal systems in Eastham are of potential concern, although the larger ones (major motels,

FIGURE 12

LOCATIONS OF WELLS SAMPLED BY BEC, INC.



WELL #	DATE(S) SAMPLED	WELL #	DATE(S) SAMPLED
1	8/28/85	13	4/16/86
2	5/21/85	14	4/16/86
3	5/8/85 & 12/4/85	15	8/13/85
4	6/6/85	16	4/16/86
5	9/10/85	17	4/16/86
6	7/16/85	18	4/16/86
7	6/18/85	19	4/16/86
8	7/2/85	20	4/16/86
9	10/1/85 & 4/16/86	21	4/16/86
10	12/4/85	22	4/16/86
11	7/30/85	23	4/16/86
12	4/16/86		

N

1cm = 310m

TABLE 3

Water Quality in Eastham Wells Sampled by BEC, INC.

Parameter Well No. / Date	1 8-28-85	2 5-21-85	3A 5-8-85	3B 12-14-85	4 6-6-85	5 9-10-85	6 7-16-85	7 6-18-85	8 7-2-85	9A 10-1-85	9B 4-16-86	10 12-4-85	11 7-30-85
Fecal Coliform (#/100ml)	0	0	0	0	0	0	0	0	0	0	0	0	0
Fecal Streptococci (#/100ml)	17	0	0	0	2	49	0	0	0	0	0	0	2
Total Alkalinity (mg/l)	4.2	3.9	15.0	15.0	3.9	29.0	13.0	16.0	16	9.0	18	13	7.1
pH (std. units)	6.3	5.5	6.8	6.4	5.7	5.8	5.6	6.1	6.2	5.5	5.6	5.9	5.5
Total Suspended Solids (mg/l)	-	0.8	3.2	15.0	3.2	5.6	1.2	1.6	0.4	0.4	1.3	6.0	1.6
Total Dissolved Solids (mg/l)	-	61	88	114	88	36	97	103	76	43	57	94	31
Conductivity (umhos/cm)	280	126	147	230	160	80	235	168	185	79	94	215	150
Chloride (mg/l)	52	31	24	22	32	27	24	21	21	17	12	23	8
Ammonia - Nitrogen (mg/l)	0.01	0.01	0.01	0.01	0.01	0.86	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Nitrate - Nitrogen (mg/l)	0.02	0.04	0.04	0.02	0.06	0.01	3.55	1.20	0.86	0.02	0.015	0.02	0.71
Total Kjeldahl-Nitrogen (mg/l)	0.12	0.13	0.21	0.52	0.06	1.40	0.17	0.13	0.11	0.20	0.058	0.37	0.28
Phosphorus, Ortho (ug/l)	10	10	60	10	10	10	10	10	10	9	10	10	10
Phosphorus, Total (ug/l)	23	30	120	10	30	10	18	30	20	9	10	30	10

Parameter Well No. / Date	12 4-16-86	13 4-16-86	14 4-16-86	15 8-1[illegible]-85	16 4-16-86	17 4-16-86	18 4-16-86	19 4-16-86	20 4-16-86	21 4-16-86	22 4-16-86	23 4-16-86
Fecal Coliform (#/100ml)	0	0	0	[illegible]	0	0	0	0	0	0	0	0
Fecal Streptococci (#/100ml)	0	0	0	[illegible]	1	0	0	0	0	0	0	0
Total Alkalinity (mg/l)	9.04	5.2	12	[illegible]	10	12	6.78	9.04	8.8	9.04	3.4	6.33
pH (std. units)	5.4	5.4	5.7	[illegible]	5.8	5.6	5.3	5.4	5.3	5.5	5.3	5.4
Total Suspended Solids (mg/l)	4.8	2.0	0.8	[illegible]	0.4	0.8	0.4	2.8	0.4	0.4	0.4	0.8
Total Dissolved Solids (mg/l)	112	127	108	[illegible]	93	84	92	287	197	92	103	107
Conductivity (umhos/cm)	189	220	183	[illegible]	167	156	180	610	340	190	180	182
Chloride (mg/l)	32	42	28	[illegible]	28	22	28	150	54	32	17	13
Ammonia-Nitrogen (mg/l)	0.03	0.8	0.018	[illegible]	0.012	0.04	0.04	0.01	0.01	0.016	0.01	0.01
Nitrate-Nitrogen (mg/l)	0.53	0.5	0.84	[illegible]	1.2	0.19	0.55	1.17	3.14	0.68	0.79	1.82
Total Kjeldahl-Nitrogen (mg/l)	0.12	1.1	0.079	[illegible]	0.02	0.064	0.072	0.075	0.056	0.019	0.016	0.055
Phosphorus, Ortho (ug/l)	10	10	10	[illegible]	10	10	10	10	10	10	10	10
Phosphorus, Total (ug/l)	10	15	14	[illegible]	13	10	10	14	24	10	13	24

restaurants, and the landfill) more often come under public scrutiny. Data collected in this study and by Dr. Moran seem to suggest a rather patchy distribution of elevated nitrate nitrogen levels, inconsistent with any hypothesis of a single source from which a definable plume might emanate. Again, lack of detailed hydro-geological information limits the conclusions that can be drawn, and further study is needed.

Ground water chloride values measured in this study also suggest an influence by man, but the proximity of the study area to the ocean provides an alternative explanation for observed elevated values. With one exception, ammonia nitrogen values are low. Again with one exception, phosphorus values appear relatively low, but undetected "hot spots" are likely, given the distribution of disposal systems in the watershed. Phosphorus is better adsorbed and retained by the soil than nitrate nitrogen, however, and even the sandy soils of Eastham may have considerable phosphorus removal capacity where the depth to ground water is great (Brown 1980).

Total dissolved solids and conductivity measurements indicate variable but generally moderate fertility for the ground water in the Great Pond watershed. The pH and alkalinity values were also quite variable over space, but were generally low and typical of Cape Cod ground water. There was also considerable temporal variability between corresponding values from two wells, each sampled twice. This temporal variability could be partly a function of laboratory error, but is more likely related to the relatively rapid movement of ground water through the sandy soil in Eastham. Water moves in the down gradient direction at a rate of more than 1 ft/day (Oldale 1985), making differences in well water quality possible in the space of a few days, if the postulated mosaic of ground water quality exists.

An effort was made to detect any dissolved substance input "hot spots" along the shoreline of Great Pond through a conductivity survey. Considerable spring activity was detected along the northeast shoreline, and conductivity values were slightly higher in that area and across the north cove from it (Figure 13). Obvious "hot spots" were lacking, however. A diffuse mode of water and dissolved substance input is postulated for Great Pond.

Bacteria

Fecal coliform (FC) and fecal streptococci (FC) bacteria were assessed during this study (Table 2). These bacteria come from the digestive system of all warm-blooded animals, human and non-human, and do not in themselves represent a serious health threat. However, as they are often accompanied by pathogens, they are considered indicators of a potential health hazard if present in substantial quantities. No FC values obtained during

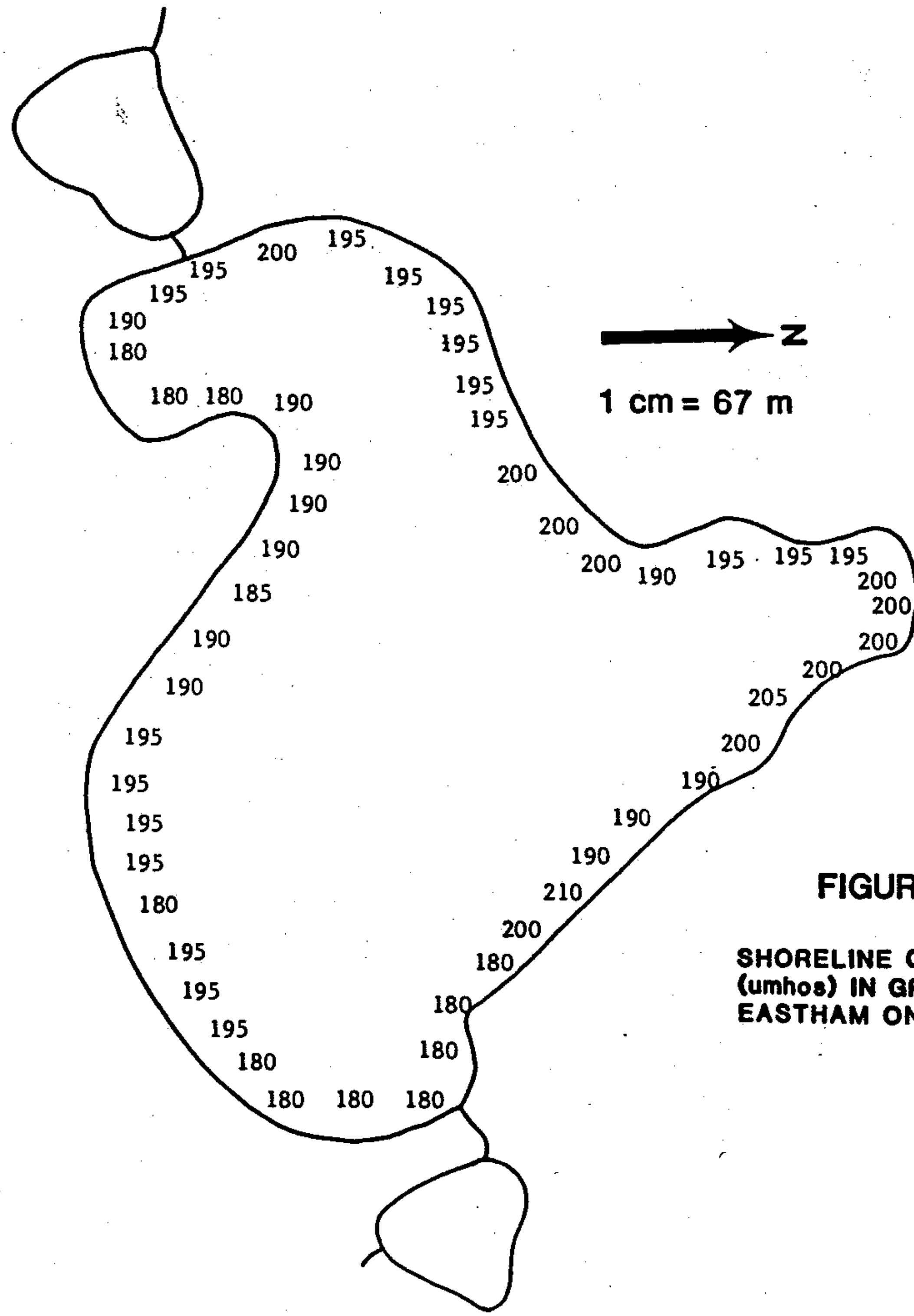


FIGURE 13

SHORELINE CONDUCTIVITY (umhos) IN GREAT POND, EASTHAM ON JULY 29,1985

this study were in excess of the Massachusetts standards for contact recreation, which are 200/100ml for multiple sample geometric means and 400/100ml for single samples. Geometric mean values were all quite small. There are no bathing standards for FS, but values were similar to those obtained for FC.

FC:FS ratios may give some indication of the origin of observed bacteria, as ratios associated with human derived bacterial assemblages are considerably higher than those associated with non-human sources. The obtained FC:FS ratios were considered meaningless, however, given the low FC and FS values obtained. The distance of most potential sources from the pond also minimizes the value of FC:FS ratios, and no conclusions are drawn from these data. Naturally occurring bacteria may cause infections in swimmers, and the transfer of pathogens in the close confines of group swimming areas is possible, but the collected data give no indication of any health hazard.

Phytoplankton

Phytoplankton, or algae suspended in the water column, are an important link in aquatic food webs, but may also be responsible for reduced water clarity and detectable color, odor, and flavor in lakes. One useful measure of phytoplankton quantity is chlorophyll a, a pigment used in photosynthesis. It is the same pigment that makes grass and leaves green. Chlorophyll a usually represents 0.5 to 2% of the total phytoplankton biomass and has been correlated with production and standing crop at various levels of the food web [illegible] and phosphorus concentration (e.g., Jones and Bachmann 1976, Oglesby and Schaffner 1978, Hanson and Leggett 1982, Vollenweider 1982).

Measured chlorophyll levels in Great Pond ranged from 1.6 to 28 ug/l, with mean values of 7.8 and 8.4 for the two in-lake stations (Table 2). Values exceeded 10 ug/l only twice at each in-lake station, both times after prolonged periods of precipitation. Values seem to rise in the east basin before they do so in the west basin. Considering the importance of ground water to this system and the pathway it must take into the pond, it appears that phytoplankton production and biomass are increased only when the ground water flow rate or concentration of phosphorus in the ground water exceeds the capacity of the abiotic and biotic filter formed at the lake bottom to remove nutrients, especially phosphorus.

The filter is a combination of size graduated sand and organic particles hosting an active microbial community and a dense mat of rooted plants. It functions very much the way a sand filter or wetland area does in a sewage treatment plant, combining the best features of both. As with a sewage treatment plant, however, it has a finite capacity for purifying water.

This capacity is apparently exceeded after substantial rainfalls, when the flow of ground water is likely to increase greatly. The July peak in chlorophyll occurred after a week of rain, during which about 12 cm of precipitation fell. The early September increase in chlorophyll followed a pair of rainstorms in which a cumulative total of more than 25 cm of precipitation was deposited on the watershed.

Chlorophyll levels are closely tied to phosphorus concentrations in many lakes, but in Great Pond chlorophyll levels are constantly lower than would be predicted from phosphorus data (Jones and Bachmann 1976, Oglesby and Schaffner 1978, Vollenweider 1982). Much of the phosphorus in the water column is apparently unavailable for algal uptake, probably as a consequence of conversion to organic forms by the benthic filter discussed above. Grazing by zooplankton is not a substantial, constant influence, and there is no evidence to suggest that algal growth is limited by light or dissolved substances. If all of the total phosphorus was available for uptake, a chlorophyll concentration about twice that which was observed could be expected.

Phytoplankton biomass is likely to constitute the major influence on water clarity in Great Pond, given the nature of watershed soils and the lack of surface transport of suspended sediment. Secchi disk readings from Great Pond are consistent [illegible] ements (Oglesby and [illegible] measure of water clarity, ranged from 2.1 to 4.8 m during this study. Mean values for the in-lake stations were 3.2 and 3.4 m (Table 2). While these values are lower than for many other more acidic, less productive Cape Cod lakes (Duerring and Rojko 1884a, 1984b), they suggest conditions entirely suitable for all types of recreation.

Assessment of phytoplankton composition and relative abundance revealed low to moderate densities of total phytoplankton, with numerical counts dominated most often by cyanophytes (bluegreen algae or cyanobacteria) and sometimes by chrysophytes (golden algae) (Figure 14). Phytoplankton biomass, however, was generally dominated by bacillariophytes (diatoms), chrysophytes (golden algae), or pyrrhophytes (dinoflagellates) (Figure 15). The smaller cell sizes associated with bluegreen algae minimize their contribution to the overall phytoplankton biomass in Great Pond. Periods of maximum chlorophyll concentration were associated with elevated biomasses of dinoflagellates and golden algae.

The composition of the phytoplankton was somewhat cosmopolitan. The types of algae observed were indicative of neither pristine nor grossly polluted conditions. Lakes

FIGURE 14

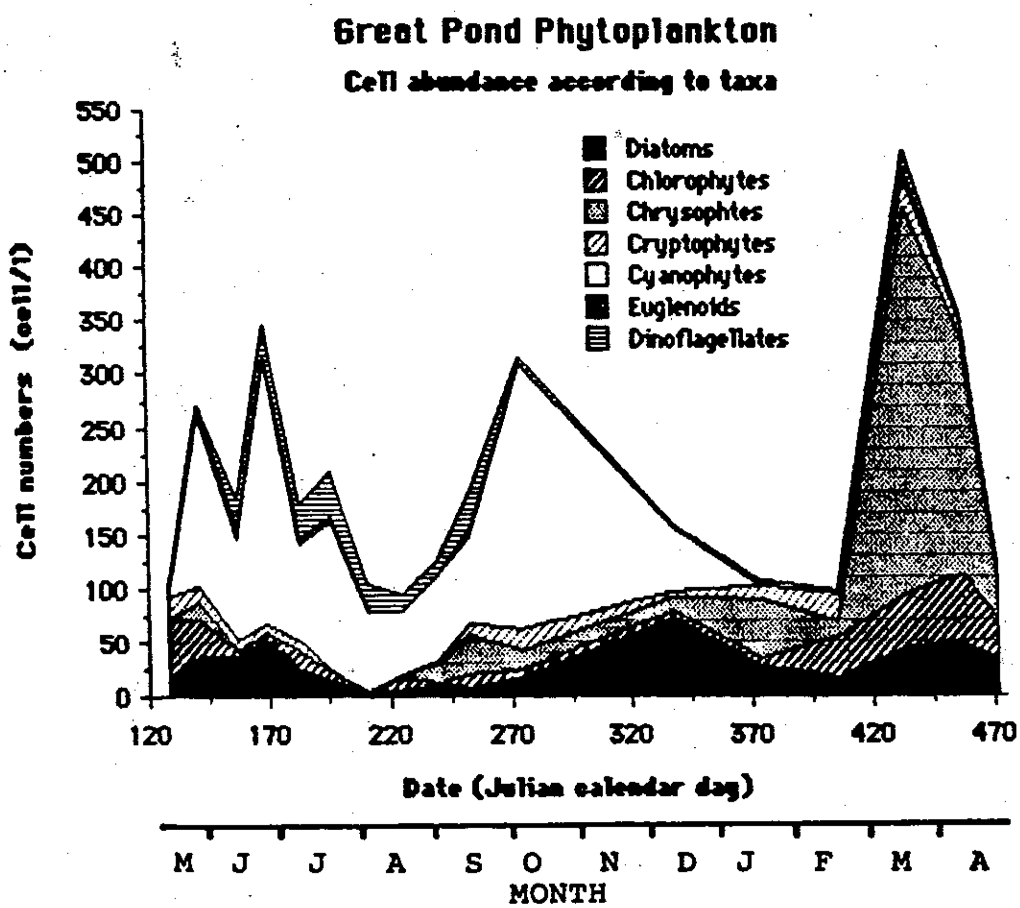
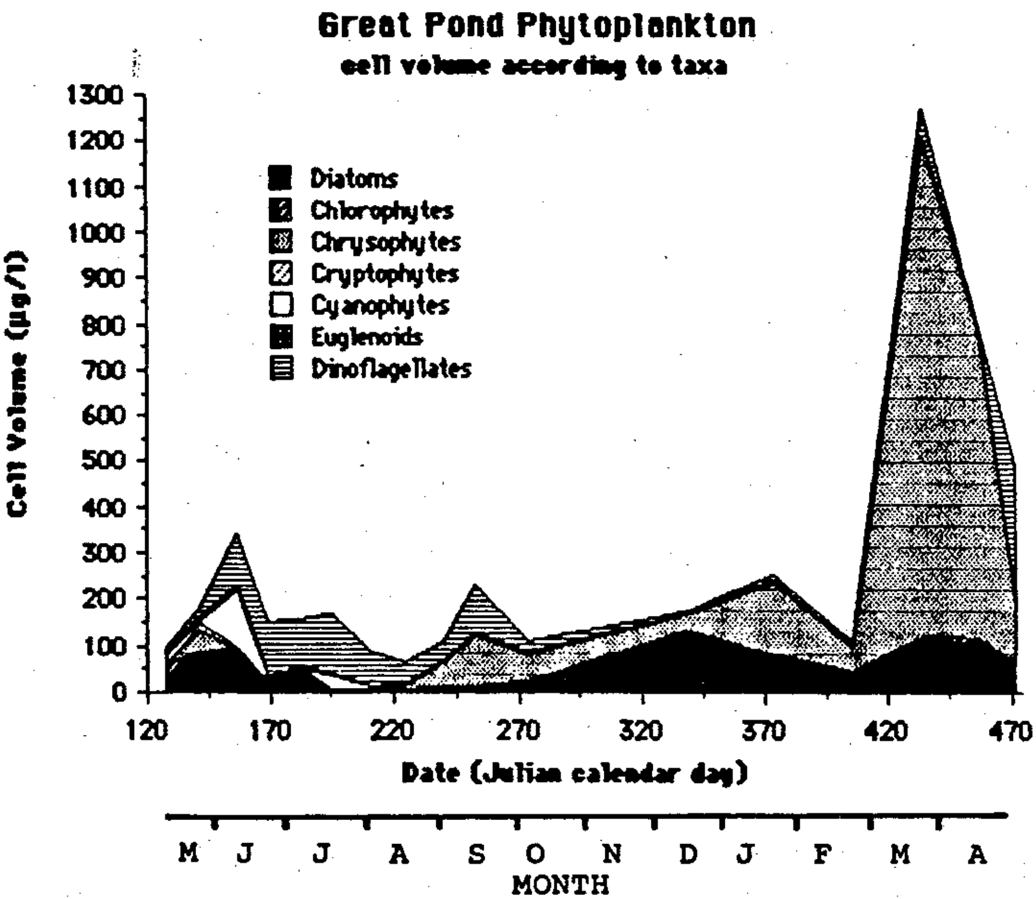

Great Pond Phytoplankton
Cell abundance according to taxa
Diatoms
Chlorophytes
Chrysophtes
Cryptophytes
Cyanophytes
Euglenoids
Dinoflagellates
Cell numbers (cell/l)
550
500
450
400
350
300
250
200
150
100
50
0
120
170
220
270
320
370
420
470
Date (Julian calendar day)
M J J A S O N D J F M A
MONTH

FIGURE 15



Great Pond Phytoplankton
cell volume according to taxa
Cell Volume (µg/l)
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Diatoms
Chlorophytes
Chrysophytes
Cryptophytes
Cyanophytes
Euglenoids
Dinoflagellates
120
170
220
270
320
370
420
470
Date (Julian calendar day)
M J J A S O N D J F M A
MONTH

receiving moderate nutrient loads in a gradual manner often exhibit a composition much like that recorded for Great Pond. The observed types of bluegreen algae are potential bloom-forming species, however, and could create nuisance conditions at much higher densities than detected. If system fertility were manifested as phytoplankton instead of benthic growths, Great Pond could suffer recreational impairment as a consequence of reduced water clarity and unsightly appearance. There appears to be no immediate danger, however, as long as the benthic filter operates effectively and the incoming nutrient loads do not increase detectably.

Macrophytes

The shallow, sandy or cobble-lined, wave-washed shoreline areas of Great Pond have little or no macrophyte cover (Figure 16), although the vegetation on shore at the water's edge is often quite dense. As one proceeds in a transect toward deeper water, macrophyte density increases, reaching nearly 100% cover in a wide, irregular band which loosely follows the 2 and 5 m water depth contours. Below 5 m of water depth there is virtually no cover by macrophytes.

There is some die-off of vascular plants in late fall, but the areal coverage is not greatly altered over the course of the year. Dense mats of Najas can be found in mid-winter, although these growths do not appear as healthy as plants observed during summer. The summer density of plants in Great Pond approaches 300 g/sq.m (dry weight), with an average for dense growths of about 200 g/sq.m.

The distribution of aquatic vascular plants (Figure 17) shows some depth-oriented segregation. Shallow species include Nitella, Lobelia, Elatine, and Scirpus, with Elodea and Valisneria occurring in slightly deeper water. Potamogeton is interspersed among these latter plants and extends into the dense beds of Najas which comprise the area exhibiting 75 to 100% cover. This zonation is more easily visualized when depicted as a hypothetical transect from shallow to deep water (Figure 18).

The tendency for Najas to grow in a fairly compact mat, close to the sediment, eliminates it as a serious nuisance to bathers and boaters in Great Pond. Disturbance by boats or extreme wind activity have caused masses of this plant to float to the surface and eventually drift into shore, where it is a nuisance, but problems with Najas are minor in comparison with other plants which could take its place were it removed from Great Pond. For example, both Myriophyllum and Nymphaea are abundant in nearby ponds. Potamogeton growths often reach the surface and could entangle bathers or boat propellers, but the

FIGURE 16

BENTHIC COVER BY AQUATIC MACROPHYTES
IN GREAT POND, EASTHAM

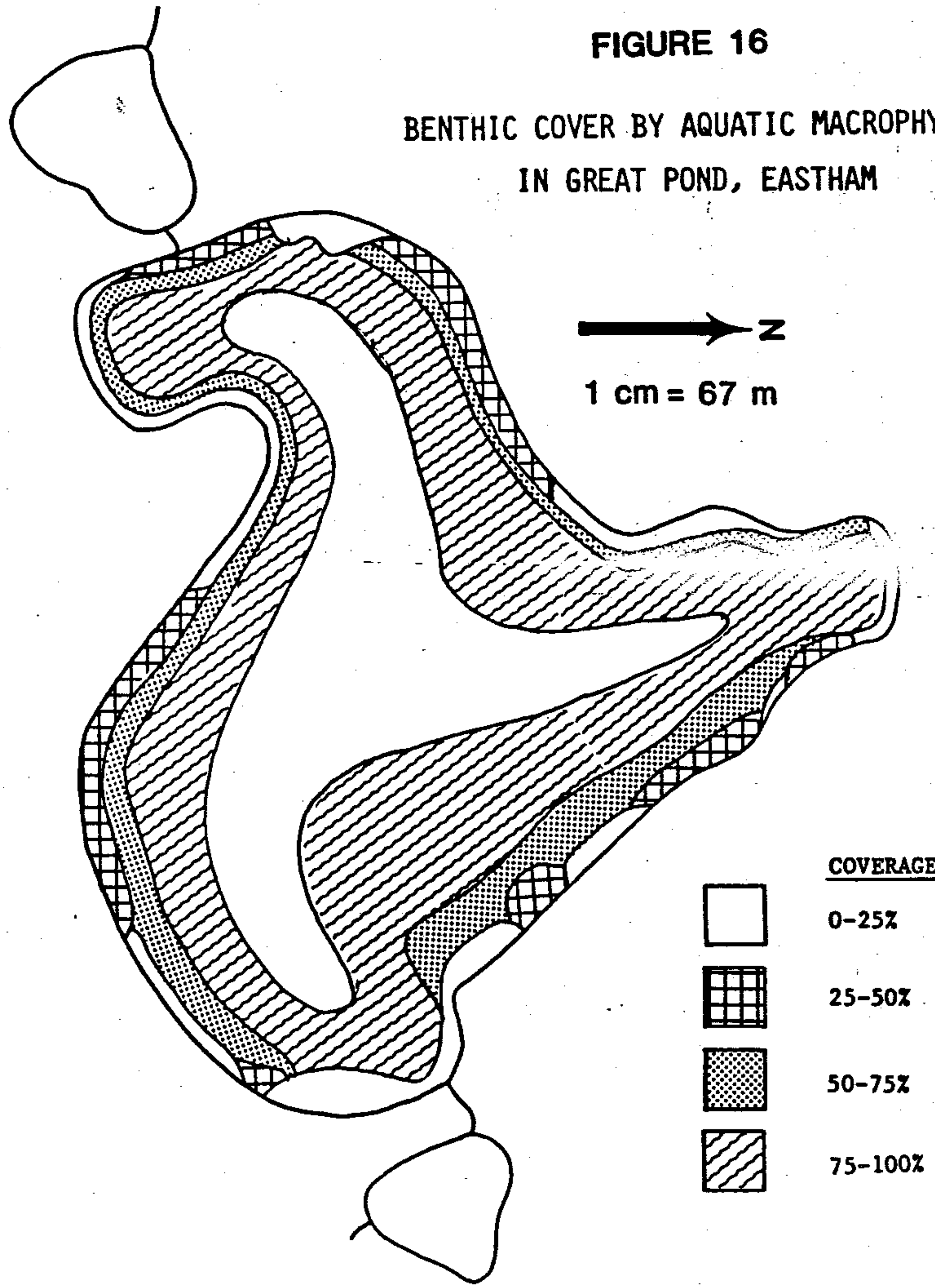
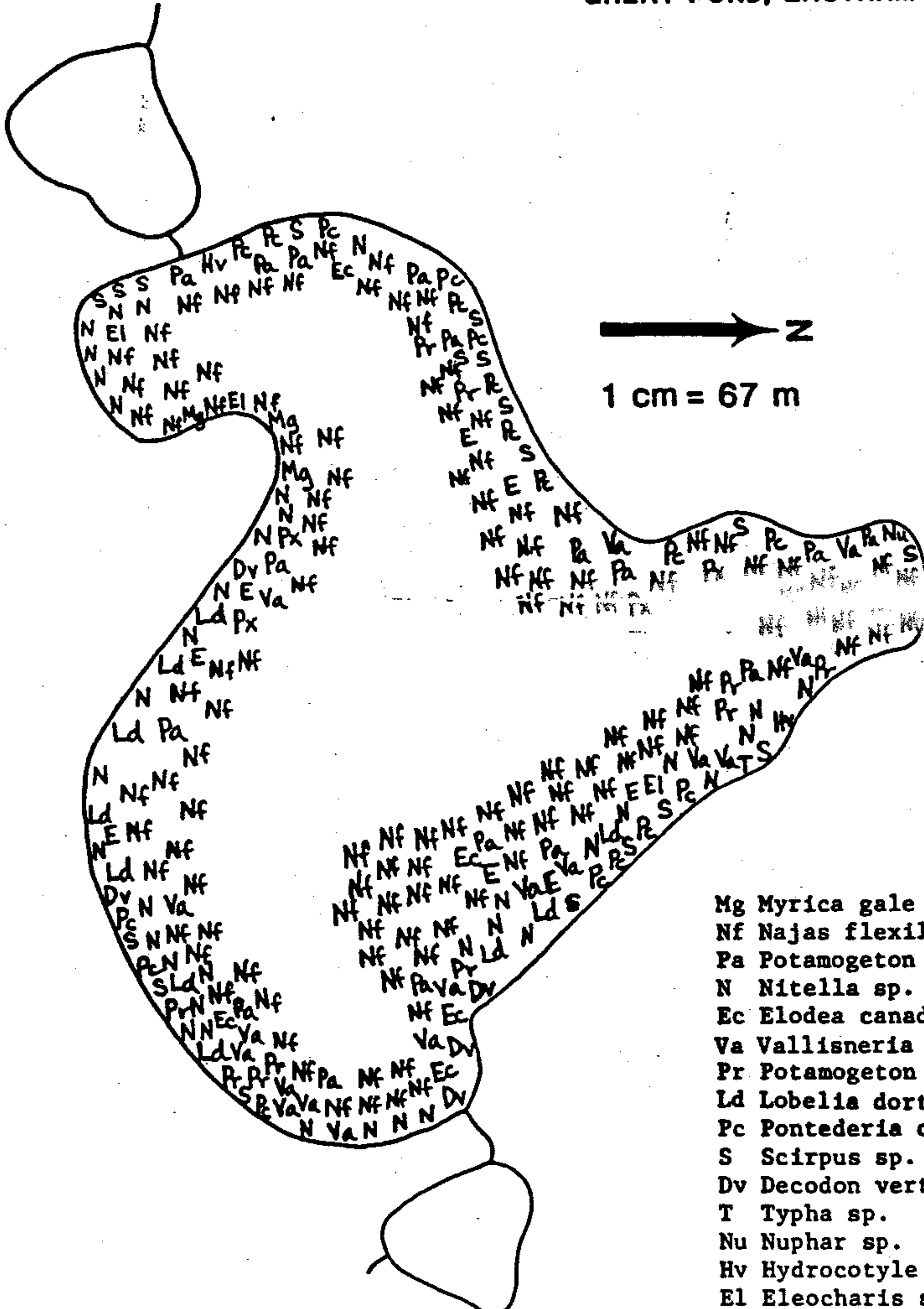


FIGURE 17

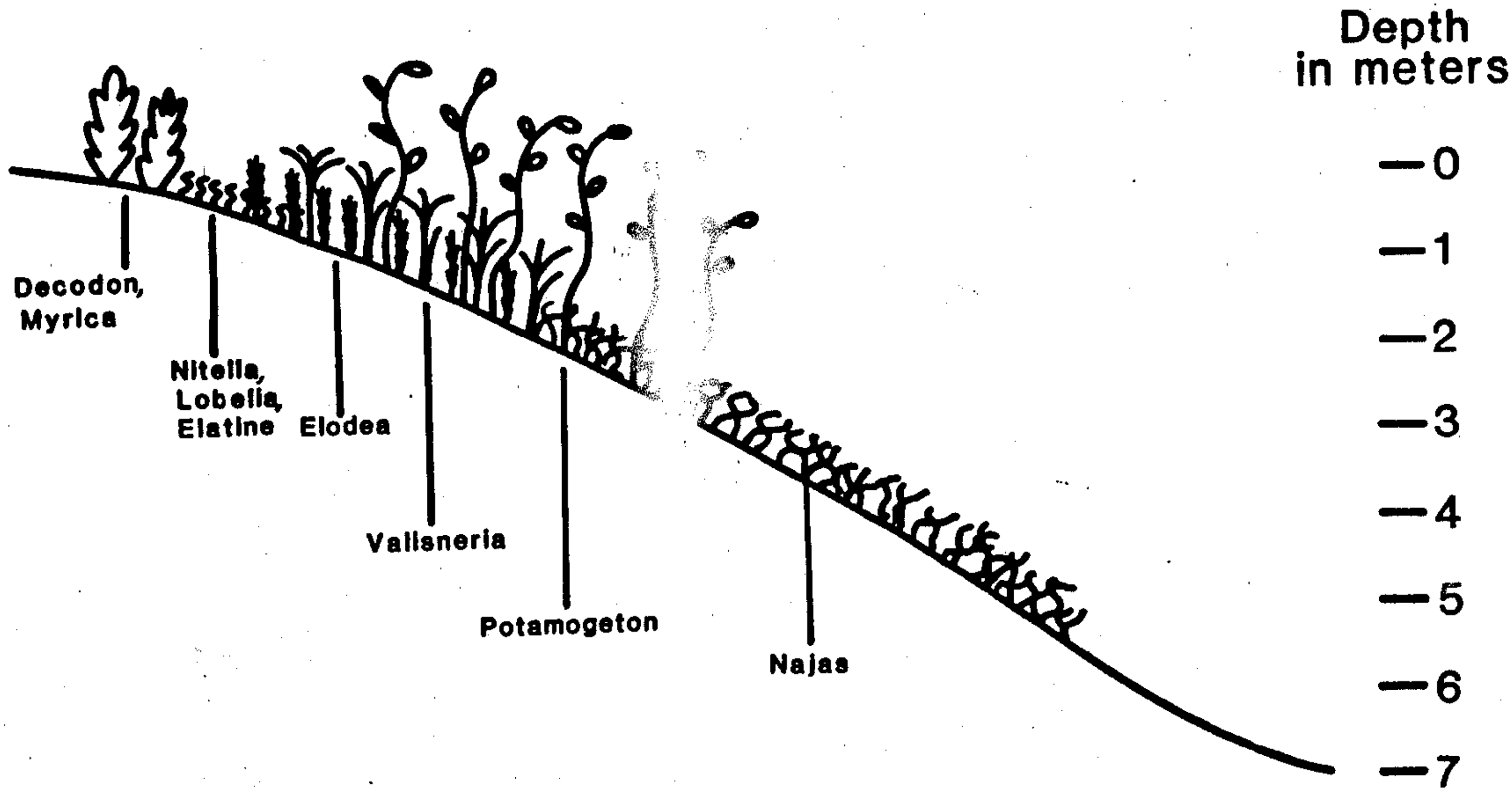
DISTRIBUTION OF AQUATIC MACROPHYTE TAXA IN GREAT POND, EASTHAM



Mg Myrica gale
Nf Najas flexilis
Pa Potamogeton amplifolius
N Nitella sp.
Ec Elodea canadensis
Va Vallisneria americana
Pr Potamogeton richardsonii
Ld Lobelia dortmannaa
Pc Pontederia cordata
S Scirpus sp.
Dv Decodon verticillatus
T Typha sp.
Nu Nuphar sp.
Hv Hydrocotyle verticillata
El Eleocharis sp.
E Elatina sp.
Px Potamogeton sp. (foliosus?)

FIG E 18

TYPICAL VEGETATION T ANSECT FOR GREAT POND



density of these plants is insufficient to represent a detectable nuisance. Other vascular plants in Great Pond have negligible to limited nuisance potential.

The rooted vascular plants, particularly Najas, form an important part of the benthic filter discussed previously. They are responsible for minimizing available nutrient inputs to the pond and deter resuspension of soft sediment by wind or boat-induced turbulence. They provide valuable cover for fish and both food and cover for macroinvertebrates, another important link in the food web of this system. They supply oxygen through photosynthesis to a system with a considerable oxygen demand. On the other hand, dead plants are a major cause of the oxygen demand, and nuisance conditions are created by plant growths in beach areas.

Zooplankton

Rotifers, copepods, and cladocerans are represented in the zooplankton of Great Pond. Large-bodied forms are generally absent, and densities are quite low except in spring, when they are moderate. Predation by fish, especially by young alewife, is believed to control the size distribution and density of zooplankton in Great Pond. The size distribution of the zooplankton (Figure 19) is indicative of alewife predation and suggests a low grazing capacity (Mills and Schiavone 1982, Wagner 1986). The zooplankton are likely to have a negligible impact on phytoplankton composition and abundance.

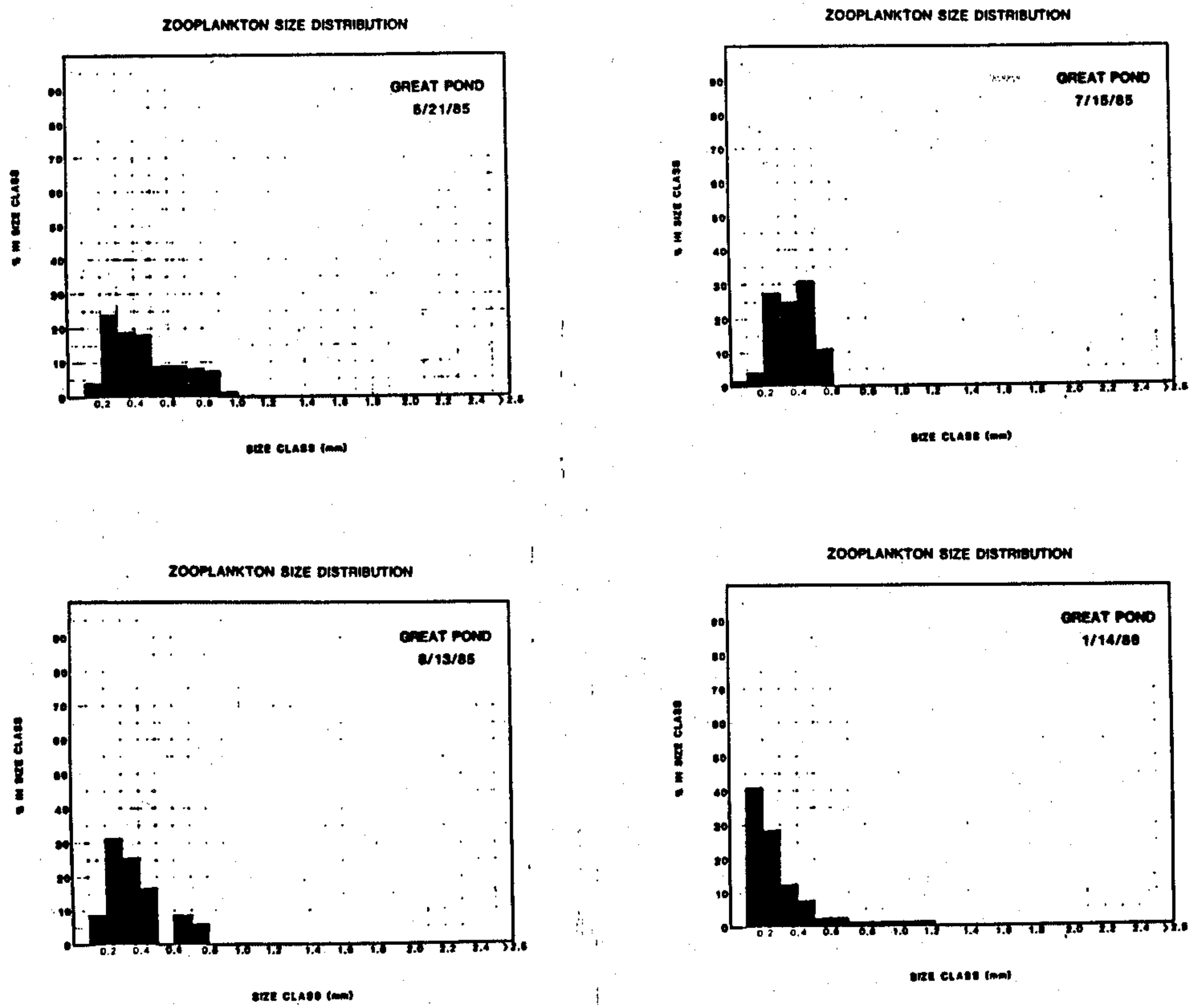
Macroinvertebrates

In the deep portions of Great Pond, beyond the depth at which macrophytes are found, low oxygen limits invertebrate diversity and biomass. Midge larvae (Chironomidae) and phantom midge larvae (Chaoboridae) were found there at densities up to 130/sq.m, with an occasional sphaeriid clam or planorbid snail also observed. A greater variety of invertebrates were found at higher densities in nearshore areas, including damselfly and dragonfly (Odonata) nymphs, mayflies (Ephemeroptera), stoneflies (Plecoptera), beetles (Coleoptera), and bugs (Hemiptera). Also abundant were large crayfish and bivalve molluscs (freshwater clams), freshwater sponges, pillow mites, and amphipods.

Densities approached 1000/sq.m in dense plant assemblages, but were usually not more than 500/sq.m, a relatively low value. The presence of large individuals of certain species inflated biomass estimates to moderate levels, however. Predation by fish may keep invertebrate populations in check in this system. A moderately productive, well balanced macroinvertebrate community was suggested by the composition and abundance data in shallow water, but a considerable portion of the benthic environment is uninhabitable by most forms as a consequence of oxygen depletion.

FIGURE 19

ZOOPLANKTON LENGTH DISTRIBUTIONS



Fish

The Massachusetts Division of Fisheries and Wildlife (MDFW) performed a survey of Great Pond in July of 1985, and provided BEC with the corresponding field and laboratory notes (Technical Appendix). Fish encountered by MDFW or BEC included golden shiners, several other small minnow species, pumpkinseed sunfish, yellow perch, white perch, alewife, killifish, chain pickerel, smallmouth bass, eels, and brown bullheads.

White and yellow perch and chain pickerel were the most abundant fish of interest to anglers, while alewife and killifish were the most abundant bait species. Yellow perch were quite small on average, with a mean length of 190 mm. White perch were larger, averaging about 265 mm in length. Chain pickerel were relatively small at an average length of 300 mm, with no specimens over 480 mm observed. Bullheads were of moderate size, averaging 280 mm in length. Although rare, smallmouth bass can get quite large in Great Pond. The one specimen captured measured over 500 mm and weighed almost 1.9 kg (over 4 pounds).

Data for the length and age of selected fish species revealed slow to moderate growth rates (Technical Appendix), relative to those reported for many other northeastern lakes. Observed growth rates for Great Pond fish are not at all unusual or low for Cape Cod lakes, however. Chain pickerel and white perch reach quality size (Gabelhouse 1984; the lower size limit for reasonable harvest) at age 3 to 4 years, while sunfish and yellow perch reach quality size at 5 to 6 years of age.

While increased management efforts could improve the Great Pond fishery, current fishing conditions are generally acceptable. Recruitment of fish into each age class appears steady, and there is a large forage base for piscivores (fish-eating predators). The use of Great Pond as a spawning/nursery area for sea-run alewife provides much of the forage base without burdening the system with the support of the adult population. The Great Pond fishery may not be able to withstand prolonged, high intensity fishing pressure, but is capable of supplying satifying angling opportunities with proper management.

Historically, Great Pond has always been a perch and pickerel lake (MDFW 1911), but a management program for smallmouth bass in the 1930's and 40's provided excellent fishing for that species through 1958 (MDFW 1958). The habitat is ideal, except for the lack of oxygen during summer in deep water, and appropriate food is abundant. Further management for smallmouth bass would seem desirable. It should also be noted that many large chain pickerel have been taken at Great Pond in recent years, despite the absence of large specimens in the DFW catch.

If the hypolimnetic oxygen problem were eliminated, Great Pond would also be quite suitable for trout; suitable trout habitat is rare on Cape Cod.

Sediment Analysis

The central, deep area of Great Pond has a deep muck layer (Figure 20) with some differentiation of layers (Figure 21). The sand intermixed with the muck at station 3 is probably the result of erosion at the town beach. The black muck layers represent incompetely oxidized sediments, while the deeper brown muck is indicative of more complete oxidation. This suggests that hypolimnetic anoxia was absent from the lake at some time in the past 10,000 yrs. While no dating of sediment layers was performed, the anoxia probably corresponds to the onset of substantial development in Eastham.

The muck layer rapidly thins as the shoreline is approached, and there is a broad apron of mostly sand at water depths less than 4 m. Patches of organic debris (sticks and leaves) and cobble are found in shallow water. While there is little current evidence of shoreline erosion, area residents recall major erosion events from the 1930's up to the late 1970's. In the last decade the Wiley Park swimming area has lost some of its depth to sand sloughing, and photographs from the 1920's show a sandy area around the peninsula owned by the Mumfords which is now absent.

Chemical analysis of Great Pond muck sediments (Table 4) reveals high levels of arsenic and vanadium, relative to standards set by the MDWPC (1979). Concentrations of iron are high in an absolute sense, but are not atypical of Cape Cod lakes. Sodium levels also appear high, but there are no standards against which observed levels can be measured. The organic content of the muck is also quite high, as might be expected, given its origin as predominantly plant matter. The muck sediments are classified as Category 3, Type C material under the Massachusetts criteria for dredged material (MDWPC 1979).

Analysis of sand near the shore was not performed, but this is terrestrially derived material of generally coarse grain size, and is unlikely to be contaminated in any serious way. The reason for high arsenic and vanadium levels in the deeper muck sediments is unknown, although bioaccumulation by the plant material from which the muck is derived may be responsible.

Questionnaire Survey

Responses to a questionnaire sent to watershed residents were helpful in evaluating the preferences and practices of residents and potential pond users. A 50% response level was achieved (Table 5), and almost half of the respondents noted

FIGURE 20

SOFT SEDIMENT DEPTH IN GREAT POND, EASTHAM

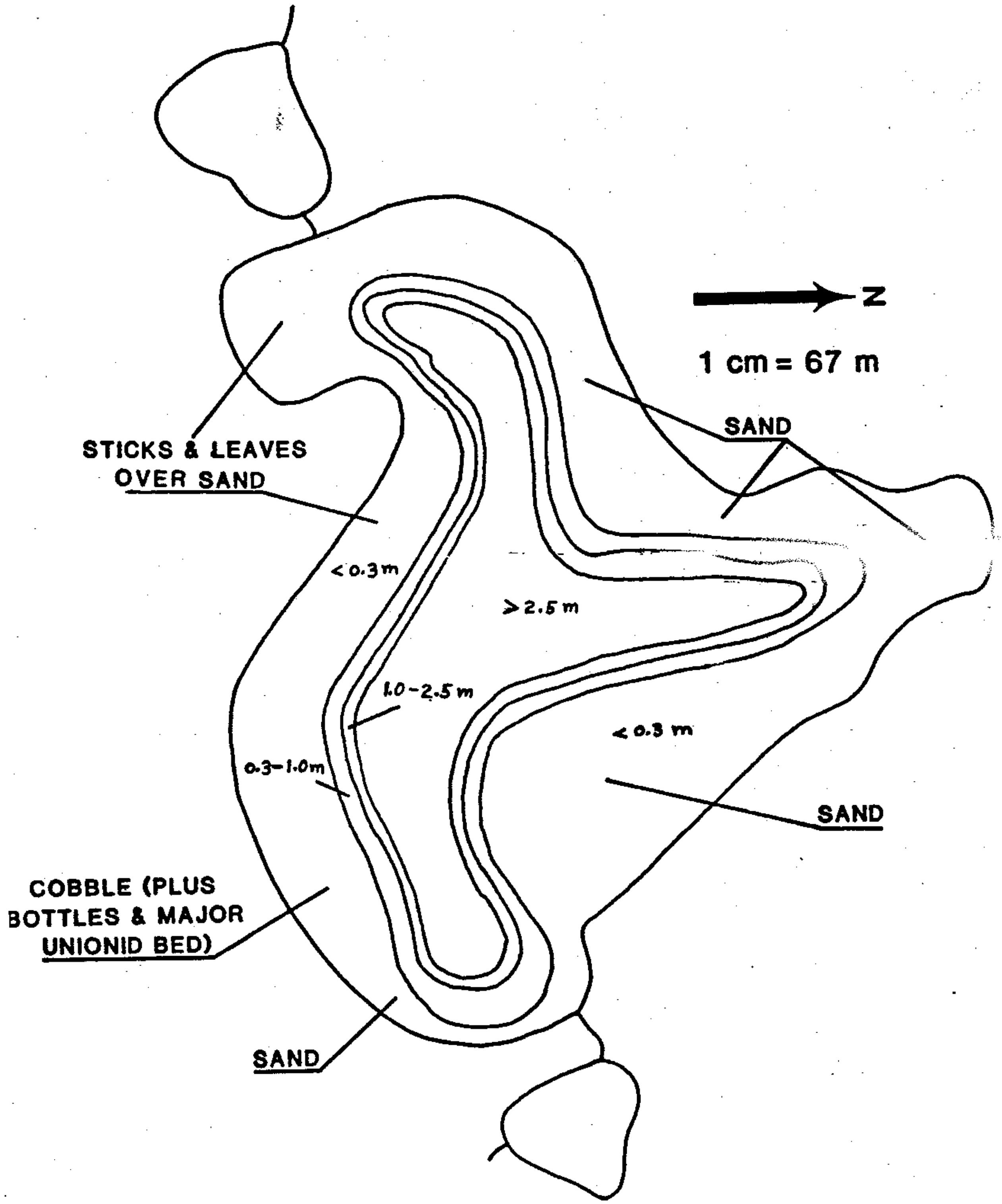


FIGURE 21

SEDIMENT CORE PROFILES FOR GREAT POND

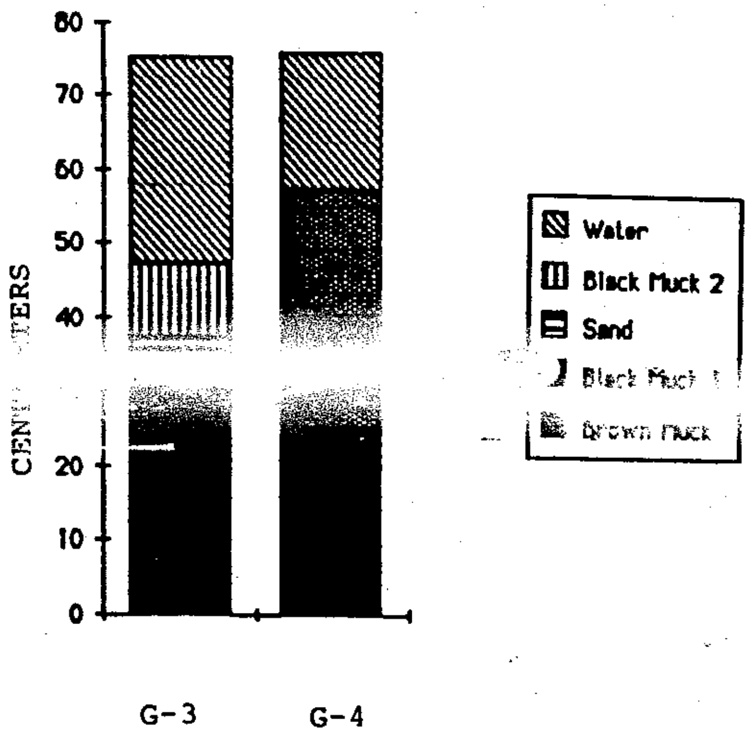


TABLE 4

CHEMICAL CHARACTERISTICS OF GREAT POND SEDIMENTS
COLLECTED ON JULY 30, 1985

Parameter	Concentration (mg/kg) at each Station	
	G - 3	G - 4
Arsenic	35	28
Cadmium	<7.6	4.1
Chromium	15	31
Copper	19	18
Iron	19,200	17,000
Manganese	107	127
Lead	57	92
Mercury	<0.093	<0.075
Nickel	11	14
Vanadium	84	33
Zinc	111	131
Sodium	708	575
Oil & Grease	616	711
TKN	2,860	1,470
Total Volatile Solids (%)	13.5%	17.4%
Phosphorus, Total	23	56
Nitrate - Nitrogen	134	24
PCB	<0.08	<0.08

TABLE 5

SUMMARY OF QUESTIONNAIRE RESPONSES FOR THE GREAT POND STUDY AREA

# responding	55
% responding	50%
Pond usage rate	
Daily	22%
Weekly	29%
Monthly or less	49%
Preferred activities	
First choice	
Swimming	60%
Sailing/boating/skiing	24%
Fishing	7%
Skating	0%
Other	9%
Second choice	
Swimming	31%
Sailing/boating/skiing	53%
Fishing	6%
Skating	0%
Other	10%
Third choice	
Swimming	38%
Sailing/boating/skiing	23%
Fishing	8%
Skating	8%
Other	23%
Persons/household	
Mean	2.9
Range	1-11
Residency (months/yr)	
9-12	40%
6-9	15%
3-6	32%
<3	13%

TABLE 5 (continued)

Property distance from lake (ft)	
>1000	43%
500-1000	21%
250-500	4%
100-250	15%
50-100	0%
<50	17%
Drinking water source	
On-site well	98%
Municipal pipeline	0%
Lake	0%
Bottled	2%
Other	0%
Washing water source	
On-site well	98%
Municipal pipeline	0%
Lake	0%
Bottled	0%
Other	2%
Waste disposal system	
Cesspool	54%
Tank and leachfield	44%
Chemical or composting toilet	0%
Municipal sewer line	0%
Other	2%
On-site disposal system	
Age (yrs)	
Mean	18
Range	1-75
Distance from lake (ft)	
>1000	52%
500-1000	15%
250-500	2%
100-250	23%
50-100	8%
<50	0%
Years since last inspection/pumping	
>5	40%
3-5	13%
1-3	36%
<1	11%

TABLE 5 (continued)

On-site wells	
Depth (ft)	
>100	0%
50-100	12%
20-50	78%
<20	10%
Distance from lake	
>1000	38%
500-1000	24%
250-500	13%
100-250	19%
50-100	4%
<50	2%
Years since last testing	
>5	31%
3-5	13%
1-3	28%
<1	28%
Well location relative to waste disposal system	
Upslope	56%
Downslope	19%
Equal elevation	25%
Distance from upslope disposal system from well	
>100	45%
50-100	45%
25-50	10%
<25	0%
Phosphate fertilizer used on lawn	15%
Washing machine used	65%
Garbage disposal used	4%
Phosphate detergent used	
Clothes	60%
Dishes	28%

seasonal use of Great Pond. A little less than a quarter of all respondents cited daily use on a year round basis. The many out-of-town summer users were not surveyed, although rental property dwellers were included in the survey. Swimming and different forms of boating were by far the preferred forms of recreation at the lake.

Household occupancy ranged from 1 to 11 with a mean of 2.9, but only 40% of the respondents were full time occupants. This is consistent with the summer resort nature of the town's population. About one third of all respondents were residents for the summer only, with the remaining quarter almost evenly divided between weekend visitors and 6 to 9 month residents.

Most respondents' properties were at least 500 ft from the pond, as were the associated wells and wastewater disposal systems. Almost all respondents obtained water from an on-site well, and 88% of the wells were less than 50 ft deep. Around 54% of all disposal systems were cesspools. Another 44% of the disposal systems were tank and leachfield arrangements, and 2% of the respondents cited "other" means of disposal (?). The mean age of disposal systems was 18 yrs, with a range of 1 to 75 yrs.

About 40% of the respondents had not had their disposal systems inspected or maintained within the last 5 yrs, but 36% of the systems had been checked and cleaned within the last 3 yrs. Almost a third of the wells had not been tested for at least 5 yrs, but 56% had been tested within the last [illegible] the importance of ground water quality is apparently increasing in Eastham. Most wells are located at least 50 ft upslope of disposal systems on the corresponding properties, but most are likely to be downslope of a system on an adjacent property. The relatively rapid movement of ground water in the watershed therefore necessitates consideration of the placement of all systems within a ground water flow line, not just on a single property.

Only 15% of the respondents fertilize their lawns and only 4% use garbage grinders, but 65% have washing machines and 60% use phosphorus-laden laundry detergent. About 28% of the dishwashing detergents used by respondents contain phosphorus. It is estimated that approximately 25% of the phosphorus entering disposal systems has its origin as detergents or other avoidable sources.

Comparison with Other Studies

Great Pond is more fertile than many other Cape Cod ponds (Duerring and Rojko 1984a, 1984b), but does not manifest its fertility as biological nuisances most of the time. An investigation of eight other Eastham ponds by BEC (Technical Appendix) indicates that Great Pond is intermediate among Eastham ponds with respect to surface nutrient levels, phytoplankton biomass, water transparency, and macrophyte cover. The anoxic hypolimnion of Great Pond and associated water chemistry is unique to that system among tested ponds, however. Long Pond is the clearest and least productive of the ponds, while Bridge Pond experiences noticable blooms of bluegreen algae. Herring Pond experiences salt water intrusion with high tides, setting its water chemistry apart from the other ponds. All have some recreational utility and together they represent a rather diverse assemblage of lakes, relative to those of other areas on the Cape.

Water quality and bacterial data collected by the Town of Eastham and the Barnstable County Health Department are consistent with the findings of this study, as are the surveys performed by the MDWPC (Duerring and Rojko 1984a). The rapidly developing nature of Eastham and the importance of ground water supply and quality are further documented in an MDWPC report from 1976, which notes the rate of population change, cites an estimated water demand of almost one half million gallons per day for the year 1990, and recommends an intensive surface and ground water monitoring program. Another MDWPC report issued in 1977 discusses water quality and wastewater discharge data, but has very little relevance to the situation in Eastham.

The Eastham Open Space [illegible] (Eastham Open Space Committee [illegible] of the town and [illegible] planning, and recreational facilities development for the coming five years. It is an ambitious plan, but is not inconsistent with any observations made by BEC regarding the water resources of Eastham. It cites only a little more than 22% of the land in town as urban, which may confuse anyone recalling the BEC estimate of over 80% residential and commercial lands. The difference appears to lie in the definition of urban, as many low density residential areas are clearly not urban. The critical nature of water resources to the well-being of the town is emphasized in the report, and BEC concurs with this emphasis.

Perhaps the most important study in Eastham to date is the ground water nitrate and sodium survey being conducted by Dr. Joseph Moran, Professor at Cape Cod Community College and a resident of Eastham. Nitrate nitrogen values in excess of 0.5 mg/l have been detected with great frequency throughout Eastham, and values greater than 10 mg/l are not uncommon. Data collection and analysis is still in progress, but the emerging pattern is a mosaic of "hot spots" indicative of numerous separate sources.

There are two plausible explanations for high nitrate levels in domestic wells in Eastham. Numerous separate sources of variable size may create localized pollution problems, depending on their interaction with area wells. Alternatively, one or a few major sources may create a distinct plume of pollution which moves in the downgradient direction, polluting wells in its path. While definitive conclusions cannot yet be drawn, the former explanation is favored at this time. Considering the potential impact of the town landfill and the Route 6 commercial complex, some combination of both explanations is certainly possible.

Explanation of high sodium levels, which also represent a health hazard, is complicated by the possible deposition of salt as an aerosol derived from ocean spray, but some impact from road salting operations is evident. Of particular interest with regard to both pollutants is the high frequency of elevated values associated with major water users and full year residences. The impact of higher water demand is an expanded cone of influence for the supplying well(s), possibly drawing in inadequately treated water from wastewater disposal systems on the same or nearby properties. Design, siting, and maintenance of on-site wastewater disposal systems appears to be critical in Eastham, and probably throughout Cape Cod.

HYDROLOGIC BUDGET

The hydrology of Great Pond is expected to typify that of kettlehole lakes in general; ground water will be the critical component of flow, rather than overland runoff. The yield coefficients of Sopper and Lull (1970) suggest a mean flow of about 1.8 to 2.7 cu.m/min, but these coefficients are less applicable to ground water flow than to surface delivery. Runoff production in New England averages about 53.3 cm/yr (Sopper and Lull 1970, Higgins and Colonell 1971), but there is virtually no runoff in the Great Pond watershed, negating that approach to flow prediction. Assuming an annual recharge of ground water of 35.6 to 40.6 cm (Strahler 1972, Guswa and LeBlanc 1985.), the mean flow through Great Pond would be 1.9 to 2.1 cu.m/min. These estimates do not account for direct precipitation and are subject to considerable temporal variability.

It is possible to make some direct measurement of ground water inflow through the use of seepage meters, but techniques for doing so have only recently been developed to an appropriate extent and are not applicable in all situations. Seepage meters were not employed in this study, but the results of this investigation suggest that their use may be appropriate in the next phase of management.

Alternatively, Darcy's formula (Dunn and Leopold 1978) can be used to estimate ground water flow through a system. Using available data for permeability (Guswa and LeBlanc 1985, SCS 1986), ground water flow into Great Pond was calculated at 2.8 to 34.5 cu.m/min (Technical Appendix). Adjusting for local factors such as clay lenses, an estimate of 6.3 cu.m/min was obtained as the mean ground water-induced flow to Great Pond. Our intuitive evaluation of ground water flow, based on a velocity of 0.6 to 3.0 m/day and the area of intersection with the pond, suggested a mean flow between 2.2 and 10.9 cu.m/min (Technical Appendix).

The contribution of direct precipitation to flow and a large portion of the variability in ground water flow are dependent on the quantity and pattern of annual precipitation in the watershed. The records of Mr. Don Sander, who lives adjacent to Long Pond, indicate local precipitation of 100.6 to 109.2 cm/yr over the last three years (Table 6). Rainfall during the study period totalled 119.7 cm, while during the year preceding the study there was only 89.2 cm of rain. These records do not include snowfall, but this causes only a very slight underestimate, as the outer portion of Cape Cod received little snow during the period of record. Precipitation values recorded by Mr. Sander are similar to those given for nearby weather stations (NOAA 1985, Table 6).

TABLE 6

PRECIPITATION DATA FOR THE EASTHAM, MA. AREA

(Centimeters of precipitation as rain)

	Sander data for Eastham			Long-term NOAA data			
Month	1984	1985	1986	Hyannis	Plymouth	Edgartown	Nantucket
J		2.36	9.65	9.75	10.74	9.98	10.26
F		0.13	1.27	9.45	9.91	9.80	9.42
M		4.52	8.51	9.45	10.46	10.44	9.98
A	4.95	5.18	5.72	10.03	10.16	10.21	9.07
M	16.41	8.20		9.75	9.27	10.41	8.41
J	15.62	9.07		6.96	6.86	6.65	5.77
J	20.93	12.57		6.73	7.54	6.73	7.04
A	4.06	39.12		10.38	11.40	10.62	8.71
S	5.94	4.24		8.89	10.57	9.27	8.59
O	4.52	5.36		9.55	10.16	9.04	8.66
N	3.43	13.54		11.38	12.04	11.13	10.24
D	6.05	2.41		11.02	12.07	11.35	11.07
TOTAL	81.91 (9 months)	106.70	25.15 (4 months)	113.34	121.18	115.63	107.22
			Maximum	157.23	177.29	166.12	153.42
			Minimum	71.12	61.47	76.45	64.26

Note: Data collected by D. Sander does not include snowfall.

Direct precipitation falling on a 44.7 ha lake in Eastham will therefore yield approximately 1.02 cu.m/min of flow, although the temporal variability of inputs will be quite high. Flow from the two inlets was also quite variable over time, but yielded mean flows of 0.11 and 0.15 cu.m/min (Table 2). Combined with an estimated mean ground water inflow of 6.3 cu.m/min, the total inflow to Great Pond is estimated at 7.58 cu.m/min (Table 7). Ground water represents the main source of water, at 83% of the total inflow. Precipitation, often only a minor direct source for lakes, contributes 13.5% of the flow. The two intermittent tributaries account for only 3.5% of the mean inflow.

The measured outflow as surface water averaged 1.65 cu.m/min, while evaporation was calculated at 0.59 cu.m/min (Higgins and Colonell 1971). This leaves an average of 5.34 cu.m/min to exit as ground water (Table 7). The partitioning of inflow and outflow among sources is shown in Figure 22. Based on the values obtained, the mean detention time for water in Great Pond is calculated at 0.41 yrs, or 148 days. Based on the variability of annual precipitation, detention time is likely to range from 0.26 to 0.77 yrs on an annual basis. Shorter and longer detention is possible during prolonged wet or dry periods, but the detention time associated with Great Pond is generally moderate.

The response time, calculated according to Dillon and Rigler (1975), indicates how much detention time is needed for the potential impact of an episodic pollutant load to be completely manifested. For Great Pond, the response time ranges from 0.4 to 0.66 yrs, or 146 to 242 days. These values are slightly larger than the calculated endpoints of the detention time range (Table 7), suggesting that most, but not all, of the impact of a pollutant will be felt by the system before the pollutant passes out of the pond. There is much variation associated with the response time, and it should not be strictly applied in a management context. It is clear, however, that nutrients and other substances entering Great Pond will experience sufficient residence time to have an impact on the system.

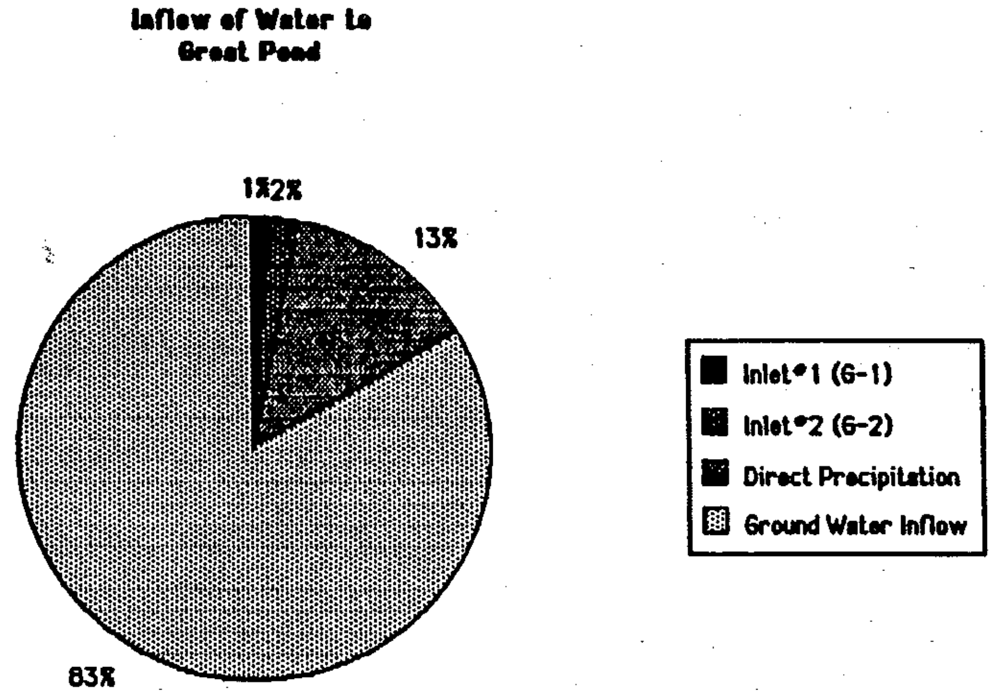
Records kept by Mr. Sander demonstrate another interesting aspect of the nearby ponds; during periods of dry weather the water level drops about 0.32 cm/day. Up to half of this could be attributed to evaporation, but at least half must be due to ground water movement. In the absence of recharge, the water table appears to be lowered daily in a detectable way by forces including use by man. Most of the water delivered to on-site waste disposal systems is returned to the ground water supply as recharge, but much of the water used for watering lawns, washing cars, and other surface applications is lost to the atmosphere as evapo-transpiration. These latter uses of water and any proposal to send wastewater out of the watershed for treatment and/or disposal have serious implications for water quantity as well as water quality in the Great Pond system.

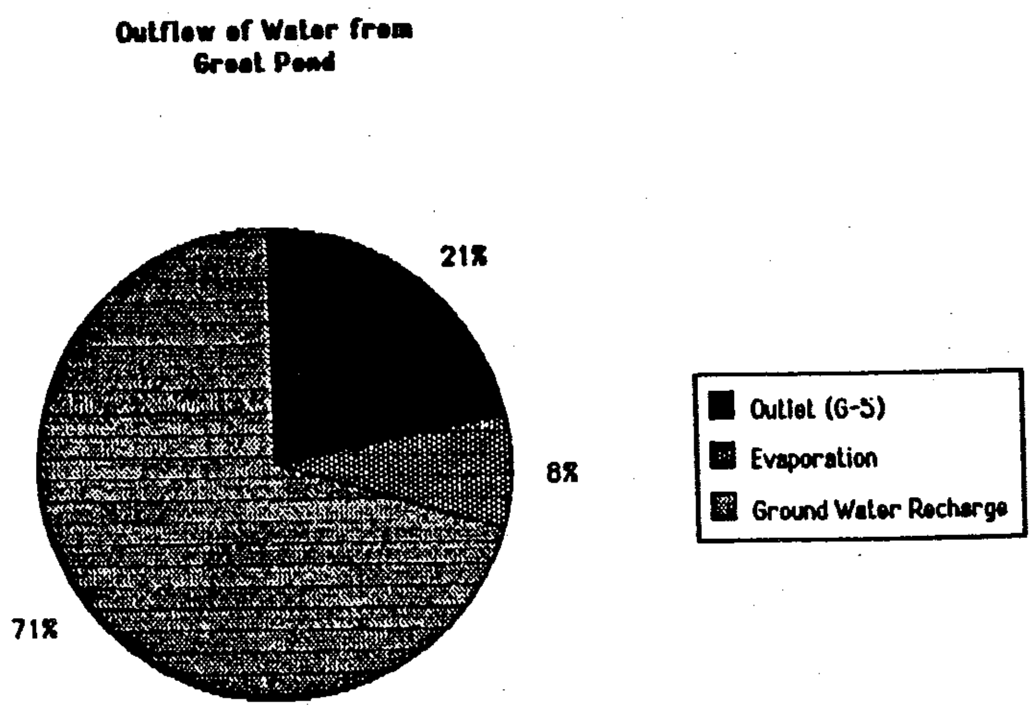
TABLE 7

HYDROLOGIC BUDGET FOR GREAT POND

Inputs	cu.m/min	% of Total
Inlet #1 (G-1)	0.11	1.5
Inlet #2 (G-2)	0.15	2.0
Direct Precipitation	1.02	13.5
Ground Water Inflow	6.30	83.0
Total Inflow	7.58	100
Outputs		
Outlet (G-5)	1.65	21.8
Evaporation	0.59	7.8
Ground Water Recharge	5.34	70.4
Total Outflow	7.58	100
Detention Time	**Years**	**Days**
Mean	0.41	148
Annual Range	0.26-0.77	95-281
[illegible]		146-242

FIGURE 22


Inflow of Water to
Great Pond
1%2%
13%
83%
Inlet#1 (G-1)
Inlet#2 (G-2)
Direct Precipitation
Ground Water Inflow


Outflow of Water from
Great Pond
21%
8%
71%
Outlet (G-5)
Evaporation
Ground Water Recharge

NUTRIENT BUDGETS

Phosphorus

Export coefficients for phosphorus can be used in conjunction with land use data to estimate the load generated in the Great Pond watershed. The best of a wealth of literature values for areal phosphorus export have been summarized by Reckhow et al. (1980), and values can be selected from the range presented after evaluation of specific watershed traits such as vegetative features, soil types, and housing density. Estimation of internal loading of phosphorus is facilitated by coefficients of release given by Nurnberg (1984), who summarized another pertinent body of literature.

Chosen export coefficients and corresponding justification are presented in Table 8. The coefficients, corresponding land areas, and the results of their multiplication are given in Table 9. Based on this analysis, 617 kg of phosphorus are generated in the watershed each year. Not all of this phosphorus reaches Great Pond, however, as much of the load must pass a great distance through soil with some adsorption capacity. Certainly no more than half of the generated load reaches the lake, but it seems probable that more than 10% will enter the water column of Great Pond each year.

Another model approach to quantifying inputs involves the use of empirical equations which rely on in-lake concentrations and hydrologic features of the system to estimate the load to the lake. A set of five equations was applied to the Great Pond system (Table 10). Appropriate values for corresponding variables and the calculated phosphorus loads are presented in Table 11. Loads ranged from 179 to 358 kg P/yr, but only one of the five equations predicted a load greater than 224 kg/yr.

Vollenweider (1968) established loading criteria based on system morphology and hydrology; a phosphorus load of less than 134 kg/yr would be considered permissible under this scheme, while a load in excess of 264 kg/yr would be deemed critical. The predicted loads span this range, suggesting the need for a more accurate quantification. The most reliable approach involves direct measurement, although not all inputs are amenable to this approach. A combination of direct measurements and calculations based on empirical data or export coefficients was therefore applied.

The mass flow of phosphorus past monitored stations (Table 12) suggests that 11.7 kg of phosphorus enter Great Pond through its two small tributaries each year. About 24.8 kg leave annually via the surface water outlet. If the load is proportional to flow, about 118 kg of phosphorus exit the pond annually, since the surface water outflow represents 21% of the

TABLE 8

NUTRIENT EXPORT COEFFICIENTS FOR LAND USES AND OTHER SOURCES IN THE GREAT POND WATERSHED

Source	Export Coefficient (kg/ha/yr) N	Export Coefficient (kg/ha/yr) P	Selection Criteria
Land Use			
Residential	8.0	2.0	Moderate density, old septic systems, sandy soils, lower part of upper half of range.
Residential/ Commercial	15.0	3.0	High density on seasonal basis, middle of upper portion of range.
Forest	1.0	0.1	Softwoods and grass over sand, low to moderate rainfall, suggests lower portion of range.
Water	-	-	Assumes no generation of loads within ponds.
Open	30.0	4.9	Includes landfill and septic system waste disposal area, high end of range.
Cemetery	2.0	0.4	Lower portion of range for pasture land.
Other Sources			
Atmospheric Deposition	8.0	0.3	Low end of urban range, middle of rural/agric./ forest range.
Ground Water	-	-	Ground water load depends on above loads and flow rate, not assessed by this approach.
Internal Recycle from Sediments *	-	7.3	Low end of range, reducing conditions not severe, phosphorus recycle only.
Aquatic Birds **	2.5	0.5	Middle of range for bird inputs.

* Requires knowledge of the duration of anoxia. Between 4.0 and 7.2 ha of the bottom of Great Pond are within the anoxic zone between late May and the end of September, or about one third of the year.

** Values based on a population of 150 birds.

TABLE 9

NUTRIENT LOAD GENERATION BY SOURCES IN THE GREAT POND WATERSHED

Source	Area Included (ha)	Export Coefficient (kg/ha/yr)		Load Generated (kg/yr)	
		N	P	N	P
Land Use					
Residential	186.5	8.0	2.0	1492	373
Residential/ Commercial	35.8	15.0	3.0	537	107
Forest	20.9	1.0	0.1	21	2
Water	14.6	-	-	-	-
Open	11.8	30.0	4.9	354	58
Cemetery	5.8	2.0	0.4	12	2
Other Sources					
Atmospheric Deposition	44.7	8.0	0.3	358	13
Ground Water	44.7	-	-	-	-
Internal Release from Sediments	4.0-7.2	-	7.3	-	29-53 (assume 40)
Aquatic Birds	44.7	2.5	0.5	112	22
Estimate of the Total Load Generated in the Great Pond Watershed				2886	617

TABLE 10

EQUATIONS AND VARIABLES FOR DERIVING PHOSPHORUS LOAD ESTIMATES FROM IN-LAKE CONCENTRATIONS

Kirchner & Dillon, 1975 $TP=L(1-R)/Z(F)$ $L=TP(Z)(F)/(1-Rp)$	(K-D)	TP=Total P as ug/l in spring L=P load as mg P/m2/yr
Vollenweider, 1975 $TP=L/(Z)(S+F)$ $L=TP(Z)(S+F)$	(V)	Z=mean depth as m F=flushing/yr
Chapra, 1975 $TP=L(1-R)/(Z)(F)$ $L=TP(Z)(F)/(1-R)$	(C)	S=effluent TP/influent TP qs=Areal water load=Z(F) m/yr
Larsen & Mercier, 1975 $TP=L(1-R_{LM})/Z(F)$ $L=TP(Z)(F)/(1-R_{LM})$	(L-M)	Vs=Settling velocity=Z(S) m R=Retention coefficient (phosphorus) =(P in - P out)/P in
Jones & Bachmann, 1976 $TP=0.84\ L/(Z)(0.65+F)$ $L=TP(Z)(0.65+F)/0.84$	(J-B)	Rp=Retention coefficient (water load =Vs/Vs+qs (Vs=13.2) 1+(F.5)

TABLE 11

PHOSPHORUS LOAD TO GREAT POND
BASED ON MODELS EMPLOYING IN-LAKE CONCENTRATIONS

Variable	Parameter Value
TP [ug/l]	37
Z [m]	3.6
F [yr-1]	2.4
S=P out/P in	0.8
qs=Z(F) [m/yr]	8.6
Vs=Z(S) [m]	2.9
R=(P in - P out)/P in	0.2
Rp=13.2/13.2+qs	0.6
R_{LM}=1/(1+F.5)	0.4
Predicted Load (g/m2/yr) By Each Model	
K-D	0.8
V	0.4
C	0.4
L-M	0.5
J-B	0.5
Predicted Load (kg/yr) By Each Model	
K-D	358
V	179
C	179
L-M	224
J-B	224
Vollenweider Criteria	
Critical Load	
g/m2/yr	0.59
kg/yr	264
Permissible Load	
g/m2/yr	0.30
kg/yr	134

TABLE 12

NITROGEN AND PHOSPHORUS MASS FLOW IN THE GREAT POND SYSTEM

PARAMETER	MASS FLOW PAST GIVEN STATION (KG/YR)		
	G-1	G-2	G-5
TOTAL PHOSPHORUS	5.5	6.2	24.8
ORTHOPHOSPHORUS	1.6	1.5	9.5
AMMONIA NITROGEN	2.8	8.6	22.6
NITRATE NITROGEN	4.0	29.1	55.9
TOTAL KJELDAHL NITROGEN	136.4	104.1	499.1
TOTAL NITROGEN	140.4	133.3	555.0

total outflow (Figure 22). Since about 20% of the input phosphorus remains in the pond (Table 11), an annual incoming phosphorus load of 148 kg is suggested.

Using a realistic value for phosphorus in rainfall (Reckhow et al. 1980), a direct precipitation-induced load of 13 kg/yr is calculated. Based on the calculated inflow of ground water (Table 7) and the concentration of phosphorus in wells near Great Pond (Table 3), the contribution of ground water to the phosphorus load is estimated at 60 to 80 kg/yr. Error is introduced here by events occurring between the lakeside wells and the water column; reductions in phosphorus concentration may occur as water passes through the size-graded sand and silt layers and benthic biological community, while increases in phosphorus level may result from interaction with pore-water into which phosphorus from decaying matter has been released.

Although the hypolimnion of Great Pond is anoxic during most of the summer, severe reducing conditions were not present during this study. In-lake phosphorus values suggest no strong vertical gradient indicative of substantial phosphorus release from anoxic sediments, but this may be a function of active wind mixing and diffusion across the thermocline (Kortmann et al. 1982). We assume that the release of phosphorus from anoxic sediments in Great Pond is commensurate with the lower end of the range given by Nurnberg (1984) to avoid underestimating the total phosphorus load.

Temporal variability in the area of sediment exposed to anoxia results in a load estimate of 29 to 53 kg of phosphorus recycled from the sediment each year. Much of this phosphorus may be precipitated with ferric iron upon exposure to oxygen when mixed into the epilimnion of the pond, but the postulated demand for phosphorus in this system suggests that phosphorus in a highly available resolubilized form will be rapidly scavenged from the water column.

Another source of phosphorus not addressed yet is the bird community associated with Great Pond. Over a hundred gulls frequent the pond on a daily basis, while substantial numbers of ducks are sometimes observed. Up to four mute swans have been sighted at the pond at the same time. Waste products from these birds are estimated to contribute between 14 and 27 kg P/yr, based on export coefficient data (Tables 8 and 9).

Summing the loads from itemized sources, the total phosphorus load to Great Pond is estimated at 127.7 to 184.7 kg/yr (Table 13). This load is intermediate to the permissible and critical loads given previously, overlapping the permissible load slightly. Given all of the load estimates derived for Great Pond, it appears that this system is receiving a moderate

TABLE 13

NUTRIENT LOADS TO GREAT POND BASED ON EMPIRICAL DATA AND SELECTED EXPORT COEFFICIENTS

Source	Total Phosphorus kg/yr	Total Phosphorus % of total	Total Nitrogen kg/yr	Total Nitrogen % of total
Inlet #1 (G-1)	5.5	3.0- 4.3	140	3.0-3.4
Inlet #2 (G-2)	6.2	3.4- 4.8	133	2.9-3.3
Precipitation	13	7.0-10.2	358	7.8-8.8
Ground Water	60-80	43.3-47.0	3377-3841	82.7-83.2
Internal Release from Sediments	29-53	22.7-28.7	----	----
Aquatic Birds	14-27	11.0-14.6	72-143	1.8-3.1
TOTAL	127.7-184.7	100	4080-4615	100

phosphorus load with the potential for substantial temporal variability. Ground water and internal release from the sediments provide 70% of the total load (Figure 23); seasonal variation associated with these sources is considerable. Birds contribute another 14% of the load, with all other itemized sources providing the remaining 15%.

The timing and magnitude of episodic inputs is critical to the condition of Great Pond. Given the moderate level of annual phosphorus loading, the subannual pattern of inputs becomes very influential in the manifestation of the load as biological productivity. If a relatively large portion of the load enters the pond in a brief time interval, especially during summer, elevated phytoplankton biomasses might be expected; the benthic mechanisms controlling phosphorus availability in this system have finite capacities. If phosphorus is delivered to the pond in a more gradual manner, the system may exhibit biological characteristics associated with ponds having lower fertility. Macrophytes which draw nutrition from the sediment are likely to be more stable in distribution, biomass, and productivity than plants relying on the water column for sustenance.

Nitrogen

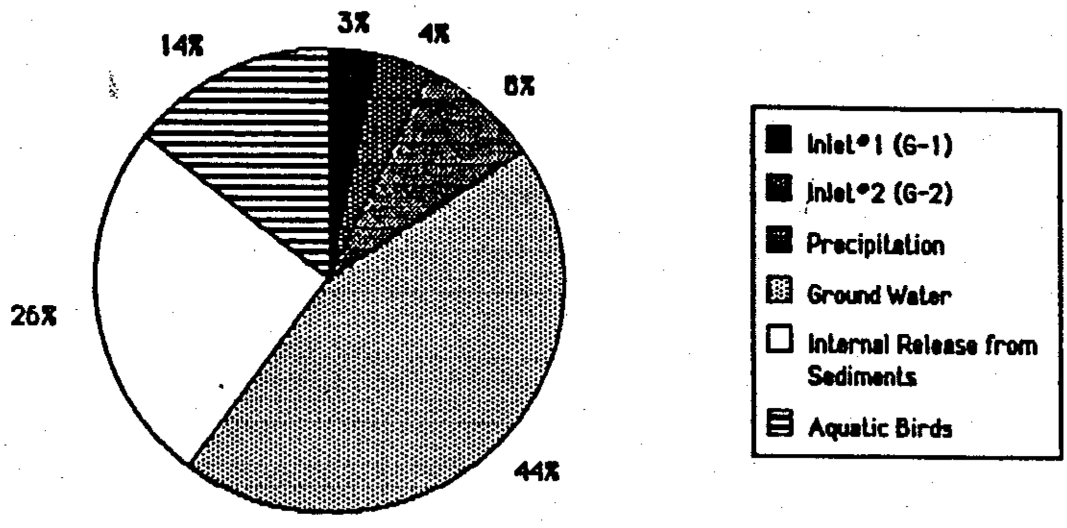
Derivation of a nitrogen budget was approached in the same manner as was the phosphorus budget. Lack of suitable equations for calculating nitrogen loads from in-lake concentrations precluded the use of that method, however. Export coefficients and resulting loads are given in Tables [illegible] three nitrogen forms and total nitrogen past monitored stations are presented in Table 12, while the loads for itemized sources are given in Table 13. A breakdown of the total nitrogen load by source is shown in Figure 23.

From export coefficients it is estimated that 2886 kg of nitrogen are generated in the Great Pond watershed each year. As with phosphorus, residential and commercial zone sources are most important. The fraction of this load reaching the pond is largely dependent on the form of nitrogen generated; nitrates move rapidly through the sandy soils of this watershed, while organic nitrogen (TKN - ammonia nitrogen) is relatively immobile where surface runoff is slight.

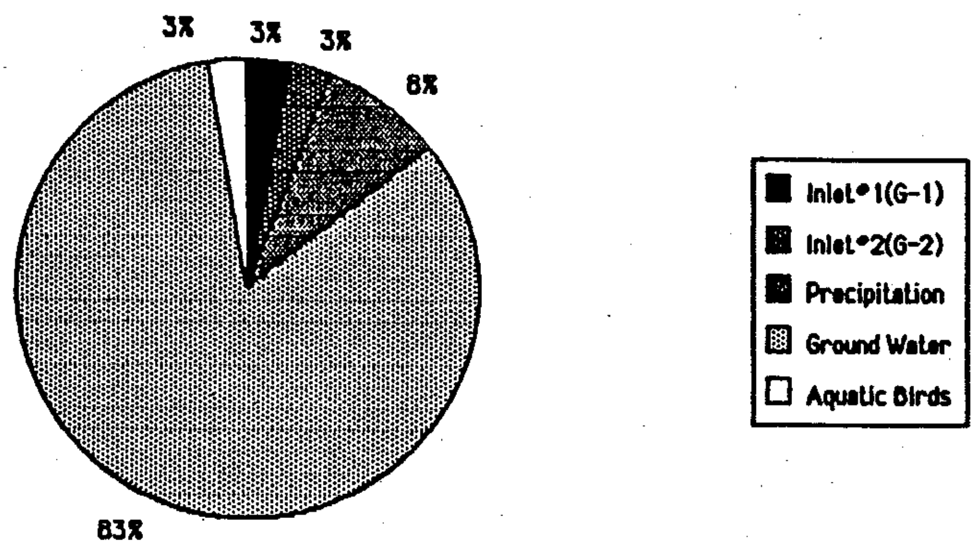
Direct measurement of nitrogen in the ground water and the calculated subsurface flow suggest a nitrogen load to Great Pond of more than 4000 kg/yr (Table 13), however. The export coefficient method may be an underestimate, but it is more likely that the observed nitrogen concentrations represent a multi-year build-up in the ground water. While water movement through the sandy soils of Eastham is rapid relative to many inland areas, the detention time for water in area aquifers is far in excess of a year.

FIGURE 23

**Total Phosphorus
in Great Pond**



**Total Nitrogen
in Great Pond**



The total nitrogen load to Great Pond is estimated at between 4080 and 4615 kg/yr, with ground water inputs accounting for 83% of this total (Table 13, Figure 23). Precipitation contributes about 8% of the nitrogen load, while other sources account for 9%. The greatest source of nitrogen to the ground water is wastewater disposal systems from which large quantities of nitrate often emanate.

The magnitude of the nitrogen load suggests that phosphorus will be in relatively shorter supply for plant growth in Great Pond, and that phosphorus would be the logical target of lake management actions. This does not mean that nitrogen should be ignored; health implications of high nitrate levels and the tendency of nitrogen sources to also be phosphorus sources suggest that an overall management plan should address nitrogen inputs. It is unlikely, however, that control of nitrogen alone (if possible) would yield any detectable improvement of Great Pond.

The relative abundance of different forms of nitrogen is more important than the total quantity of nitrogen in the Great Pond system. The presence of nitrates at high levels in water supplies can render them non-potable, and Dr. Joseph Moran (pers. comm.) has detected high nitrate concentrations in Eastham well water. Ammonia levels are of greater concern in Great Pond, where toxicity to aquatic life is a possibility. A build-up of ammonia in the anoxic hypolimnion during summer results in potentially toxic levels in that water layer, but low oxygen concentrations already preclude most desirable forms of aquatic life from that zone. Dilution with epilimnetic water upon turnover eliminates any hazard to aquatic life in the rest of the pond.

DIAGNOSTIC SUMMARY

Great Pond is a kettlehole lake of moderate area and depth which lies in a sandy Cape Cod watershed that has experienced considerable residential development over the last four decades. The primary source of water for the pond is ground water flow, which brings with it a moderate nutrient load and results in a detention time of three to nine months. Phosphorus is in relatively shorter supply than nitrogen, and most of the phosphorus in the water column is bound in organic complexes. A benthic filter comprised of sand, muck, an active microbial community, and a dense plant assemblage appears to control phosphorus availability to the phytoplankton. Plankton blooms occur only in response to episodic nutrient inputs beyond the capacity for inactivation by the benthic filter.

During the summer Great Pond stratifies and the relatively small hypolimnion becomes anoxic. There is a slight build-up of ammonia and phosphorus is probably released from the sediment into this layer during anoxia. While this condition is regarded as an indicator of deteriorating environmental quality, it is not of primary concern at this time. If the impact of anoxia on the system increases over time, however, corrective measures may become essential.

Great Pond is a very popular facility for water-based recreation of all kinds. Biological nuisances do sometimes occur, but have only minimally impaired the recreational utility of the pond. Use restrictions intended to manage the pond for maximum benefit to all of the many summer users and the environment affect recreation more than natural factors. Encroachment of macrophyte growths on swimming areas is perceived as a problem, but rooted aquatic plants create few problems elsewhere and are believed to aid phosphorus control and limit resuspension of fine particles.

While improvements are certainly possible, Great Pond is generally in a condition appropriate to its multiple uses. A diverse recreational fishery exists, although most fish are small, and the pond hosts an annual run of alewife, thus acting as a nursery for a valuable saltwater forage species. The clarity of water in Great Pond is less than many more acidic, less fertile Cape Cod lakes, but visibility is sufficient for all forms of contact recreation. Although not especially large or deep, Great Pond has a morphology which is conducive to most types of boating and sailing. The aquatic habitat and shoreline vegetation are suitable for many types of waterfowl, and the low density of waterfront buildings gives the pond an aesthetic appeal.

MANAGEMENT RECOMMENDATIONS

The greatest threat to the condition of Great Pond is the deteriorating quality of the ground water supply. Mechanisms of phosphorus inactivation have finite capacities, and periods of intense precipitation force ground water into Great Pond at a rate in excess of that which can be effectively processed by the benthic filter. Nutrients entering Great Pond have a relatively long residence time and considerable potential for nutrient recycling exists. If the quality of ground water, particularly with regard to phosphorus, declines further, the quantity of phosphorus and other pollutants reaching the water column in an available state may increase to a point at which unappealing blooms of algae are sustained. While improvement of ground water quality is not likely to be realized in the immediate future, a reversal of the deterioration process associated with waste disposal and other human influences is possible now. Steps should be taken to manage the quality and quantity of water entering the ground water supply within the watershed of Great Pond.

Within the pond itself, there appears to be little need for extensive, immediate restoration action. While the macrophyte community is considered to be a valuable component of this system, plant nuisances could be controlled in swimming areas without causing detectable impairment of water quality. It would also be desirable to restore the former depth to the Wiley Park swimming area and implement measures to control future erosion and sand sloughing in that area. Other than these largely cosmetic actions, Great Pond should be left unaltered to function on its own as a natural system.

PART II

FEASIBILITY ASSESSMENT

EVALUATION OF MANAGEMENT OPTIONS

Available Techniques

The number of actual techniques available for lake and watershed management is not overwhelming (Table 14). The combination of these techniques and level of their application, however, result in a great number of possible management approaches. Since each lake is to some extent a unique system, a restoration and management program must be tailored to a specific waterbody. Techniques are essentially taken "off the rack" and altered to suit the individual circumstances of a specific lake ecosystem.

Review of the management options in light of the characteristics and problems of Great Pond and its watershed allows elimination of certain alternatives from further consideration. Dredging is generally unwarranted in Great Pond. Macrophyte harvesting is applicable to swimming areas, but should be discouraged on any large scale. Biocidal chemicals and dyes are inappropriate here; besides, biocides are considered by BEC to be an ecologically unsound management tool in most cases. It is interesting to note that biocides are not even mentioned as lake management tools in a recent textbook on the subject (Cooke et al. 1986).

Less than one meter of vertical change in water surface elevation could be achieved by removing the flashboards at the outlet of Bridge Pond (there is no control structure at the Great Pond outlet). Most macrophyte nuisances are associated with growths at depths greater than one meter, so drawdown would not be effective. Also, a drawdown could negatively affect the alewife run by reducing water depth in Herring Run to a negligible level. A drawdown is therefore not recommended.

Dilution and flushing are not viable alternatives, as the necessary quantity of water would be great and the only sources are ground water and saltwater. The former is also the domestic supply source, and the source of most nutrients entering the pond. Use of the latter would totally disrupt the ecology of Great Pond. Under current conditions it would appear desirable to maximize the detention time of (minimize the delivery of water to) Great Pond.

Biomanipulation usually involves the removal or introduction of species, and no such action is desired at Great Pond. To improve grazing pressure by zooplankton it would be necessary to sacrifice the production of alewife, which are an important component of the marine food web. The current assemblage of macrophyte species is generally a desirable one; most species

TABLE 14

LAKE RESTORATION AND MANAGEMENT OPTIONS

Technique	Descriptive Notes
A. In-Lake Level	Actions performed within a water body.
1. Dredging	Removal of sediments under wet or dry conditions.
2. Macrophyte Harvesting	Removal of plants by mechanical means.
3. Biocidal Chemical Treatment And Dyes	Addition of inhibitory substances intended to eliminate target species.
4. Water Level Control	Flooding or drying of target areas to aid or eliminate target species.
5. Hypolimnetic Aeration Or Destratification	Mechanical maintenance of oxygen levels and prevention of stagnation.
6. Hypolimnetic Withdrawal	Removal of oxygen poor, nutrient rich bottom waters.
7. Bottom Sealing/Sediment Treatment	Physical or chemical obstruction of plant growth, nutrient exchange, and/or oxygen uptake at the sediment-water interface.
8. Nutrient Inactivation	Chemical comlexing and precipitation of undesirable dissolved substances.
9. Dilution And Flushing	Increased flow to minimize retention of undesirable materials.
10. Biomanipulation/Habitat Management	Facilitation of biological interactions to alter ecosystem processes.
B. Watershed Level	Approaches applied to the drainage area of a water body.
1. Zoning/Land Use Planning	Management of land to minimize deleterious impacts on water.
2. Stormwater/Wastewater Diversion	Routing of pollutant flows away from a target water body.
3. Detention Basin Use And Maintenance	Lengthening of time of travel for pollutant flows and facilitation of natural purification processes.

TABLE 14 (continued)

4. Provision Of Sanitary Sewers	Community level collection and treatment of wastewater to remove pollutants.
5. Maintenance And Upgrade Of On-Site Disposal Systems	Proper operation of localized systems and maximal treatment of wastewater to remove pollutants.
6. Agricultural Best Management Practices	Application of techniques in forestry, animal, and crop science intended to minimize impacts.
7. Bank And Slope Stabilization	Erosion control to reduce inputs of sediment and related substances.
8. Increased Street Sweeping	Frequent removal of potential runoff pollutants from roads.
9. Behavioral Modifications	Actions by individuals.
a. Use Of Non-Phosphate Detergents.	Elimination of a major wastewater phosphorus source.
b. Eliminate Garbage Grinders	Reduce load to treatment system.
c. Minimize Lawn Fertilization	Reduce potential for nutrient loading to a water body.
d. Restrict Motorboat Activity	Reduce wave action, vertical mixing, and sediment resuspension.
e. Eliminate Illegal Dumping	Reduce organic pollution, sediment loads and potentially toxic inputs to a water body.

present have limited to negligible nuisance potential. Biomanipulation would be inconsistent with the management objectives set for Great Pond by Town concensus.

At the watershed level, there is very little overland flow to impound, treat, or reroute. Pit drains, which accumulate runoff and allow it to percolate into the soil, are used wherever existing percolation capacity is insufficient (mainly by roads). The use of large detention basins, diversion of stormwater, and frequent sweeping of streets are not applicable techniques in this watershed. The provision of sanitary sewers or diversion of domestic wastewater from the watershed has some merit, but potential drawbacks appear to outweigh the benefits. The loss of recharge from on-site disposal systems may pose water supply problems, and the cost of providing wastewater treatment would be astronomical. Modification of the existing disposal approach appears preferable.

There is no agricultural activity in the watershed to which best management practices could be applied, and only a few localized portions of the Great Pond shoreline (e.g., near present beaches) would benefit from erosion control measures. Few watershed residents fertilize their lawns or use garbage grinders, and illegal dumping does not appear to be a problem in this watershed. Motorboat use on the pond is currently restricted. Applicable management techniques for this system are relatively few.

Not all of the applicable management techniques are appropriate for Great Pond, either. While a hypolimnetic withdrawal could be brought about with substantial modification of the Great Pond outlet or by pumping, the normal flow rate is insufficient to allow an effective withdrawal rate without artificial replacement of withdrawn water. The expense associated with treating and replacing withdrawn water is not justified by the magnitude of the problem. Aeration or destratification could also be used to eliminate hypolimnetic anoxia, but again the associated expense does not appear warranted; a capital investment of more than $70,000 would be required, with an anticipated annual maintenance and operation cost of at least $3,000.

Nutrient inactivation could be used to aid the benthic filter in limiting phosphorus availability, but it would be preferable to limit the input of phosphorus and other pollutants to the ground water. Also, repeated treatment is likely to be necessary at a cost of up to $80,000 per treatment, since much ground water enters the epilimnion directly and most compounds used to inactivate phosphorus will form a flocculant that will slough into the hypolimnion. Such treatments are likely to provide some relief from sediment release of phosphorus, but cannot be relied upon as a means of treating incoming ground water.

Management techniques remaining for consideration therefore include: macrophyte harvesting; bottom sealing/sediment treatments; zoning/land use planning; maintaining and upgrading on-site disposal systems; and using non-phosphate detergents. Some combination of these techniques could eliminate biological nuisances at Great Pond and preserve its desirable features for future generations.

<u>Evaluation of Viable Alternatives</u>

Macrophyte harvesting and bottom sealing/sediment treatments are both strategies for the control of rooted plant growths. Purchase of a harvester by the town at a cost of over $100,000 is not an economically realistic solution, but manual harvesting or the use of a drag-line to clear swimming areas is possible. Where the substrate is entirely sand there would be little residual turbidity, but anywhere that silt has accumulated there could be a turbidity problem. Resuspended fine sediment may take more than a week to settle out and could impair recreational appeal during the busy summer season. As all harvesting operations are likely to take place in late July, some interference with recreational use would have to be suffered.

[illegible] use of [illegible] material which could be placed on the bottom of swimming areas to inhibit the growth of macrophytes. Sheets of film or screen could be weighted with steel reinforcement bars (re-bars) and then rolled out on the sediment like a carpet by divers. Alternatively, framed or loose sections of covering material could be staked to the lake bottom. This operation should take place in late April, when macrophytes begin a regenerative phase in Great Pond. The covering would be removed in mid-June, just prior to the start of the summer swimming season. Macrophyte growths would be retarded by about two months, and would not reach nuisance proportions until after Labor Day, if at all.

This approach requires no disposal of harvested materials, and would allow some growth of plants in the treated areas, thereby limiting sediment resuspension and aiding the benthic filter in phosphorus control. All associated actions would occur outside of the busy summer season, minimizing interference with recreational pursuits. The choice of a covering material is dependent on effectiveness, ease of application, durability, and affordable price. Available storage space and an active maintenance program at town recreation facilities suggest that the application of a reusable material would be very feasible. As in most cases, minimization of costs is desired.

An evaluation of bottom covering materials performed by Cooke et al. (1986) suggests that mesh materials are currently the optimal choice for macrophyte control. Solid sheeting of considerable thickness (e.g., Hypalon, a commercial product used to line landfills) was most manageable and durable, but was prohibitively expensive. Thin pigmented films were relatively inexpensive, but were not durable or particularly manageable under water. For an intermediate price, mesh materials such as Aquascreen (a commercial product consisting of PVC-coated fiberglass mesh with 62 apertures/sq.cm) provided an easily applied, durable covering which effectively controlled macrophyte growths. Revegetation was slight for at least three months after removal, and the screen was reusable.

An area of approximately 0.5 ha will require treatment with a bottom covering. At a cost of about $25,000/ha (including mesh and weights or stakes), a necessary capital investment of $12,500 is estimated, with an annual installation and maintenance cost of less than $2,000. Occasional replacement of damaged mesh material will be necessary, and extra rolls of bottom cover should be purchased at the start of the project. While the initial capital outlay is greater than for some other macrophyte control means, management through bottom covering seems to be the most appropriate approach at Great Pond, and the associated annual costs are no greater than for other approaches.

The major thrust of a management plan for Great Pond will be centered not on the pond itself, but on the watershed and its influence on ground water quality. Three actions need to be taken to reverse the present trend of degradation and preserve ground water integrity: reduce the unnecessary loading of pollutants into on-site wastewater disposal systems and watershed soils, maintain and upgrade existing disposal systems, and regulate the establishment of new disposal systems within the watershed. These actions would be most effectively carried out through an officially adopted watershed management plan.

A watershed management plan is needed to prevent further degradation of Great Pond. Since the condition of the pond is currently suitable for all desired recreational uses, it is not critical that current loadings of nutrients and other pollutants be reduced. It does appear necessary to improve ground water quality for potable purposes in certain localities, however, and the establishment of a loading margin of safety for Great Pond is desirable. Furthermore, the existing development pressure in Eastham and the Great Pond watershed threatens to increase current loadings substantially.

Although ground water movement on Cape Cod is rapid relative to ground water elsewhere, it is still slow relative to surface waters in general. Impacts caused by any load reduction are likely to be felt gradually after a considerable time delay. Short-term changes in Great Pond water quality are therefore likely to be imperceptible. Yet nutrient load reductions may be essential to the long-term preservation of recreational utility. Steps should therefore be taken to implement the most stringent watershed management plan possible.

As the Great Pond watershed is not especially well defined, and the smallest associated governmental unit is the Town of Eastham, an environmental management plan should be adopted on a town-wide basis. Certain elements of such a plan have been described in the recent report of the Eastham Open Space Committee (1986), and other aspects have been discussed at various public meetings. This report will attempt to provide some guidelines for management activities related to water resources.

As noted previously, the most appropriate watershed management techniques for the system in question include zoning/land use planning, maintenance and upgrade of on-site wastewater disposal systems, and elimination of phosphate detergent use. All should be applied, and steps should be taken to ensure that the use of garbage grinders and lawn fertilizers remains low. The most difficult task will be the enactment of a zoning bylaw which is stringent and enforceable. The provisions of an effective management plan will require enforcement. It is therefore desirable to take legislative action in association with each element of the plan. A strong educational program will greatly aid the passage of appropriate legislation and subsequent enforcement.

RECOMMENDED MANAGEMENT APPROACH

After consideration of pond and watershed characteristics and the available options for improving or preserving the existing conditions, the following actions are recommended for the management of Great Pond:

1. Apply a mesh bottom covering between mid-April and mid-June each year, as warranted, to portions of swimming areas susceptible to excessive macrophyte growths. Avoid large-scale direct interference with the in-lake ecology of Great Pond.

2. Enact and implement a town-wide environmental management plan designed to improve and preserve ground water quality. Critical actions which need to be taken include prevention of unnecessary nutrient loadings to wastewater disposal systems and soils, maintenance and upgrade of existing disposal systems, and regulation of potential new systems to minimize loadings.

3. As an aid to the passage and implementation of the management plan, conduct an educational program designed to inform town residents of their impact on water resources and their role in protecting these assets. Circulation of a brochure containing pertinent information is recommended as a first step in the educational process.

4. As an aid to the implementation of the management plan, a monitoring program should be instituted, with emphasis on ground water quality and flow. A network of monitoring wells should be established and tested on at least a quarterly basis. Water quality and biological features of Great Pond should also be periodically assessed. Seepage meters should be employed to further evaluate the quantity and quality of ground water entering Great Pond.

IN-LAKE MANAGEMENT ACTIONS

The recommended approach to macrophyte control in swimming areas involves the application of bottom covers. While alternative cover materials could again be considered in the design process of a Phase II program, the preferred material at this time is Aquascreen. It is manufactured by the Menardi-Southern Division of U.S. Filter Corporation in Augusta, GA. It is a fiberglass screen coated with polyvinyl chloride, having a specific gravity of 2.54 and 62 apertures/sq.cm. Aquascreen comes in 30.5 m (100 ft) rolls of 2.1 m (7 ft) width, and is amenable to anchoring with stakes or weights. It is durable, manageable, and reusable (Cooke et al. 1986). The price per roll is about $150, and the estimated cost for all materials necessary to treat Great Pond is $17,400 (Table 15).

Application of the screen can be complicated, but the composition and slope of the sediment in the target areas of Great Pond suggest that no major problems will be encountered. If applied in April, macrophyte growths in the target areas will be slight and close to the sediment, allowing a relatively tight fit of the covering to the substrate. Either staking or weighting would be appropriate, and steel reinforcement bars could be used for either method. Cinderblocks could also be used as inexpensive, durable weights. Alternative methods of securing the cover are presented in Figure 24. The cover can be rolled onto the bottom by divers or from a boat. In either case it is advisable to have a diver anchor the cover and check for proper positioning.

The bottom cover should be removed just prior to the swimming season, which typically coincides with the end of the school year and the start of summer vacations. Within the first month of application any existing growths should die and decompose; the associated oxygen demand will be slight, relative to the oxygen supply during spring mixis. New growths are precluded by a properly functioning bottom cover, and revegetation is usually minimal for several months after removal of a cover that has been in place for at least two months (Cooke et al. 1986). In some cases it has not been necessary to apply the cover again for two years.

TABLE 15

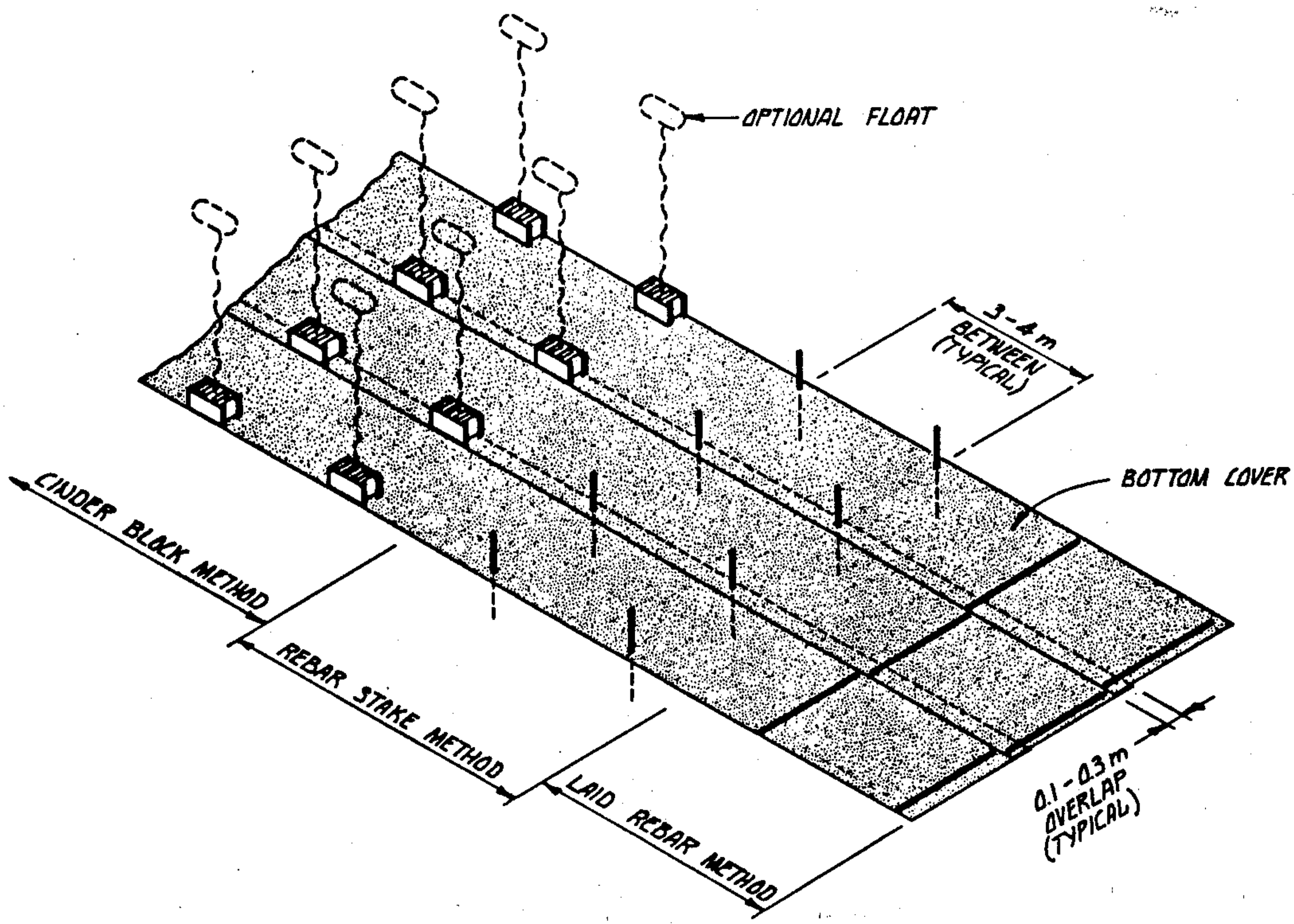
COSTS ASSOCIATED WITH MACROPHYTE CONTROL BY A BOTTOM COVER

Item or Task	Estimated Cost ($)	Maximum Percent Reimbursable Under Clean Lakes Program
100 rolls of Aquascreen @ $150/roll	15,000	75
1200 stakes or weights @ $2/	2,400	75
Installation and Removal (2-man crew @ $300/day for 6 days)	1,800/yr	0*
Additional Support (gas, brushes for cleaning, useful [illegible]	[illegible]	0**
Total Capital Outlay	17,400	75
Annual Expenses	2,000	0

* If arranged by contract, some installation/removal costs could be fundable under the Clean Lakes Program.

** If included as capital expenses in the initial grant request, some or these expenses might be funded under the Clean Lakes Program

Figure 24 - APPLICATION OF A BOTTOM COVER



Prevention of Unnecessary Loading

Proper environmental stewardship requires that conservation be practiced and pollutant loads to any system be reduced or eliminated. Many loads are unavoidable, but a few sources represent environmental abuse for reasons of convenience or societal approval. The use of garbage grinders, phosphate detergents, and lawn fertilizers fall into the latter category. While their use is tolerable in many systems, they represent an unnecessary threat to water quality in fragile or densely populated watersheds, such as many of those on Cape Cod.

Neither garbage grinders nor lawn fertilizers are used with great frequency in the Great Pond watershed (Table 5), but steps should be taken to ensure that their use will not increase. Phosphate detergents are used in about 40% of watershed households (Table 5), however, suggesting that they comprise 20% of the phosphorus entering on-site wastewater disposal systems (Goldman and Horne 1983, Lee and Jones 1986). While the change in water quality resulting from a ban on phosphate detergent use would be only marginally detectable by itself (Lee and Jones 1986), it represents an important portion of the potential long-term change achievable through a complete management program.

The Massachusetts Coalition of Lake and Pond Associations is currently promoting legislation at the state level which will ban the sale of phosphate-laden detergents in Massachusetts. Similar legislation has failed to pass in the past, however. Even if a ban on the sale of phosphate detergents is enacted, further discouragement of the use of phosphate detergents will be needed at the local level, as the seasonal population may bring them from other states. Anti-lawn fertilization and garbage grinder laws may eventually be necessary, but the current low frequency of fertilizer and grinder use suggests that an educational program revealing the associated consequences may be sufficient at this time. Useful booklets on detergents and fertilizers have been prepared by the Lake Cochituate Watershed Association (1984a, 1984b). Information from these and other references pertaining to unnecessary nutrient sources are included in Appendix B.

Pending the outcome of a current study in Eastham on the safety consequences of low intensity road salting, consideration should be given to reducing salt applications to area roads during the winter. Traffic safety may necessitate some salting, but minimization of salt applications could improve ground water quality in the Great Pond watershed.

Maintenance and Upgrade of Existing Wastewater Disposal Systems

On-site, in-ground, wastewater disposal systems (commonly called septic systems) include a diverse assemblage of arrangements designed to process wastes delivered in an aqueous medium. Outhouse pits and cesspools (single chamber disposal units) are the most rudimentary systems, and their installation has been outlawed for over a decade. Tank and leachfield systems, known as conventional units, represent about 95% of the systems installed each year in New England (Baker and Ott 1986), and include a primary settling tank with a secondary leaching system (perforated pipes, trenches, or chambers). The remaining 5% of disposal units installed include composting or waterless systems, recirculating or multiple process systems, pressure distribution systems, and other arrangements designed to provide more advanced waste treatment (Laak 1986, Nicholson 1986, Wall 1986). In reality the soil between the leaching area and the ground water table is also part of each system, and much of the removal of nutrients takes place in the soil (Brown 1980).

Improving the operation of on-site wastewater disposal systems has been the subject of considerable recent literature (e.g., Veneman and Wright 1986). The two most critical site variables related to the performance of in-ground disposal systems are the depth to ground water and the type of soil below the system (Veneman 1986). The greatest possible vertical distance to ground water and an intermediate percolation rate are desirable. While dilution by ground water may be substantial, conversion of pollutants to harmless or immobile forms is often minimal once a substance enters the saturation zone. Slow movement of effluent through a large aerated zone of soil with high adsorptive capacity is the optimal situation, but these conditions are not often achieved in practice.

One major stumbling block is the need for the disposal system to handle the volume of waste delivered to it without causing a back-up of flow. The slower percolation rates associated with some soils preclude their use for on-site systems, and most states have laws which set the minimum acceptable percolation rate. Not many states set standards for the maximum percolation rate, however, and this causes many systems to be underdesigned. The actual percolation rate will be determined by the permeability of the biofilm layer which forms in the aerated soil below the leaching area (Lavigne 1986), not just the soil permeability. When sized according to the percolation rate of highly permeable soils, leaching areas may be insufficient to pass the design flow. Further, effluent passing into the highly permeable soil may move into the ground water too quickly for effective removal of contaminants through soil adsorption processes.

Other important operational considerations are the detention time in the settling tank (preferably >1 day), waste delivery rate (preferably continuous enough to maintain the microbial community but with breaks to regenerate soil capacities), and available leaching area (preferably as great as possible). Both system design and maintenance affect these parameters. The movement of liquid through the pipes, chambers, and soils of the system is critical to operation; clogging or flow restriction must be avoided. This involves not only proper design and maintenance, but control over what is placed in the system as well. Solids such as disposable diapers and liquids such as greases should not be routed into on-site wastewater disposal systems (DiLibero 1986).

In the Great Pond watershed the depth to the ground water table can be as great as 12.2 m (40 ft), but most residential land surfaces are between 3 and 9 m (10 and 30 ft) above the ground water table. As most disposal systems are less than 1 m below the ground surface, they are likely to satisfy the minimum elevational difference of about 2 m recommended for proper function of conventional disposal systems (Brown 1980). Some residences are situated on land not more than 1 m (3 ft) above the water table, however, and certain older systems may have exhausted the adsorptive capacity of the soil for contaminants such as phosphorus.

The Great Pond watershed soils are extremely porous and allow rapid percolation. Adsorptive capacity for phosphorus is likely to be very similar to that of New Jersey Pineland soils, at 100 ug/g (Brown 1980). While this is not a large capacity, it may be sufficient for years of nearly complete phosphorus removal where the leaching area and depth to ground water are large. Also, the adsorptive capacity of the soil is apparently regenerated by periods of rest, suggesting that there is some benefit from the seasonal use pattern of many watershed residences. Nitrates move freely through these soils, however, and represent the greatest threat to the potable water supply from disposal systems.

Since only 40% of the population is in residence for more than nine months of the year (Table 5), the delivery of wastes to disposal systems is rather discontinuous. While this allows regeneration of soil adsorptive capacity, it presents problems for important microorganisms in the settling tank and biofilm. Well developed microbial communities can greatly reduce pollutant loads to the ground water, but cannot sustain themselves under highly variable waste flows.

The BEC survey of watershed residents (Table 5) indicated that 54% of the on-site disposal systems were cesspools and that 44% were conventional tank and leachfield units. The mean age of these systems was 18 yrs, and 40% of them had not been inspected or cleaned for over 5 yrs. DiLibero (1986) has recommended an inspection interval of six months to two years, with cleaning and maintenance as warranted by inspection.

Wastewater treatment conditions in Eastham are therefore likely to be suboptimal, even with proper maintenance. If ground water quality is to be improved and preserved, it is imperative that all disposal systems be properly maintained and upgrades be encouraged. While regulatory procedures are typically inadequate to deal with enforcing maintenance codes (Janaros 1986), it is possible to mandate maintenance and enforce the statute. Mandating system upgrades is usually more difficult as a consequence of grandfather clauses and a lack of appropriate data on the impact of inadequate systems. Both maintenance and upgrading of wastewater disposal systems may be possible in Eastham, however.

One appropriate approach to implementing an effective disposal system maintenance program involves taxing all residences for the cost of an annual inspection and pumping, and having the town arrange for the service (much as with trash collection or sanitary sewer operation). Alternatively, the homeowners could be made responsible for maintaining their systems, with the town keeping a record of maintenance checks and [illegible] court system. A [illegible] this process. Approved disposal system maintenance firms would report visits to the town, these visits would be logged into the file for the corresponding property, and the listing of that property as delinquent would be suppressed for another calendar year.

The cost of an annual inspection and cleaning ranges from $50 to $150 in the northeastern United States (DiLibero 1986), depending on geographic area and the distance over which septage must be transported for ultimate disposal. A cost of no more than $100 should be assumed for Eastham, as septage may be deposited in a specified lagoon area within the town landfill. The price may rise somewhat if the treatment facility proposed for Orleans is built, or if another alternative means of disposal is arranged. The cost of developing a computerized system for tracking system maintenance should be less than $5,000, but the town would also have to supply support personnel to log in maintenance visits and send out violation notices (if taxation is not applied).

Maintenance visits might have to be more frequent for intensively used systems, such as those associated with motels and restaurants, but a computerized maintenance schedule could handle this added complication easily. If proceded by an appropriate educational campaign, an article relating to wastewater disposal system maintenance should pass at the annual town meeting. It is very difficult to be against protecting a drinking water supply at a per home cost of $100/yr, especially since a single well water testing to determine potability could cost more. One useful booklet describing the design and function of conventional on-site wastewater treatment facilities and the importance of maintaining them has been prepared by the Lake Cochituate Watershed Association (1984c). Information from this and other publications is included in Appendix A.

The subject of the town landfill, which is believed to lie in the Great Pond watershed (Figure 5), is a troublesome one. There is little conclusive evidence at this time to indicate any substantial flow of pollutants from the refuse or septage disposal areas to the remainder of the watershed or Great Pond. Sampling efforts have been inadequate, however, to conclude that the landfill has no influence on ground water quality. It would seem desirable to investigate this situation further before making management recommendations, but diversion of septage collected from on-site disposal systems to a treatment facility elsewhere appears to be prudent.

As regards system upgrades, data collected by Dr. Joseph Moran may be sufficient to allow some mandatory upgrading by virtue of health hazards, and it may be possible to amend grandfather clauses to apply only to the present owners. Further monitoring efforts and more strict health codes could lead to the elimination of antiquated cesspools and certain tank and leachfield units in favor of more effective systems. Key parameters are fecal coliform bacteria and nitrates, which represent health hazards at concentrations above the corresponding water quality standards. An efficiently functioning tank and leachfield system will virtually eliminate fecal bacteria, but only those systems with extensive biofilms will reduce nitrates. Dilution by ground water is the primary means by which the nitrate standard (10 mg/l) is met in all but advanced disposal systems designed to denitrify the effluent.

Upgrades should be enforceable when violations of health standards can be demonstrated. The practical limits of treatment and legal challenges may hinder progress, but steps must be taken to eliminate poorly functioning systems, if ground water quality is to be improved. Upgrading cesspools to properly designed and sited tank and leachfield systems would probably reduce most pollutant loads to acceptable levels, but is unlikely to provide nitrate control. This is not a major issue for Great Pond, but is of concern for the potable water supply, and could result in continued high nitrate levels in the ground water near the new system. If an upgrade is mandated by virtue of a health hazard caused by high nitrate levels, it may be necessary to install an expensive advanced treatment system.

The mandatory installation of advanced on-site disposal facilities will be unpopular, but alternatives are few. Holding tanks, which release nothing and require periodic pumping, could be installed, but maintenance costs are likely to be high. Disposal of such wastes should be at an approved treatment facility. Alternatively, the installation of new systems could be regulated to minimize additional loadings to the ground water. This option will be discussed further in the section on zoning. One way to make upgrading more palatable is to offer tax incentives for improvements of poorly functioning systems. Another approach would involve mandatory upgrade of problem systems only as a condition of sale of the property. This would be a slow process, but allows the cost of improvements to be figured into the property sale price.

According to Ms. Tara Gallagher of the MDEQE, Division of Water Supply, several Cape Cod towns are already requiring on-site waste water disposal facility upgrades as prerequisites for approval for certain building improvements. Such action is therefore not unprecedented. From past experience with such upgrades, it is recommended that satisfactory upgrading of on-site disposal systems be determined by a trained health agent, not just the building inspector.

Zoning and Land Use Management

The regulation of new inputs to the ground water reservoir is theoretically easier than reducing existing loadings, but is also quite troublesome in practice. Zoning and other land use restrictions must have strong scientific backing and popular appeal if they are to be adopted and successfully defended. The need to protect ground water through land use control is not unique to Cape Cod, but in few places is the need so great or so urgent. Yet a very similar situation exists in the New Jersey Pinelands, an area which exhibits soil, vegetation, and development characteristics very similar to those on the Cape. The New Jersey Pinelands Commission has established guidelines for development in areas of varying sensitivity, and has successfully defended its restrictions for about five years (Nicholson 1986). The Pinelands experience provides considerable information which may be applicable to Cape Cod, Eastham, and the Great Pond watershed.

Although phosphorus is the key nutrient in most surface water systems, nitrogen has been chosen as the parameter of interest in the control of ground water quality. Aside from the health hazard imposed by high nitrate levels, the mobility of nitrate in sandy soils makes it the most difficult compound to control. Logically, if the concentration of nitrate in ground water can be successfully regulated, it is unlikely that other common contaminants (e.g., phosphorus or fecal bacteria) will pose water quality problems. A target concentration for nitrate nitrogen is selected and a combination of monitoring and modeling is applied to evaluate the results of different management techniques.

For sensitive areas in the Pinelands, a rather stringent nitrate nitrogen target concentration of 2 mg/l at the property border or any surface water interface was chosen. Conventional wastewater disposal systems have been found to allow more than 90% of the incoming nitrogen to reach the ground water supply, primarily in the form of nitrates. Achieving the target nitrogen level is therefore largely a function of dilution. Areal dilution models, which are mass balance equations incorporating such variables as nitrogen load, wastewater flow, and ground water recharge rate, have been used to determine the land area necessary to adequately dilute the nitrogen wastes from a single family dwelling. For the sensitive sections of the Pinelands, a parcel of 1.3 ha (3.2 ac) in area was required (Nicholson 1986).

When alternative treatment systems were considered, the necessary land area dropped considerably. Given nitrogen removal efficiencies of 40 to 83% for these advanced systems (pressure distribution, RUCK, and waterless toilet), the land area necessary to supply sufficient dilution to meet the target level of 2 mg/l ranged from 0.7 ha (1.7 ac) to 0.2 ha (0.5 ac). A potentially fair regulation scheme becomes evident; assign an areal nitrogen loading limit and let the developer decide what combination of lot size, housing type, and treatment system are to be employed to meet the loading limit.

The Cape Cod Planning and Economic Development Commission has been urging the adoption of a 5 mg/l nitrate nitrogen standard for use in determining necessary lot size or treatment level through an areal dilution model. The Town of Falmouth began employing this approach about a year ago. While it is too early to evaluate the success of this approach, there has been little outcry against it. Application of a 5 mg/l standard is intended to minimize the occurrence of values higher than 10 mg/l (considered to represent a health hazard).

Using the 5 mg/l standard for nitrate nitrogen and an annual recharge rate of 40.6 cm/yr, the areal dilution model (Technical Appendix) predicts a tolerable load of around 20.4 kg of nitrogen per hectare per year (18.1 lbs/ac/yr). With a conventional disposal system an area of 0.21 ha (0.52 ac) would be needed per person per year to meet the standard. With a more advanced treatment system the required area per person would decline to a minimum of 0.04 ha (0.09 ac). Given an average family size of

2.9 (Table 5), a single family dwelling should be placed on a parcel of land with an area of at least 0.61 ha (1.5 ac), if a conventional system is to be used. As little as 0.1 ha (0.26 ac) would be needed if the most advanced disposal system is installed (Technical Appendix).

Since summer vacationers swell the town population by as much as a factor of five, the average number of persons per household may not be the best multiplier for determining minimum lot size. Single family dwellings housed as many as 11 people in 1985 (Table 5), and motel and restaurant business was highly seasonal. A limit might be set for the maximum number of persons dwelling on lots of different sizes, or the minimum single family lot size could be increased to adjust for the higher summer population. The former approach would be difficult to enforce, and the latter action would be unfair to year round residents who do not open their homes to large numbers of guests each summer. Further discussion at the town level is needed to reach a compromise.

Based on this model, it is likely that major motels and the town landfill are contributing large quantities of nitrogen to the ground water, although the temporal instability of loads makes accurate prediction of their contributions very uncertain. Although nitrate levels emanating from these large sources may be high, there is some question regarding the movement of phosphorus from the associated properties. For example, it is hard to envision a substantial quantity of phosphorus passing from the landfill through an aerated soil zone over 12 m (40 ft) thick, even with the low adsorptive capacity of sand. The aerated soil below each square meter of landfill has an adsorptive capacity of approximately 3.2 kg of phosphorus, with regeneration of this capacity possible. Intense loading on a small area could cause a breakthrough, however, and such loading may occur in association with septage disposal. Further field investigation is warranted.

Areal load allocations appear to be the fairest approach to improving and protecting ground water quality, but they may not be applicable to existing systems. Grandfather clauses may be unavoidable in the formulation and passage of appropriate legislation. Load allocations might be applied whenever a property changes hands, or the town may opt to employ other means of dealing with existing systems (such as the upgrades discussed previously).

Two other regulatory approaches are possible. A flat limit could be set for the concentration of any pollutant of interest at the property boundary, with no development allowed if the standard is already violated. This has the disadvantage of penalizing the owners of undeveloped property for the environmental abuses of others. Alternatively, regulation of the quantity of water removed from the ground on a given property could effectively restrict the generation of wastewater and protect residents from their own disposal systems and those of their neighbors. Restriction of the zone of contribution to either the property boundary or an area which includes no disposal systems would be justifiable in terms of both health and water rights. Considerable research would be necessary, however, to determine the site specific relationships between lot layout, well depth, and the zone of contribution.

As an alternative to restricting land use through zoning or load allocations, the town could opt to purchase as much undeveloped property as possible. This would be a rather expensive option, and would require dealing with a large number of small lot owners. Although money may be available from state and federal sources for some land purchases, it is unlikely that enough land could be purchased to maintain the appropriate housing density. This approach would not be entirely consistent with the town Open Space Plan, as the appropriate pattern of land purchases would be very diffuse and not likely to result in any substantial recreational gain.

The installation of monitoring wells and further evaluation of patterns of ground water quality are recommended before any zoning regulation or land use restriction is formulated. A program for further defining ground water quality and movement in the Great Pond watershed is presented in the Monitoring Program section of this report. The preceding analysis provides considerable food for thought, however, and is believed to give an accurate description of the magnitude of controls needed to improve and protect ground water integrity.

Relevant water resource-based zoning experiences include those of the New Jersey Pinelands and the Massachusetts Towns of Falmouth and Littleton. Based on the research discussed previously, the New Jersey Pinelands Commission adopted zoning regulations in accordance with acceptable nitrate loading per unit area (Nicholson 1986). There have been no successful legal challenges to these regulations in five years of application. The Town of Falmouth has adopted a set of maximum concentration standards for various pollutants and water resources (Whitten pers. comm.). If the concentration of a regulated pollutant (most notably nitrate) is exceeded in the ground water under a property which could be developed, any development action must be negotiated through the Town, with denial possible. This statute has held up well for three years.

Of particular interest are the bylaws adopted by the Town of Littleton. These regulations protect ground water resources through zoning and land use restrictions, based on a pollutant loading model applied by Metcalf and Eddy/Philip B. Herr (1981).

After computing an allowable load and evaluating the potential loading from various activities, restrictions were placed on lot sizes and waste disposal practices in specific areas. Regulations are therefore based on a strong scientific foundation, but are stated in a practical, applicable fashion. Adoption of a similar set of bylaws by the Town of Eastham is recommended, with adjustments to suit the particular circumstances in Eastham.

MONITORING PROGRAM

A monitoring program will be necessary to assess the success of remedial actions and aid in the formulation of appropriate management policies, particularly those related to land use. Specific objectives of the monitoring program for Great Pond and its watershed include verification of the effectiveness of the bottom cover in controlling plant growths, assessment of long-term water quality trends in Great Pond, delineation of the land area to which controls must be applied to protect Great Pond, and evaluation of the spatial pattern of ground water quality and associated influences. The elements of the program and associated cost estimates are presented in Table 16.

Macrophyte density should be expressed as both percent cover and biomass per unit area for covered and uncovered locations. Field investigations in April (pre-treatment), June (immediate post-treatment), July, and late August or early September are recommended.

Surface water quality should be evaluated in June and late August or early September at the surface and bottom locations of the two in-lake stations (Figure 1). Parameters of interest include: total and ortho-phosphorus; ammonia, nitrate, and Kjeldahl nitrogen; pH; conductivity; and Secchi disk transparency. Temperature-dissolved oxygen profiles should also be constructed. More frequent sampling would be desirable, but is not necessary to assess long-term water quality trends. No short-term changes of great concern are expected, and monitoring costs should be minimized.

Assessment of ground water elevation, movement, and quality are critical to the protection of both Great Pond and the potable water supply. There is a need to more accurately define the Great Pond watershed and the path of ground water within it. Lack of detailed information on the depth of residential wells and the difficulty of uncapping them for water level measurement necessitates the installation of monitoring wells. Monitoring wells would provide standard locations at which water level and quality could be assessed at any desired frequency. It would also be possible to conduct crude pumping or percolation tests using these wells. Installation of wells at different depths would allow vertical as well as horizontal profiles of water quality.

Proposed well locations are shown in Figure 25. Piezometer clusters will include three wells with depths of approximately 6, 15 and 24 m (20, 50, and 80 ft); alteration of depths will be made as warranted by the elevation of the water table. These wells will provide information on both water quality at different depths and the path of ground water flow. The relative elevation

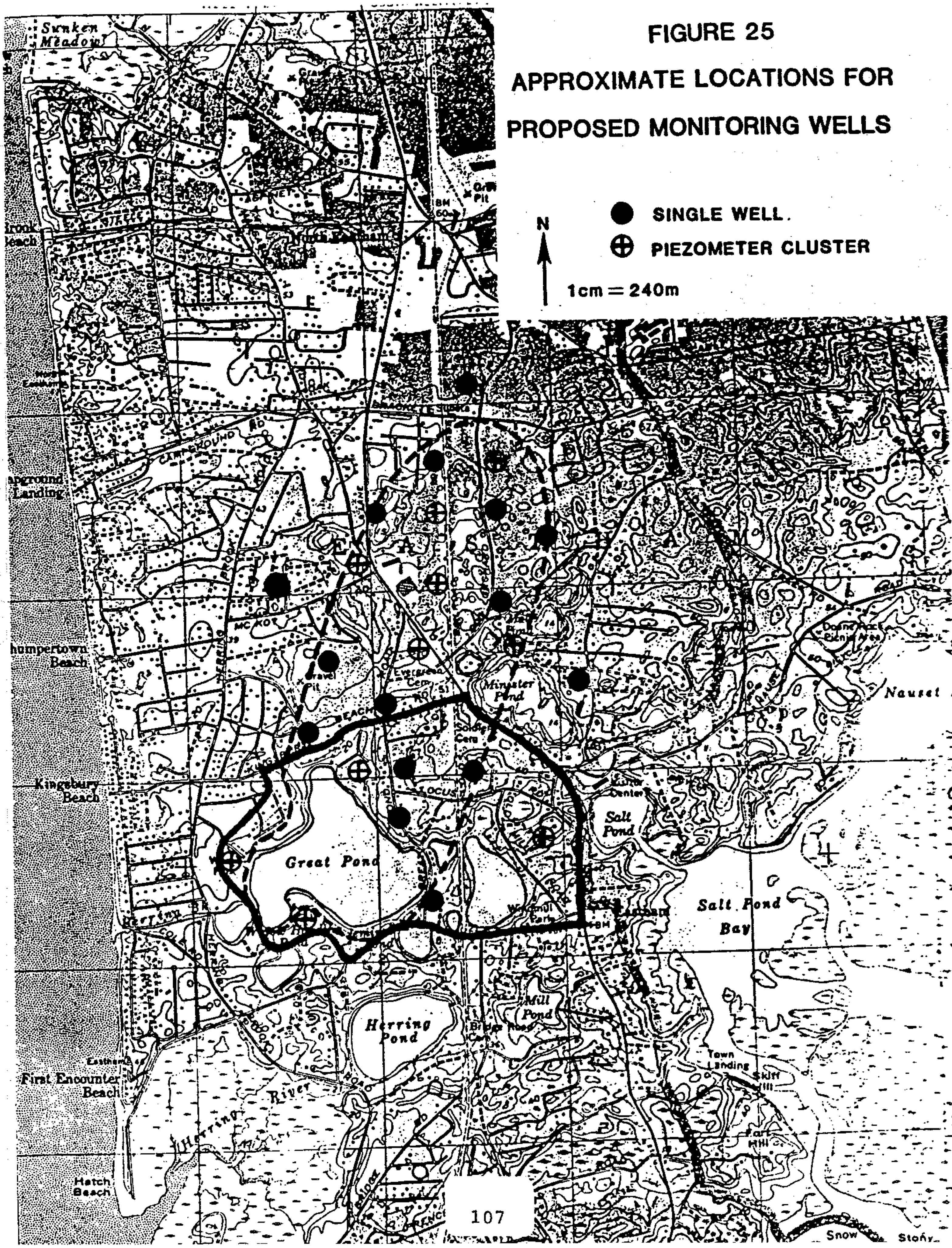
TABLE 16

COSTS ASSOCIATED WITH A ONE-YEAR MONITORING PLAN

Item or Task	Estimated Cost ($)
1. Macrophyte Monitoring	
a. Field evaluation of plant density in treated and control areas in April, June, July and August - September by a 2-man crew	3,200.00
2. Surface Water Quality Monitoring	
a. Sampling of 2 in-lake stations at surface and bottom in June and August-September by a 2-man crew	1,600.00
b. Analysis of samples for phosphorus and nitrogen series, pH, conductivity, D.O./T profile, SDT (4 samples @ $100/sample)	400.00
3. Ground Water Assessment	
a. Well Installation	
Crew and rig for 17 d @ $1,000/d	17,000.00
Materials for 15 single wells @ $300/well	4,500.00
Materials for 10 well clusters @ $700/well	7,000.00
b. Well sampling - 45 wells checked 4 times by a team @ 2400/trip (includes assessment of water table elevation and flow path)	9,600.00
c. Lab analysis of 180 samples for phosphorus and nitrogen series, pH, conductivity, alkalinity, Na, Fecal coliform and streptococci @ $100/sample	18,000.00
d. Seepage measurements in Great Pond to verify flow by a 2-man team for 2 days on each of 2 occasions	3,200.00
e. Lab analysis of 10 seepage samples taken during performance of Item d., for parameters noted in Item c.	1,000.00
4. Summary Report and Meetings	3,500.00
Total	$69,000.00

Note: Monitoring after the first year would probably involve only 50% of the sampling/analysis and none of the capital costs (e.g. wells). An annual cost of $22,000 is estimated for annual monitoring efforts after the initial year.

FIGURE 25
APPROXIMATE LOCATIONS FOR PROPOSED MONITORING WELLS



of water in each of the three wells in each cluster can be used to detect areas of distinctly downward flow, upwelling, or horizontal flow. When combined with the elevational data collected from single wells nearby, a pattern of ground water movement can usually be discerned. A diagram of a sample piezometer cluster (set in soil unlike that of Cape Cod) is shown in Figure 26.

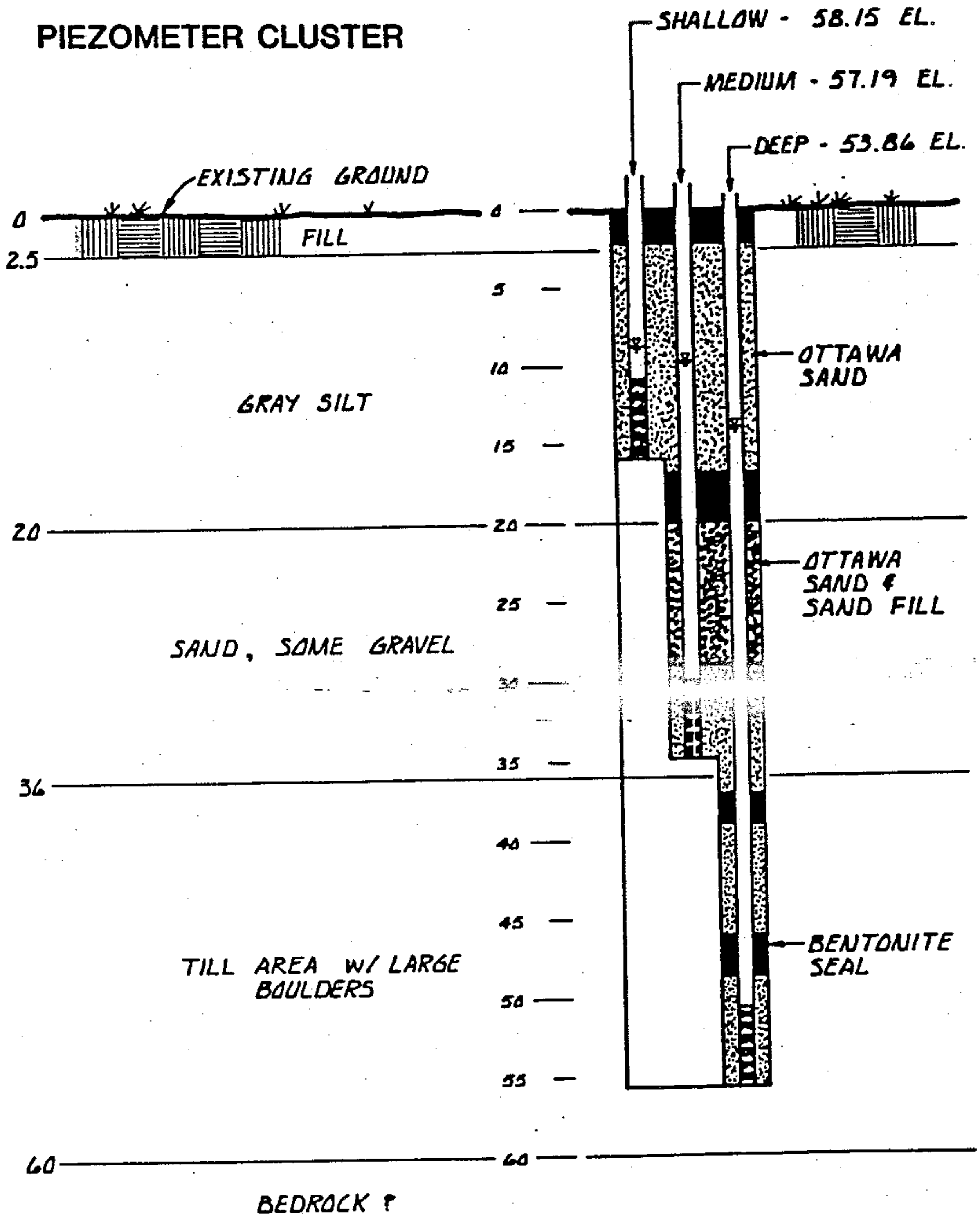
The Cape Cod Aquifer Management Project, sponsored in part by the Massachusetts Department of Environmental Quality Engineering, is currently searching out existing monitoring wells installed during other projects which might be useful for ground water monitoring in Eastham (Gallagher pers. comm.). Some could be used in the proposed monitoring project, but they should not be relied upon until located and their utility verified. Only one qualifying well now exists in the Great Pond watershed, that being located on a grass island in the Wiley Park parking lot. In conjunction with an additional two wells at different depths it could be used as one of the proposed piezometer clusters.

All wells should be sampled four times, once in each season, with analysis of total and ortho-phosphorus, ammonia, nitrate, and Kjeldahl nitrogen, pH, alkalinity, conductivity, sodium, and fecal coliform and streptococci. The town or other agencies may wish to take advantage of the opportunity to conduct a study on the distribution of other substances, such as priority pollutants. Such studies would be valuable in assessing the potable water supply, but have relatively little bearing on Great Pond. After the intital year of sampling (four sets), one or two samplings per year should be sufficient to characterize ground water quality.

Measurements of the quantity and quality of water seeping into Great Pond should be made on two occasions each year, employing recently developed seepage meters and pore water samplers. Actual measurement of the ground water entering Great Pond will allow verification of the estimates and processes described in the Limnological Data Base section of this report. It would be desirable to perform one seepage evaluation during a dry period and the other following an extended period of precipitation. Analysis of ten seepage water samples for the parameters monitored in wells is recommended.

FIGURE 26

SCHEMATIC OF A SAMPLE PIEZOMETER CLUSTER



PIEZOMETER CLUSTER

FUNDING ALTERNATIVES

Several sources of funding may be available for management activities in the Great Pond watershed (Table 17), but the Clean Lakes Program represents the single most versatile source of support. Special grants from the Massachusetts Division of Water Supply or the federal Office of Ground Water Protection may also be available for activities relating to the prevention of ground water contamination. Eastham is being considered for funding under these programs, although a formal application has been submitted only to the Clean Lakes Program. The Office of Ground Water Protection is especially interested in programs involving ground water monitoring near landfills, making Eastham an attractive candidate.

The Aquifer Lands Acquisition Program can be used to purchase land to protect an existing public supply well. Should public wells be developed in Eastham, this would be a viable source of funding for ground water protection measures and the preservation of open space, another concern in Eastham. Other listed potential sources of funding are either less reliable or more appropriate for activities which are less relevant to the situation in Eastham. It would be wise to further investigate the process associated with ground water protection grants, and to express the town's interest in related programs in a formal way, even though Eastham is apparently already being considered under certain programs. No other action appears warranted at this time.

TABLE 17

Potential Funding Sources for the Proposed Management of Great Pond.

Source	Funding Level	Notes
Massachusetts Clean Lakes Program (Ch. 628 of the Acts of 1981, DEQE)	75%	Sound Program; July 1 application deadline; likely source.
Federal Clean Lakes Program (Sec. 314 of PL 92-500, USEPA)	50%	Financially restricted; few new projects accepted.
Rivers and Harbors Program (Division of Waterways, DEM)	75%	Recently reorganized, Jan. 15 deadline. If renewed in subsequent FY appropriations it could supply 50% funding
Small Watershed Protection Program (PL 83-566, SCS)	(up to) 100%	Requires high cost-benefit ratio; project likely to have low priority. Funding cutbacks proposed.
Resource Conservation and Development Program (Food & Agric. Act of 1962, SCS)	100%	Requires established RC&D district, limited funding opportunities at present
Federal Land and Water Conservation Fund; Division of Conservation Services, EOEA (Federal Pass Through)	50%	Acquisition of lands for outdoor recreation; could be useful under certain land use approaches applicable to Eastham
Mass. Self Help Program M.G.L. Chap. 132A, Sec. 11 (DCS/EOEA)	(up to) 80%	Grants to Conservation Commissions for Land Acquisition; need an approved open space plan. Funds available.
Aquifer Lands Acquisition Program, Ch. 286, Secs. 5, 20, Acts of 1982 (DEQE)	100% for studies to $50,000; Total grants up to $250,000 including purchase	$10 M obligated to 26 towns to date; $4.25 M available. Potentially very appropriate in Eastham.
Line items in DEQE budget; possible grants through the Division of Water Supply.	(Up to) 100%	Possible allocations related to groundwater protection; some interest already shown in Eastham through a grant involving the Barnstable County Health Department.
Office of Ground Water Protection, USEPA, Region I	(Up to) 100%	Money to be distributed to qualifying towns for monitoring, particularly with regard to landfills.

CONTACT AGENCIES

Quite a few agencies have expressed an interest in environmental activities in Eastham, but there is considerable confusion regarding which agency is responsible for what program or task. One active research program directly involving Eastham is a multi-faceted ground water investigation (The Cape Cod Aquifer Management Program) being conducted jointly by the USEPA, USGS, MDEQE, and CCPEDC. Its components include review of existing information (incorporating the current study by Dr. Joseph Moran) and evaluation of existing ground water protection programs. Subsidiary program objectives include the preparation of a new water table map (if sufficient information is available), preparation of a general hydrologic map of Eastham (for use in locating potential water supplies and educational endeavors), and refinement of the nitrate loading formula (CCPEDC 1986). The results of this project should be very useful in the formulation of land use regulations for Eastham.

A second research project involves the National Park Service and the Department of Landscape Architecture and Regional Planning at the University of Massachusetts (Amherst). A predictive model of land use changes in Eastham is to be developed. Its utility in assessing development impacts on ground water is unknown at this time, but this project will provide a framework for examining the relationship between development and ground water problems.

Any management activity associated with the water resources of Eastham (or anywhere else on Cape Cod) should be brought to the attention of the appropriate town committees (e.g., Conservation Commission, Board of Health), CCPEDC, the Barnstable County Board of Health, appropriate divisions of the Department of Environmental Quality Engineering, and the appropriate offices of USEPA, Region I. The U.S. Army Corps of Engineers should also be informed of water related activities, but at this point there do not appear to be any proposed actions which fall within their jurisdiction. The major contact agencies will be the MDWPC Clean Lakes Program (all aspects of the proposed project), the Massachusetts Division of Waterways/Wetland Regulation (permits related to in-lake improvements), the Massachusetts Division of Water Supply (technical support and possible funding), the federal Office of Ground Water Protection (technical support and possible funding), and CCPEDC (technical support and agency coordination). The Eastham Conservation Commission and Board of Health are the key local organizations, with possible technical support available from the Barnstable County Board of Health. Actual applications and letters of correspondence will originate from the Eastham Board of Selectmen.

ENVIRONMENTAL EVALUATION

Environmental Notification Form

Appendix B contains the Environmental Notification Form (ENF) which must be filed under the Massachusetts Environmental Policy Act (MEPA). The MEPA unit will evaluate the proposed actions and their potential impacts and make a determination regarding the need for an impact study prior to implementation. The ENF also serves as a useful summary document for the project. No impact statement is likely to be required for the proposed project.

Comments by Interested Parties

Copies of the draft report were sent to the Eastham Board of Selectmen and Conservation Commission, Dr. Joseph Moran, Mr. Wallace Ruckert, Mr. Donald Sander, CCPEDC, the MDWPC Clean Lakes Program, the Division of Water Supply, the Division of Fisheries and Wildlife, the Soil Conservation Service, and the Massachusetts Historical Commission for review. Comments by these parties are addressed in this report or appended to it (Appendix C), as warranted. Written and verbal comments recieved from citizens and agencies during the course of the project are also addressed or appended to this report.

To date, two public meetings and numerous informal discussions have been conducted by BEC in the Town of Eastham. Participants were encouraged to express their views and make recommendations. Local support for the project has been strong, and cooperation has been most gratifying. Only two issues were raised which are not specifically addressed in this report. The first involves the restriction of boat engines to less than 50 hp. The point was made that it is not the engine size alone that dictates boat speed, wake, and subsurface turbulence. Consideration for boat size and other factors was not included in the boating regulations. This issue could not be resolved within the framework of this study.

The second issue involves the desire by several lakefront property owners to slightly reduce the elevation of the water surface to prevent flooding and provide a possible beach area. It was believed that the lake level had been considerably lower at some time in the past, but no evidence of a prolonged period of lower lake level could be found. The natural variation in lake level is 0.6 to 1.0 m (2 to 3 ft, DEQE 1980); observed fluctuations in lake level are likely to be natural and uncontrollable in this system. Potentially detrimental environmental impacts (e.g., erosion and loss of fish habitat) might also result from a forced drawdown.

TABLE 18 SUMMARY OF MANAGEMENT ACTIONS, IMPLEMENTATION SCHEDULE, AND ASSOCIATED COSTS

Task	Spring/ Summer 1987	Fall 1987	Winter 1987-88	Spring 1988	Summer 1988	Fall 1988- Summer 1989	TOTAL COST ($)
Final funding arrangements, permits obtained	1,000						1,000
Bottom cover obtained & applied for macrophyte control			17,400	2,000		2,000	21,400
Monitoring wells installed		28,500					28,500
Monitoring program		6,900	6,900	11,600	15,100	22,000	62,500
Educational program (brochure distributed, town forum meetings)		5,000	?	?			5,000 (?)
Computerized recording of disposal system maintenance and upgrade		5,000	?	?	?	?	5,000 (?)
Consideration and enactment of ordinances related to land use		?	?	?	?	?	(?)
TOTAL COST ($)	1,000	45,400	[illegible],300	13,600	15,100	24,000	123,400

Note: ? denotes potential but uncertain costs associated with management actions. Most ?'s are associated with actions requiring considerable labor by town employees which may not be part of their normal work load or functions.

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APPENDIX A

EDUCATIONAL INFORMATION ABOUT LAND AND WASTEWATER MANAGEMENT FOR MINIMIZATION OF GROUND WATER POLLUTION

AN ANNOTATED BIBLIOGRAPHY OF USEFUL PUBLICATIONS

Bolger, R.C. 1965. Ground Water. Educational Series #3. Commonwealth of Pennsylvania, Dept. of Internal Affairs, Harrisburg, PA.

Although slightly outdated, this primer clearly explains processes and phenomena associated with ground water. A discussion of well development is included.

Brown, K.W. 1980. An Assessment of the Impact of Septic Leach Fields, Home Lawn Fertilization and Agricultural Activities on Ground Water Quality. K.W. Brown and Associates, College Station, TX.

This technical document discusses the results of ground water investigations in sandy soils. The impacts of wastewater disposal, lawn fertilization, and agricultural activities on ground water resources are described in conceptual and experimental terms. A model for determining the land area necessary to support a given activity without excessive ground water pollution is presented and applied.

Connecticut Department of Environmental Protection. 1984. A Watershed Management Guide for Connecticut Lakes. CTDEP, Water Compliance Unit, Hartford, CT.

The process of eutrophication is described and the [illegible] controling phosphorus is emphasized. Sources of information for evaluating lake condition are presented. Sources of pollution are discussed and recommendations for controling inputs are given, including tips on minimizing residential contributions.

Klessig, L.L., N.W. Bouwes, and D.A. Yanggen. 1983. The Lake in Your Community. Univ. of Wisconsin Extension Service, Madison, WI.

This booklet describes lakes and lake processes, including natural aging and accelerated eutrophication. Management techniques, limitations, and costs are given. The formation of lake management districts is discussed, and additional sources of information are listed.

Lake Cochituate Watershed Association. 1984a. Detergents and Your Lake. MDWPC Publ. # 13,810-21-200-10-84-C.R.

The role and behavior of phosphates in the environment are discussed in layman's terms. The composition of detergents and the use of phosphate as a builder are described. Alternatives to phosphate detergents and associated limits are discussed, and possible approaches to reducing detergent phosphorus inputs to the environment are described. Attempts at legislating detergent phosphorus reductions are reviewed. The publication

concludes with a long (although incomplete) list of cleaning products and their phosphorus content.

Lake Cochituate Watershed Association. 1984b. Fertilizers and Your Lake. MDWPC Publ. # 13,808-11-200-10-84-C.R.

The use of fertilizers, their composition, and natural processes affecting them are described in layman's terms. Interactions with the hydrologic cycle and the role of fertilizer in the eutrophication of surface waters are explained. Fertilizer requirements for typical lawns are given, and the hazards of overfertilization are described. The substitution of natural landscaping for maintenance-intensive lawns is recommended wherever possible, and tips are given for achieving an attractive residential setting through appropriate plantings and selective controls.

Lake Cochituate Watershed Association. 1984c. Septic Systems and Your Lake. MDWPC Publ. # 13,807-14-200-10-84-C.R.

The proper management of septic systems and problems resulting from improper design or lack of maintenance are described in layman's terms. Alternatives to conventional wastewater disposal systems are discussed and techniques are suggested for repairing poorly functioning systems which represent a health hazard or threat to environmental quality. The relation of system design and maintenance to ground water quality is emphasized.

North American Lake Management Society. 1985. Starting and Building and Effective Lake Association. NALMS, Washington, D.C.

This booklet describes types of organizational arrangements for managing a lake. Discussions include the formulation of objectives, fund raising, and organizational by-laws.

North American Lake Management Society. 1985. A Layman's Bibliography of Lake Management. NALMS, Washington, D.C.

A lengthy list of popular articles and technical papers relevant to the management of lakes is presented. A breakdown by key words is provided.

Pastor, D., and C. Alleva (editors). 1986. Water: Life Depends On It. Reprints from the Citizens' Bulletin. CTDEP, Hartford, CT.

This collection of articles deals with water and man's influence on it. One very informative article lists facts and fiction regarding water supplies and notes conservation/pollution prevention methods. Other articles introduce components of aquatic systems and describe their role in system ecology.

Strahler, A.N. 1972. The Environmental Impact of Ground Water Use on Cape Cod. Assoc. for the Preservation of Cape Cod, Orleans, MA.

This detailed treatise on the geology and hydrology of Cape Cod is written largely in layman's terms or with explanation of terms. Many useful diagrams aid understanding of the processes that determine the quantity and quality of ground water on Cape Cod. Detailed appendices describe phenomena and models of interest to laymen and professional alike.

Veneman, P.L.M., and W.R. Wright (Editors). 1986. On-Site Sewage Disposal. The Society of Soil Scientists of Southern New England, Storrs, CT.

This collection of papers from a recent symposium covers the range of technical, economic, social, and regulatory issues associated with on-site wastewater disposal. Conventional and advanced on-site treatment systems are described, maintenance recommedations are made, and the legal and regulatory options for dealing with ground water pollution are discussed. While technical in nature, most presentations are clear and comprehensible.

SUMMARY OF KEY POINTS RELATING TO MAN'S INFLUENCE ON GROUND WATER

Detergents and Other Cleaning Agents

1. Except where water contains excessive quantities of dissolved substances ("hard" water), phosphorus is an unnecessary component of cleaning agents; clothes and dishes are unlikely to be detectably cleaner, and no health hazard is created by the elimination of phosphorus from cleaning agents.
2. Cleaning agents can contribute up to 75% of the phosphorus entering disposal systems, and usually provide at least 30% of the phosphorus input from households where phosphate detergents are used.
3. If a detergent does not contain phosphorus, it usually will state this on the container. Most phosphate detergents list the weight fraction comprised by phosphorus. Liquid cleaners tend to contain less phosphorus than powdered forms.
4. In the Great Pond watershed, at least 20% of the phosphorus entering the system can be attributed to phosphate detergents. Elimination of this source could have a detectable effect on long-term water quality in Great Pond.
5. Legislation calling for a ban on phosphate detergents or a restriction of the allowable phosphorus content is currently being considered by the Commonwealth of Massachusetts. Support is needed.

Garbage Grinders

1. Garbage grinders cause unnecessary loading of solids and nutrients to wastewater disposal systems, resulting in a need for more frequent maintenance and a higher potential for system failure and ground water pollution.
2. Composting of garbage is a much more environmentally sound method of disposal, if done properly.

Lawn Fertilizers

1. If properly applied at an appropriate dosage, fertilizer can enhance a lawn without gross ground water pollution, but some addition of contaminants to the ground water must be expected.
2. Overfertilization or improper application of fertilizer can be a major source of ground water contamination by phosphorus, nitrogen, and biocidal compounds, resulting in a health hazard in many instances.
3. Maintenance of a lush green lawn of one or a few species represents an unnecessary expenditure of time and resources to satisfy a questionable perception of beauty or order.
4. The use of many species of natural vegetation maintains potentially valuable diversity and requires less money and effort to maintain. To the discerning eye, a natural landscape is far more attractive than a close-cropped grass lawn. Recycling of nutrients in a natural landscape results in less ground water contamination.

On-Site Wastewater Disposal

1. Improper placement of systems (choice of sites) is a major cause of system inefficiency and resultant ground water contamination.
2. Improper installation or settling/upheaval can negate proper design and

siting of a system; care and forethought are critical elements of installation.

3. A vertical distance of at least 6 ft between the point of discharge to the soil and the ground water table is necessary to minimize environmentally tolerable performance of a system.
4. Cesspools provide considerably less treatment of wastes than conventional systems, require more maintenance to operate properly, are more prone to failure, and can no longer be legally installed.
5. For cesspools and conventional tank and leachfield systems, treatment will be insufficient to control nitrogen release into the ground water. More than 90% of the nitrogen put into the system will enter the ground water as potentially hazardous nitrate. Dilution of effluent by percolating rain water or the ground water supply itself is necessary to avoid a health hazard.
6. Alternative treatment methods include systems which separate blackwater (toilet wastes and garbage) and greywater (shower, sink, and washing machine water) and treat each appropriately, systems that recirculate effluent for further treatment, and systems which have no effluent (holding tanks). While more expensive to install or maintain, these systems have less environmental impact than conventional systems. Their use should be encouraged in environmentally sensitive or densely populated areas not served by a community sewerage system.
7. An on-site wastewater treatment system functions in the same capacity as a municipal wastewater treatment plant, only at an individual site level. As with large treatment plants, maintenance of an on-site system is essential to its proper operation. Failure to spend a little time and money on system inspection and maintenance can result in the [illegible] repair or replace the system at a much larger cost to the owner and environment.
8. On-site systems should be inspected every 6 months to 2 years, depending on the intensity of use. If the lower limit of the floating scum layer or upper limit of the settled sludge layer exceed design specifications (too close to outlet port), removal of accumulated solids is needed. If the available volume in the settling tank provides less than a one-day detention time, solids removal is needed.
9. To avoid clogging of pipes, large solids and solidifying substances should not be put into the system. Problem materials include diapers, sanitary napkins, cigarette butts, garbage, and greases. Clogging of leaching areas by such materials is a major cause of system failure.
10. To avoid upsetting the biological balance of the system (an active microbial community is essential to proper function), caustic solutions, cleaning agents, and other potentially biocidal compounds should not be put into the system.
11. Water conservation results in longer detention times in the settling tank, greater breakdown of inputs, less build-up of sludge, and lower maintenance costs.
12. There are many alledged remedies and products available for the restoration of failed systems and for improving system treatment efficiency. Despite some potentially valid claims, there is no hard evidence that any of these actually works. The best solution to septic system problems is to prevent their occurrence.

Ground Water in General

1. There is no magic underground river or lake that supplies ground water. Percolation and infiltration of rain water is the only substantial source of replenishment. Contaminants on the surface of the land or in the soil may be carried with percolating water into the ground water supply.
2. Ground water moves and is replaced much more slowly than most surface waters. Creation of a ground water problem will therefore have a longer-term impact than pollution of surface waters.
3. Where wells and septic systems are employed, some portion of the water consumed in each household is certainly derived from the wastewater of other households in the same subsurface drainage basin. Renovation of wastewater prior to its entry into the ground water is therefore critical to the prevention of health hazards.
4. Placement and depth of a well and the water demand placed on it will determine the corresponding zone of contribution. A shallow well with a relatively great demand may have a zone of contribution that extends into the wastewater discharge area of the same or neighboring properties. Even proper treatment of wastes prior to discharge into the soil may be insufficient to maintain appropriate ground water quality in such wells.
5. Major sources of contamination (e.g., large motels, housing complexes, and landfills) may create an expanding, attenuating plume of polluted ground water which moves vertically and horizontally away from the source in the down-gradient direction. The surface location and intake depth of wells in the area will determine which ones become contaminated.
6. Preliminary calculations indicate that at densities of more than 2 people per acre of land, ground water pollution to the point of possible health hazards is possible in Eastham. Elevated nitrate levels constitute the primary threat.

APPENDIX B

ENVIRONMENTAL NOTIFICATION FORM

APPENDIX A
COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS

ENVIRONMENTAL NOTIFICATION FORM

I. SUMMARY

A. Project Identification

1. Project Name Great Pond Management Project

2. Project Proponent Eastham Board of Selectmen
Address Town Hall, Rt. 6, Eastham, MA 02640

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

1. Location within city/town or street address Great Pond, off Great Pond Road and Herring Brook Road

2. Est. Commencement Date: Fall, 1987 **Est. Completion Date:** Fall, 1989
% of Project Design: 90 **% 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).

A mesh bottom cover (Aquascreen or equivalent) will be applied to macrophyte-infested portions of the Wiley Park and Town Beach swimming areas between April and June of the spring of 1988, and potentially in subsequent springs, to retard rooted growths. A large watershed monitoring program is also planned for 1987-89, focusing on ground water flow and quality. Some in-lake monitoring will also be conducted. Resultant data will be used to develop effective land and water use controls to improve water resources in Eastham. Public education and the enactment of Town ordinances are viewed as the major courses of action to control land use and protect water resources.

Copies of this may be obtained from:
Name: Board of Selectmen **Firm/Agency:**
Address: Town Hall, Rt. 6, Eastham, MA 02640 **Phone No.** (617) 255-0333

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__X___

D. 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
en Space & Recreation	X	X
storical		
chaeological		
sheries & Wildlife	X	X
getation, Trees		
her Biological Systems		
and Wetlands	X	X
astal Wetlands or Beaches		
od Hazard Areas		
emicals, Hazardous Substances, High Risk Operations		
ologically Unstable Areas		
ricultural Land		
her (Specify)		

	Construction Impacts	Long Term Impacts
Mineral Resources		
Energy Use		
Water Supply & Use		
Water Pollution		
Air Pollution		
Noise		
Traffic		
Solid Waste		
Aesthetics	X	X
Wind and Shadow		
Growth Impacts		
Community/Housing and the Built Environment		

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

E. Has this project been filed with EOEA before? Yes ____ No X
If Yes, EOEA No. ____ EOEA Action? ____

F. Does this project fall under the jurisdiction of NEPA? Yes ____ No X
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
MDEQE	Ch. 91 License/Water Quality Certifica
USACOE	Sec. 404 Permit

H. Will an Order of Conditions be required under the provisions of the Wetlands Protection Act (Chap. 131, Section 40)?
Yes X 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
MDEQE, MDWPC, Clean Lakes Program	75% of all costs ($14,550 for noted project elements, + monitoring and education expenses)
Possibly the Office of Ground Water Protection, USEPA Region I	?

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. See Figures 1,2,6

B. State total area of project: Approximately 0.5 ha (1.2 ac)
Estimate the number of acres (to the nearest 1/10 acre) directly affected that are currently:

1. Developed .... 0 acres
2. Open Space/Woodlands/Recreation 1.2 acres
3. Wetlands .... 1.2 acres
   (under water)
4. Floodplain (under water)..... 1.2 acres
5. Coastal Area .... 0 acres
6. Productive Resources
   Agriculture .... 0 acres
   Forestry .... 0 acres
   Mineral Products .... 0 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. None required

III. 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 __X__ No ____

   Explanation and Source:

Actual construction or treatment will be in the off-season. Swimming (and diving) conditions will be enhanced.

Sources for all information unless otherwise noted: BEC, 1986, DIAGNOSTIC/FEASIBILITY STUDY FOR THE MANAGEMENT OF GREAT POND.

B. Historic Resources

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

   Explanation and Source:

   None known-(letter from MHC)

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

   Explanation and Source:

   None known-(letter from MHC)

C. Ecological Effects

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

   Explanation and Source:
   Actions will be in a very limited area; no detectable impact on system ecology anticipated. No rare or endangered species are reported for Great Pond by the Massachusetts Heritage Program.

2. **Might the project significantly affect vegetation, especially any rare or endangered species of plant?**
Yes X **No** ___
(Estimate approximate number of mature trees to be removed: 0 **)**

Explanation and Source:

Growth of Submerged Vegetation will be retarded in swimming areas. No rare or endangered species are involved.

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** X **No** ___

Explanation and Source:

The lake is considered wetland. No adverse impact is anticipated, however.

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

Explanation and Source:

No adverse impact is anticipated.

5. **Might the project involve other geologically unstable areas? Yes** ___ **No** X

Explanation and Source:

D. Hazardous Substances

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

Explanation and Source:

E. Resource Conservation and Use

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

   Explanation and Source:

   No agricultural land is involved.

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 __X__**

   Explanation and Source:

   No mineral or energy resources are known for project area.

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

   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 __X__**

   Explanation and Source:

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

(a) Marine Waters	Yes ____	No __X__
(b) Surface Fresh Water Body	Yes ____	No __X__
(c) Ground Water	Yes ____	No __X__

   Explain types and quantities of pollutants.

   A slight increase in BOD may result from macrophyte control actions, but no detectable impact is expected. This represents recycling, not introduction, of potential pollutants.

3. Will the project generate sanitary sewage? Yes ____ No X

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 X

Explanation and Source:

5. Is the project in the watershed of any surface water body used as a drinking water supply?

Yes ____ No X

Are there any public or private drinking water wells within a 1/2-mile radius of the proposed project?

Yes X No ____

Explanation and Source:

[illegible]osed project will have no

[illegible]

6. Might the operation of the project result in any increased consumption of water? Yes ____ No X

Approximate consumption ______ gallons per day. Likely water source(s) ________________

Explanation and Source:

7. Does the project involve any dredging? Yes ____ No X

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:

G. Air Quality

1. Might the project affect the air quality in the project area or the immediately adjacent area?
   Yes ______ No __X__
   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 __X__

   Explanation and Source:

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

   None needed.

H. Noise

1. Might the project result in the generation of noise? Yes ______ No __X__

   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 __X__

   Explanation and Source:

I. Solid Waste

1. Might the project generate solid waste? Yes _____ No X

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 X

Explanation and Source:

No visible change (from above water) is anticipated. From below the water, by sight or feel, conditions will be improved.

[illegible] **...mpatible with existing adjacent structures** [illegible] **...ficant differences in land use?**
Yes _____ No X

Explanation and Source:

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

Explanation and Source:

K. Wind and Shadow

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

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.**

The proposed project is entirely consistent with the existing Open Space Plan and the ecology of the pond. Relevant agencies requested to review the BEC report are in agreement with its findings and recommendations.

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

COMMENTS BY INTERESTED PARTIES

The Commonwealth of Massachusetts

Office of the Secretary of State
Michael Joseph Connolly, Secretary

Massachusetts Historical Commission
Valerie A. Talmage
Executive Director
State Historic Preservation Officer

August 19, 1986

Mr. Kenneth J. Wagner
Baystate Environmental Consultants, Inc.
296 North Main Street
East Longmeadow, MA

RE: Diagnostic/Feasibility Study, Great Pond, Eastham

Dear Mr. Wagner:

Thank you for supplying the Massachusetts Historical Commission with information concerning the diagnostic/feasibility study for Great Pond in Eastham. Staff of the MHC have reviewed the materials you submitted.

MHC feels that this project is unlikely to affect significant historic or archaeological resources. No further review is required in compliance with Massachusetts General Laws, Chapter 9, Sections 26C and 27C, as amended by Chapter 152 of the Acts of 1982 (950 CMR 71).

If you have any questions, please feel free to contact Jordan Kerber at this office.

Sincerely,

[signature] DSHPO

Valerie A. Talmage
Executive Director
State Historic Preservation Officer
Massachusetts Historical Commission

VAT/JK/dr

80 Boylston Street, Boston, Massachusetts 02116 (617) 727-8470

The Commonwealth of Massachusetts

Division of Fisheries and Wildlife

Field Headquarters, Westboro 01581

August 18, 1986

Dr. Ken Wagner
Baystate Environmental Consultants, Inc.
296 North Main Street
East Longmeadow, MA 01028

RE: Great Pond, Eastham
Diagnostic/Feasibility Study

Dear Dr. Wagner:

Thank you for sending the Division of Fisheries and Wildlife the "Diagnostic/Feasibility Study for the Management of Great Pond, Eastham" for review and comment. Accordingly, we have completed our review of the proposed management actions with respect to impacts to fish and wildlife.

As described in the report, only two in-lake management actions will be initiated, (1) dredging of the Wiley Park swimming area, and (2) the application of [illegible] to portions of swimming areas to control [illegible] macrophytes. The former work, involving the removal of 380 cu.m (500 cy), is scheduled for the fall/winter time of the year. The restricting of this work to this time period is encouraged by MDFW to minimize conflicts with fish spawning, egg hatching and the sensitive early life stages of fishes indigenous to Great Pond. The least acceptable time frame, from a fisheries standpoint, would run from April 1 to August 30. While essentially clean sand material will be excavated, there is still the potential for considerable turbidity. If dredging is contemplated during this sensitive period, some type of barrier or similar device should be installed to contain turbidity. The combination of uncontrolled excessive turbidity, warm summertime water temperatures and low dissolved oxygen levels could produce a lethal environment for fish, macroinvertebrates and amphibians.

The installation of some kind of bottom mesh should be limited to only those areas designated for intensive recreation, such as the public swimming area. Although not mentioned in the study, we would anticipate that the sealing of the bottom substrate with an artificial medium will prohibit the use of this area of the pond by certain fish species for spawning. While the pumpkinseed is a species likely to utilize beach type area for spawning, more than enough alternative spawning habitat will still be available. Also, the pumpkinseed is also a particularly plentiful fish. It also has a demonstrated tendency for multiple spawning, which offsets the potential problems presented by conditions such as fluctuating water levels or other habitat disturbances. We also expect that bottom sealing will adversely impact the macroinvertebrate population in the immediate area. Again, this should represent a small loss in comparison to the overall macroinvertebrate population of the pond.

Analysis of data on the fish population collected by MDFW in July 1985 have been completed and is available for inclusion in the final report. On this date fisheries personnel collected a total of 148 fish represented by five species. The banded killifish (*Fundulus diaphanus*) was observed in schools along the shallow littoral zone, but were not captured. The absence of young-of-the-year alewives is probably due to simple sampling bias. The report incorrectly states that young alewives remain in the Great Pond ecosystem for a year. Young-of-the-year alewives have all pretty much emigrated to marine waters by November 1. The single smallmouth bass captured probably reflects the difficulty in accurately sampling this species and is not necessarily indicative of an overall low bass population. However, MDFW will continue to monitor the status of this species in Great Pond in the future as it is one of the more important gamefish in Massachusetts. Scale analysis of chain pickerel, yellow perch and white perch indicates slightly better than average growth, while pumpkinseed growth is average. Overall, the fish population appears to be in good shape.

[illegible] is subject or require [illegible] to call me at (617) 366-4479/4470. Thank you for contacting the Division concerning this matter.

Sincerely,

Bob Madore

Robert P. Madore
Aquatic Biologist

cc. Jack Dixon, MDFW
Clean Lakes Program, MDFW

Since the MDFW comments were received, review of the need for a dredging project at the Wiley Park swimming area has resulted in the deletion of that action from the management plan. It is currently believed that control of the dense macrophyte stands in that area will be sufficient to restore acceptable recreational utility.

APPENDIX D

USEFUL CONVERSIONS AND GLOSSARY

USEFUL CONVERSIONS

Multiply...	by...	to obtain...
Acre (ac)	0.4047	Hectare (ha)
Acre (ac)	43,560	Square Feet (sq.ft)
Acre (ac)	4,047	Square Meters (sq.m)
Acre (ac)	0.00156	Square Miles (sq.mi)
Acre Feet (af)	1613.3	Cubic Yards (cy)
Centimeters (cm)	0.3937	Inches (in)
Cubic Feet (cu.ft)	0.0283	Cubic Meters (cu.m)
Cubic Feet (cu.ft)	0.0370	Cubic Yards (cy)
Cubic Feet (cu.ft)	7.4805	Gallons (gal)
Cubic Feet (sq.ft)	28.32	Liters (l)
Cubic Feet/Second (cfs)	1.7	Cubic Meters/Minute (cu.m/min)
Cubic Feet/Second (cfs)	0.6463	Million Gallons/Day (mgd)
Feet (ft)	0.3048	Meters (m)
Feet (ft)	0.0001894	Mile (mi)
Kilograms (kg)	2.205	Pounds (lb)
Kilometers (km)	0.6214	Miles (mi)
Liters (l)	0.2642	Gallons (gal)
Liters (l)	1.057	Quarts (qt)
Meters (m)	1.094	Yards (yd)
Milligrams/Liter (mg/l)	1.0	Parts Per Million (ppm)
		Parts Per Billion (ppb)
		Square Miles (sq.mi)
Square meters (sq.m)	0.0001	Hectares (ha)

GENERAL AQUATIC GLOSSARY

<u>Abiotic</u> - Pertaining to any non-biological factor or influence, such as geological or meteorological characteristics.

<u>Acid precipitation</u> - Atmospheric deposition (rain, snow, dryfall) of free or combined acidic ions, especially the nitrates, sulfates and oxides of nitrogen and sulfur fumes from industrial smoke stacks.

<u>Adsorption</u> - External attachment to particles, the process by which a molecule becomes attached to the surface of a particle.

<u>Algae</u> - Aquatic single-celled, colonial, or multi-celled plants, containing chlorophyll and lacking roots, stems, and leaves.

<u>Alkalinity</u> - A reference to the carbonate and bicarbonate concentration in water. Its relative concentration is indicative of the nature of the rocks within a drainage basin. Lakes in sedimentary carbonate rocks are high in dissolved carbonates (hard-water lakes) whereas lakes in granite or igneous rocks are low in dissolved carbonate (soft-water lakes).

<u>Ammonia Nitrogen</u> - A form of nitrogen present in sewage and is also generated from the decomposition of organic nitrogen. It can also be formed when nitrites and nitrates are reduced. Ammonia is particularly important since it has high oxygen and chemical demands, is toxic to fish in un-ionized [illegible] important aquatic plant nutrient because it is readily available.

<u>Anadromous</u> - An adjective used to describe types of fish which spawn in freshwater rivers but spend most of their adult lives in the ocean. Before spawning, anadromous adult fish ascend the rivers from the sea.

<u>Anoxic</u> - Without oxygen.

<u>Aphotic Zone</u> - Dark zone, below the depth to which light penetrates. Generally equated with the zone in which most photosynthetic algae cannot survive, due to light deficiency.

<u>Aquifer</u> - Any geological formation that contains water, especially one that supplies wells and springs; can be a sand and gravel aquifer or a bedrock aquifer.

<u>Artesian</u> - The occurrence of groundwater under sufficient pressure to rise above the upper surface of the aquifer.

<u>Assimilative Capacity</u> - Ability to incorporate inputs into the system. With lakes, the ability to absorb nutrients or other potential pollutants without showing extremely adverse effects.

Attenuation - The process whereby the magnitude of an event is reduced, as the reduction and spreading out of the impact of storm effects or the removal of certain contaminants as water moves through soil.

Background Value - Value for a parameter that represents the conditions in a system prior to a given influence in space or time.

Bathymetry - The measurement of depths of water in oceans, seas, or lakes or the information derived from such measurements.

Benthic Deposits - Bottom accumulations which may contain bottom-dwelling organisms and/or contaminants in a lake, harbor, or stream bed.

Benthos - Bottom-dwelling organisms living on, within or attached to the sediment. The phytobenthos includes the aquatic macrophytes and bottom-dwelling algae. The zoobenthos (benthic fauna) includes a variety of invertebrate animals, particularly larval forms and molluscs.

Benthic - Living or occupying space at the bottom of a water body, on or in the sediment.

Best Management Practices - [illegible] of-the-art techniques [illegible] farming or waste disposal in [illegible] to minimize [illegible] or waste.

Bio-available - Able to be taken up by living organisms, usually refers to plant uptake of nutrients.

Biocide - Any agent, usually a chemical, which kills living organisms.

Biological Oxygen Demand - The BOD is an indirect measure of the organic content of water. Water high in organic content will consume more oxygen due to the decomposition activity of bacteria in the water than water low in organic content. It is routinely measured for wastewater effluents. Oxygen consumption is proportional to the organic matter in the sample.

Biota - Plant (flora) and animal (fauna) life.

Biotic - Pertaining to biological factors or influences, concerning biological activity.

Bloom - Excessively large standing crop of algae, usually visible to the naked eye.

Bulk Sediment Analysis - Analysis of soil material or surface deposits to determine the size and relative amounts of particles composing the material.

CFS - Cubic feet per second, a measure of flow.

Chlorophyll - Major light gathering pigment of all photosynthetic organisms imparting the characteristic color of green plants. Its relative measurement in natural waters is indicative of the concentration of algae in the water.

Chlorophyte - Green algae, algae of the division Chlorophyta.

Chrysophyte - Golden or golden-brown algae, algae of the division Chrysophyta.

Color - Color is determined by visual comparison of a sample with known concentrations of colored solutions and is expressed in standard units of color. Certain waste discharges may turn water to colors which cannot be defined by this method; in such cases, the color is expressed qualitatively rather than numerically. Color in lake waters is related to solids, including algal cell concentration and dissolved substances.

Combined Sewer - A sewer intended to serve as both a santiary sewer and a storm sewer. It receives both sewage and surface runoff.

Composite Sample - A number of individual samples collected over time or space and composited into one representative sample.

Concentration - The quantity of a given constituent in a unit of volume or weight of water.

Conductivity - The measure of the total ionic concentration of water. Water with high total dissolved solids (TDS) level would have a high conductance. A conductivity meter tests the flow of electrons through the water which is heightened in the presence of electrolytes (TDS).

Confluence - Meeting point of two rivers or streams.

Conservative Substance - Non-interacting substance, undergoing no kinetic reaction; chlorides and sodium are approximate examples.

Cosmetic - Acting upon symptoms or given conditions without correcting the actual cause of the symptoms or conditions.

Cryptophyte - Small, flagellated algae of variable pigment composition, algae of the division Cryptophyta, which is often placed under other taxonomic divisions.

Cyanophyte - Bluegreen algae, algae of the division Cyanophyta, actually a set of pigmented bacteria.

Decomposition - The metabolic breakdown of organic matter, releasing energy and simple organic and inorganic compounds which may be utilized by the decomposers themselves (the bacteria and fungi).

Deoxygenation - Depletion of oxygen in an area, used often to describe possible hypolimnetic conditions, process leading to anoxia.

Diatom - Specific type of chrysophyte, having a siliceous frustule (shell) and often elaborate ornamentation, commonly found in great variety in fresh or saltwaters. Often placed in its own division, the Bacillariophyta.

Dinoflagellate - Unicellular algae, usually motile, having pigments similar to diatoms and certain unique features. More commonly found in saltwater. Algae of the division Pyrrhophyta.

Discharge Measurement - The volume of water which passes a given location in a given time period, usually measured in cubic feet per second (cfs) or cubic meters per minute (m^3/min).

[illegible] ...mbined oxygen in [illegible] Temperature affects the amount of oxygen which water can contain. Biological activity also controls the oxygen level. D.O. levels are generally highest during the afternoon and lowest just before sunrise.

Diurnal - Varying over the day, from day time to night.

Domestic Wastewater - Water and dissolved or particulate substances after use in any of a variety of household tasks, including sanitary systems and washing operations.

Drainage Basin - A geographical area or region which is so sloped and contoured that surface runoff from streams and other natural watercourses is carried away by a single drainage system by gravity to a common outlet. Also referred to as a watershed or drainage area. The definition can also be applied to subsurface flow in groundwater.

Dystrophic - Trophic state of a lake in which large quantities of nutrients may be present, but are generally unavailable (due to organic binding or other causes) for primary production. Often associated with acid bogs.

Ecosystem - A dynamic association or interaction between communities of living organisms and their physical evironment. Boundaries are arbitrary and must be stated or implied.

Elutriate - Elutriate refers to the washings of a sample of material.

Epilimnion - Upper layer of a stratified lake. Layer that is mixed by wind and has a higher average temperature than the hypolimnion. Roughly approximates the euphotic zone.

Erosion - The removal of soil from the land surface, typically by runoff water.

Eskar - A winding, narrow ridge of sand or gravel deposited by a stream flowing under glacial ice.

Euglenoid - Algae similar to green algae in pigment composition, but with certain unique features related to food storage and cell wall structure. Algae of the division Euglenophyta.

Eutrophic - High nutrient, high productivity trophic state generally associated with unbalanced ecological conditions and poor water quality.

Eutrophication - Process by which a body of water ages, most often passing from a low nutrient concentration, low productivity state to a high nutrient concentration, high productivity stage. Eutrophication is a long-term natural process, but it can be greatly accelerated by man's activities. Eutrophication as a result of man's activities is termed cultural eutrophication.

Evapotranspiration - Process by which water is lost to the atmosphere from plants.

Fauna - A general term referring to all animals.

Fecal Coliform Bacteria - Bacteria of the coli group that are present in the intestines or feces of warm-blooded animals. They are often used as indicators of the sanitary quality of the water. In the laboratory they are defined as all organisms which produce blue colonies within 24 hours when incubated at $44.5^{\circ}C \pm 0.2^{\circ}C$ on M-FC medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 ml of sample.

Fecal Streptococci Bacteria - Bacteria of the Streptococci group found in intestines of warm-blooded animals. Their presence in water is considered to verify fecal pollution. They are characterized as gram positive, cocciod bacteria which are capable of growth in brain-heart infusion broth. In the laboratory they are defined as all the organisms which produce red or pink colonies within 48 hours at $35^{\circ}C \pm 1.0^{\circ}C$ on KF medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 ml of sample.

Flora - A general term referring to all plants.

Food Chain - A linear characterization of energy and chemical flow through organisms such that the biota can be separated into functional units with nutritional interdependence. Can be expanded to a more detailed characterization with multiple linkage, called a food web.

French (or Pit) Drain - Water outlet which allows fairly rapid removal of water from surface, but then allows subsurface percolation. Generally consists of sand and gravel layers under grating or similar structure, at lowest point of a sloped area. Water runs quickly through the coarse layers, then percolates through soil, often without the use of pipes. The intent is the purification of most percolating waters.

Grain Size Analysis - A soil or sediment sorting procedure which divides the particles into groups depending on size so that their relative amounts may be determined. Data from grain size analyses are useful in determining the origin of sediments and their behavior in suspension.

Groundwater - Water in the soil or underlying strata, subsurface water.

Hardness - A physical-chemical characteristic of water that is commonly recognized by the increased quantity of soap required to produce lather. It is attributable to the presence of alkaline earths (principally calcium and magnesium) and is expressed as equivalent calcium carbonate ($CaCO_3$).

Humus - Humic substances form much of the organic matter of sediments and water. They consist of amorphous brown or black colored organic complexes.

Hydraulic Detention Time - Lake water retention time, amount of time that a random water molecule spends in a water body; time that it takes for water to pass from an inlet to an outlet of a water body.

Hydraulic Dredging - Process of sediment removal using a floating dredge to draw mud or saturated sand through a pipe to be deposited elsewhere.

Hydrologic Cycle - The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hypolimnion - Lower layer of a stratified lake. Layer that is mainly without light, generally equated with the aphotic zone, and has a lower average temperature than the epilimnion.

Impervious - Not permitting penetration or percolation of water.

Intermittant - Non-continuous, generally referring to the occasional flow through a set drainage path. Flow of a discontinuous nature.

Kame - A short, steep ridge or hill of stratified sand or gravel deposited in contact with glacial ice.

Kjeldahl Nitrogen - The total amount of organic nitrogen and ammonia in a sample, as determined by the Kjeldahl method, which involves digesting the sample with sulfuric acid, transforming the nitrogen into ammonia, and measuring it.

Leachate - Water and dissolved or particulate substances moving out of a specified area, usually a landfill, by a completely or partially subsurface route.

Leaching - Process whereby nutrients and other [illegible] removed from matter (usually soil or [illegible] often this is a chemical replacement action, prompted by the quality of the water.

Lentic - Standing, having low net directional motion. Refers to lakes and impoundments.

Limiting Nutrient - That nutrient of which there is the least quantity, in relation to its importance to plants. The limiting nutrient will be the first essential compound to disappear from a productive system, and will cause cessation of productivity at that time. The chemical form in which the nutrient occurs and the nutritional requirements of the plants involved are important here.

Limnology - The comprehensive study of lakes, encompassing physical, chemical and biological lake conditions.

Littoral Zone - Shallow zone occurring at the edge of aquatic ecosystems, extending from the shoreline outward to a point where rooted aquatic plants are no longer found.

Loading - Inputs into a receiving water that may exert a detrimental effect on some subsequent use of that water.

Lotic - Flowing, moving. Refers to streams or rivers.

Macrofauna - A general term which refers to animals which can be seen with the naked eye.

Macrophyte - Higher plant, macroscopic plant, plant of higher taxonomic position than algae, usually a vascular plant. Aquatic macrophytes are those macrophytes that live completely or partially in water. May also include algal mats under some definitions.

Mesotrophic - An intermediate trophic state, with variable but moderate nutrient concentrations and productivity.

Metalimnion - The middle layer of a stratified lake, constituting the transition layer between the epilimnion and hypolimnion and containing the thermocline.

Mixis - The state of being mixed, or the process of mixing in a lake.

MGD - Million gallons per day, a measure of flow.

Micrograms per Liter (ug/l) - A unit expressing the concentration ... ss (micrograms) of ... e thousand micrograms ... liter.

Nitrate - A form of nitrogen that is important since it is the end product in the aerobic decomposition of nitrogenous matter. Nitrogen in this form is stable and readily available to plants.

Nitrite - A form of nitrogen that is the oxidation product of ammonia. It has a fairly low oxygen demand and is rapidly converted to nitrate. The presence of nitrite nitrogen usually indicates that active decomposition is taking place (i.e., fresh contamination).

Nitrogen - A macronutrient which occurs in the forms of organic nitrogen, ammonia nitrogen, nitrite nitrogen and nitrate nitrogen. Form of nitrogen is related to a successive decomposition reaction, each dependent on the preceding one, and the progress of decomposition can be determined in terms of the relative amounts of these four forms of nitrogen.

Nitrogen fixation - The process by which certain bacteria and bluegreen algae make organic nitrogen compounds (initially NH_4^+) from elemental nitrogen (N_2) taken from the atmosphere or dissolved in the water.

Non-point Source - A diffuse source of loading, possibly localized but not distinctly definable in terms of location. Includes runoff from all land types.

Nutrients - Are compounds which act as fertilizers for aquatic organisms. Small amounts are necessary to the ecological balance of a waterbody, but excessive amounts can upset the balance by causing excessive growths of algae and other aquatic plants. Sewage discharged to a waterbody usually contains large amounts of carbon, nitrogen, and phosphorus. The concentration of carbonaceous matter is reflected in the B.O.D. test. Additional tests are run to determine the concentrations of nitrogen and phosphorus. Storm water runoff often contributes substantial nutrient loadings to receiving waters.

Oligotrophic - Low nutrient concentration, low productivity trophic state, often associated with very good water quality, but not necessarily the most desirable stage, since often only minimal aquatic life can be supported.

Organic - Containing a substantial percentage of carbon derived from living organisms; of a living organism.

Outwash - Sand and gravel deposited by meltwater streams in front of glacial ice.

Overturn - The vertical mixing of major layers of water caused by seasonal changes in temperature. In temperate climate zones overturn typically occurs in spring and fall.

Oxygen Deficit - A situation in lakes where respiratory demands for oxygen become greater than its production via photosynthesis or its input from the drainage basin, leading to a decline in oxygen content.

Periphyton - Attached forms of plants and animals, growing on a substrate.

pH - A hydrogen concentration scale from 0 (acidic) to 14 (basic) used to characterize water solutions. Pure water is neutral at pH 7.0.

Phosphorus - A macronutrient which appears in waterbodies in combined forms known as ortho- and poly-phosphates and organic phosphorus. Phosphorus may enter a waterbody in agricultural runoff where fertilizers are used. Storm water runoff from highly urbanized areas, septic system leachate, and lake bottom sediments also contribute phosphorus. A critical plant nutrient which is often targeted for control in eutrophication prevention plans.

Photic Zone - Illuminated zone, surface to depth beyond which light no longer penetrates. Generally equated with the zone in which photosynthetic algae can survive and grow, due to adequate light supply.

Photosynthesis - Process by which primary producers make organic molecules (generally glucose) from inorganic ingredients, using light as an energy source. Oxygen is evolved by the process as a byproduct.

Phytoplankton - Algae which are suspended, floating or moving only slightly under their own power in the water column. Often this is the dominant algal form in standing waters.

Plankton - The community of suspended, floating, or weakly swimming organisms that live in the open water of lakes and rivers.

Point Source - A specific source of loading, accurately definable in terms of location. Includes effluents or channeled discharges that enter natural waters at a specific point.

Pollution - Undesirable alteration of the physical, chemical or biological properties of water, addition of any substance into water by human activity that adversely affects its quality. Prevalent examples are thermal, heavy metal and nutrient pollution.

Potable - Usable for drinking purposes, fit for human consumption.

Primary Productivity (Production) - Conversion of inorganic matter to organic matter by photosynthesizing organisms. The creation of biomass by plants.

Riffle Zone - Stretch of a stream or river along which morphological and flow conditions are such that rough motion of the water surface results. Usually a shallow rocky area with rapid flow and little sediment accumulation.

Riparian - Of, or related to, or bordering a watercourse.

Runoff - Water and its various dissolved substances or particulates that flows at or near the surface of land in an unchanneled path toward channeled and usually recognized waterways (such as a stream or river).

Saturation Zone - Volume of soil in which all pore spaces are filled with water; the volume below the water table.

Secchi Disk Transparency - An approximate evaluation of the transparency of water to light. It is the point at which a black and white disk lowered into the water is no longer visible.

Secondary Productivity - The growth and reproduction (creation of biomass) by herbivorous (plant-eating) organisms. The second level of the trophic system.

Sedimentation - The process of settling and deposition of suspended matter carried by water, sewage, or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material.

Sewage (Wastewater) - The waterborne, human and animal wastes from residences, industrial/commercial establishments or other places, together with such ground or surface water as may be present.

Specific Conductance - Yields a measure of a water sample's capacity to convey an electric current. It is dependent on temperature and the concentration of ionized substances in the water. Distilled water exhibits specific conductance of 0.5 to 2.0 micromhos per centimeter, while natural waters show values from 50 to 500 micromhos per centimeter. In typical New England lakes, Specific Conductance usually ranges from 100-300 micromhos per cm. The specific conductance yields a generalized measure of the inorganic dissolved load of the water.

Stagnant - Motionless, having minimal circulation or flow.

Standing Crop - Current quantity of organisms, biomass on hand. The amount of live organic matter in a given area at any point in time.

Storm Sewer - A pipe or ditch which carries storm water and surface water, street wash and other wash waters or drainage, but excludes sewage and industrial wastes.

Stratification - Process whereby a lake becomes separated into two relatively distinct layers as the result of temperature and density differences. Further differentation of the layers usually occurs as the result of chemical and biological processes. In most lakes, seasonal changes in temperature will reverse this process after some time, resulting in the mixing of the two layers.

Stratified Drift - Sand, gravel or other materials deposited by a glacier or its meltwater in a layered manner, according to particle size.

Substrate - The base of material on which an organism lives, such as cobble, gravel, sand, muck, etc.

Succession - The natural process by which land and vegetation patterns change, proceeding in a direction determined by the forces acting on the system.

Surface Water - Refers to lakes, bays, sounds, ponds, reservoirs, springs, rivers, streams, creeks, estuaries, marshes, inlets, canals, oceans and all other natural or artificial, inland or coastal, fresh or salt, public or private waters at ground level.

Suspended Solids - Those which can be removed by passing the water through a filter. The remaining solids are called dissolved solids. Suspended solids loadings are generally high in stream systems which are actively eroding a watershed. Excessive storm water runoff often results in high suspended solids loads to lakes. Many other pollutants such as phosphorus are often associated with suspended solids loadings.

Taxon (Taxa) - Any hierarchical division of a recognized classification system, such as a genus or species.

Taxonomy - The division of biology concerned with the classification and naming of [illegible] The classification of [illegible] ne beginning with [illegible] ...ding to the species level or even lower.

Thermocline - Boundary level between the epilimnion and hypolimnion of a stratified lake, variable in thickness, and generally approximating the maximum depth of light penetration and mixing by wind.

Till - Unstratified, unsorted sand, gravel, or other material deposited by a glacier or its meltwater.

Trophic Level - The position in the food chain determined by the number of energy transfer steps to that level; 1 = producer; 2 = herbivore; 3, 4, 5 = carnivore.

Trophic State - The stage or condition of an aquatic system, characterized by biological, chemical and physical parameters.

Turbidity - The measure of the clarity of a water sample. It is expressed in Nephelometric Turbidity Units which are related to the scattering and absorption of light by the water sample.

Volatile Solids - That portion of a sample which can be burned off, consisting of organic matter, including oils and grease.

Water Quality - A term used to describe the chemical, physical, and biological characteristics of water, usually with respect to its suitability for a particular purpose or use.

Watershed - Drainage basin, the area from which an aquatic system receives water.

Zone of Contribution - Area or volume of soil from which water is drawn into a well.

Zooplankton - Microscopic animals suspended in the water; protozoa, rotifers, cladocera, copepods and other small invertebrates.

Technical Appendix

in support of the

DIAGNOSTIC/FEASIBILITY STUDY FOR THE MANAGEMENT OF GREAT POND

Eastham, Massachusetts

Prepared by

BAYSTATE ENVIRONMENTAL CONSULTANTS INC

August 1986

TECHNICAL APPENDIX

This appendix includes raw data, calculation sheets, and other information related to the study of Great Pond conducted by BEC, Inc. It is intended to function as a support document for the report entitled "Diagnostic/Feasibility Study for the Management of Great Pond". The information contained in this document is divided into five sections: water quality data, biological data, calculation sheets, a sample survey questionaire, and data from surveys of Eastham Ponds other than Great Pond.

WATER QUALITY DATA

FLOW (CU.M/MIN) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-5
05-08-85	.07	.24	1.87
05-21-85	0	.17	1.02
06-06-85	.17	.19	1.36
06-18-85	0	.12	1.02
07-02-85	0	.10	1.09
07-16-85	0	.07	.42
07-30-85	0	.02	.85
08-13-85	0	.02	.34
08-28-85	0	.34	2.55
09-10-85	.68	.17	3.74
10-01-85	.02	.05	1.53
12-04-85	.17	.29	1.53
01-14-86	.09	.12	1.53
02-10-86	.17	.10	2.72
03-11-86	.26	.24	1.36
04-03-86	.03	.02	1.70
04-16-86	.14	.24	3.40
MEAN	.11	.15	1.65
MAXIMUM	.68	.34	3.74
MINIMUM	0	.02	.34

TOTAL PHOSPHATE (UG/L AS P) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	60	40	20			290			20
05-21-85		51	50		50	40	75	45	40
06-06-85	100	40	10	20	25	20	30	70	20
06-18-85		40	40	80	50	40	70	50	40
07-02-85		50	50	20	55	30	30	20	10
07-16-85			20	38	18	20	20	18	12
07-30-85			20	20	30	15	30	30	10
08-13-85			50	70	30	50	28	20	70
08-28-85		56	15	20	15	20	18	30	10
09-10-85	23	190	13	13	20	13	35	23	13
10-01-85			17		23	37		10	5
12-04-85	80	30	80		70	60		60	70
01-14-86	19	10	25		30	10		15	10
02-10-86	10	10				10		10	10
03-11-86	30	120	100		100				100
04-03-86	31	23	42		19	25		28	42
04-16-86	14	12	10		20	20		10	20
MEAN	41	52	35	35	37	44	37	30	30
MAXIMUM	100	190	100	80	100	290	75	70	100
MINIMUM	10	10	10	13	15	10	18	10	5
MASS FLOW (KG/YR)	5.47	6.22							24.83

ORTHOPHOSPHATE (UG/L AS P) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	20	20	20			20			20
05-21-85		10	10		10	10	10	10	35
06-06-85	10	20	10	10	10	10	10	10	10
06-18-85		10	10	10	10	10	10	10	10
07-02-85		10	10	10	10	10	10	10	10
07-16-85		10	10	10	10	10	10	10	10
07-30-85			10	10	10	10	10	10	10
08-13-85			10	10	10	10	10	13	10
08-28-85		10	10	10	10	10	10	10	10
09-10-85	10	43	10	10	13	10	13	10	10
10-01-85			5		13	5		5	5
12-04-85	10	10	10		10	10		10	10
01-14-86	10	10	10		10	10		10	10
02-10-86	10	10				10		10	10
03-11-86	18	10	10		10				10
04-03-86	10	10	10		10	10		10	10
04-16-86	10	10	10		10	10		10	10
MEAN	12	14	10	10	10	10	10	10	12
MAXIMUM	20	43	20	10	13	20	13	13	35
MINIMUM	10	10	5	10	10	5	10	5	5
MASS FLOW (KG/YR)	1.57	1.51							9.46

NITRATE NITROGEN (MG/L AS N) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	.01	.03	.02			.02			.04
05-21-85		.01	.01		.01	.01	.01	.01	.01
06-06-85	.01	.14	.02	.01	.03	.01	.01	.02	.01
06-18-85		.08	.03	.05	.02	.02	.03	.03	.09
07-02-85		.14	.01	.01	.02	.01	.01	.01	.01
07-16-85			.16	.07	.29	.13	.09	.11	.03
07-30-85			.05	.11	.10	.14	.11	.21	.05
08-13-85			.04	.02	.01	.01	.01	.01	.01
08-28-85		.42	.02	.04	.02	.02	.02	.02	.02
09-10-85	.01	.14	.01	.06	.05	.02	.01	.01	.01
10-01-85			.05		.04	.01		.03	.03
12-04-85	.12	.59	.12		.12	.11		.04	.14
01-14-86	.06	.21	.05		.08	.12		.03	.05
02-10-86	.02	.14				.02		.03	.20
03-11-86	.04	.11	.04		.01				.01
04-03-86	.01	.11	.05		.04	.02		.02	.03
04-16-86	.01	.10	.03		.01	.02		.03	.01
MEAN	.03	.17	.04	.05	.06	.04	.03	.04	.04
MAXIMUM	.12	.59	.16	.11	.29	.14	.11	.21	.20
MINIMUM	.01	.01	.01	.01	.01	.01	.01	.01	.01
MASS FLOW (KG/YR)	3.99	29.13							55.94

AMMONIA NITROGEN (MG/L AS N) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	.01	.01	.02			.02			.01
05-21-85		.01	.02		.02	.02	.02	.02	.01
06-06-85	.01	.01	.01	.01	.10	.01	.01	.10	.01
06-18-85		.04	.01	.01	.16	.01	.01	.26	.01
07-02-85		.01	.01	.01	.06	.01	.01	.04	.01
07-16-85			.01	.01	.04	.01	.01	.01	.02
07-30-85			.01	.01	.77	.01	.02	.88	.02
08-13-85			.01	.01	1.70	.01	.01	2.10	.01
08-28-85		.10	.07	.03	.03	.03	.02	.20	.03
09-10-85	.02	.20	.01	.04	.15	.01	.02	.02	.12
10-01-85			.01		.03	.01		.02	.01
12-04-85	.04	.11	.01		.01	.01		.01	.01
01-14-86	.04	.03	.01		.01	.01		.03	.01
02-10-86	.01	.09				.01		.04	.01
03-11-86	.02	.08	.02		.01				.02
04-03-86	.02	.05	.03		.03	.03		.11	.03
04-16-86	.01	.02	.02		.05	.01			.01
MEAN	.02	.06	.02	.02	.21	.01	.01	.27	.02
MAXIMUM	.04	.20	.07	.04	1.70	.03	.02	2.10	.12
MINIMUM	.01	.01	.01	.01	.01	.01	.01	.01	.01
									22.57

TOTAL KJELDAHL NITROGEN (MG/L AS N) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	.34	.33	.37			.41			.38
05-21-85		.62	.29		.54	.36	.34	.50	.28
06-06-85	.62	.85	.37	.31	.38	.25	.28	.42	.24
06-18-85		.43	.37	.36	.53	.39	.33	.60	.36
07-02-85		2.06	.59	.46	.39	.45	.36	.48	.46
07-16-85			.52	.56	.62	.61	.71	1.03	.64
07-30-85			.50	.50	1.00	.25	.40	1.20	.62
08-13-85			.30	.36	2.10	.28	.36	1.90	.25
08-28-85		1.80	.60	.58	.63	1.00	2.80	1.20	.44
09-10-85	1.20	2.60	.81	.55	.85	.80	1.20	1.00	.80
10-01-85			.18		.12	.34		.23	.22
12-04-85	.35	.50	.62		.59	.76		.89	.81
01-14-86	.60	.62	.52		.28	.38		.40	.40
02-10-86	.98	.61				.56		.65	.99
03-11-86	.32	.24	.26		.30				.37
04-03-86	.32	.22	.25		.28	.28		.45	.35
04-16-86	.56	.31	.38		.39	.47		.43	.53
MEAN	.59	.86	.43	.46	.60	.47	.75	.76	.45
MAXIMUM	1.20	2.60	.81	.58	2.10	1.00	2.80	1.90	.99
MINIMUM	.32	.22	.18	.31	.12	.25	.28	.23	.22
MASS FLOW (KG/YR)	136.45	104.13							499.09

NITROGEN:PHOSPHORUS RATIOS IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	13.4	20.6	44.6			3.4			48.3
05-21-85		28.3	13.7		25.1	21.1	10.7	25.9	16.6
06-06-85	14.4	56.6	88.2	36.8	37.1	29.7	22.3	14.4	28.8
06-18-85		29.1	22.9	11.7	25.1	23.4	11.8	28.8	25.7
07-02-85		100.6	27.4	53.7	17.0	35.1	28.2	56.0	107.4
07-16-85			77.7	38.2	115.6	84.6	91.1	144.8	127.8
07-30-85			62.9	69.7	83.8	59.4	38.9	107.4	153.2
08-13-85			15.3	12.4	161.0	13.4	30.4	218.6	8.6
08-28-85		90.6	94.5	70.9	99.1	116.6	358.1	93.0	105.2
09-10-85	120.5	33.0	144.6	107.3	102.9	144.2	79.2	100.6	142.9
10-01-85			31.2		16.4	21.5		58.1	113.4
12-04-85	13.4	83.1	21.1		23.2	33.1		35.4	31.0
01-14-86	79.4	189.7	52.1		27.4	114.3		65.5	102.9
02-10-86	228.6	171.4				132.6		155.4	272.0
03-11-86	27.4	6.7	6.9		7.1			0.0	8.7
04-03-86	24.5	32.8	16.1		39.1	27.6		38.6	20.7
04-16-86	93.9	79.1	94.0		46.2	55.7		105.6	62.0
MEAN	34.8	45.6	31.0	33.0	40.6	27.0	48.2	54.3	40.6
MAXIMUM	30.2	38.4	22.2	19.7	54.6	9.0	88.7	48.2	27.2
MINIMUM	75.4	53.0	44.3	56.3	19.8	59.4	36.8	53.7	105.6

TEMPERATURE (C) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	12.7	10.9	13.7			13.4			13.9
05-21-85		13.0	16.5	16.0	14.2	16.2	15.4	12.5	17.2
06-06-85	16.1	11.3	18.9	18.9	15.8	18.9	18.9	12.2	17.9
06-18-85		12.3	19.4	18.7	16.4	19.4	18.3	12.2	18.8
07-02-85		14.9	19.9	18.5	17.1	20.8	18.8	12.8	21.5
07-16-85		16.8	24.8	18.8	14.3	24.8	18.8	14.6	24.8
07-30-85		14.0	24.7	24.1	14.2	24.7	22.2	12.8	23.9
08-13-85		14.8	24.6	23.0	14.4	24.1	23.2	12.7	23.2
08-28-85		24.5	23.5	21.9	14.0	23.4	20.1	13.2	23.0
09-10-85	19.9	14.2	20.8	19.3	15.8	20.5	18.7	15.2	21.0
10-01-85			19.1		15.7	18.7		18.2	19.2
12-04-85	2.2	5.2	4.5		4.2	5.0		5.7	4.0
01-14-86	2.3	5.9	0.0		.2	.1		3.2	3.2
02-10-86	1.0	4.0				.2		2.2	.2
03-11-86	1.5	5.8	1.2		1.1				1.5
04-03-86	13.0	9.0	10.1		8.2	9.0		5.5	10.8
04-16-86	13.0	10.0	10.0		8.0	10.5		8.0	12.0
MAXIMUM	19.9	24.5	24.8	24.1	17.1	24.8	23.2	18.2	24.8
MINIMUM	1.0	4.0	0.0	16.0	.2	.1	15.4	2.2	.2

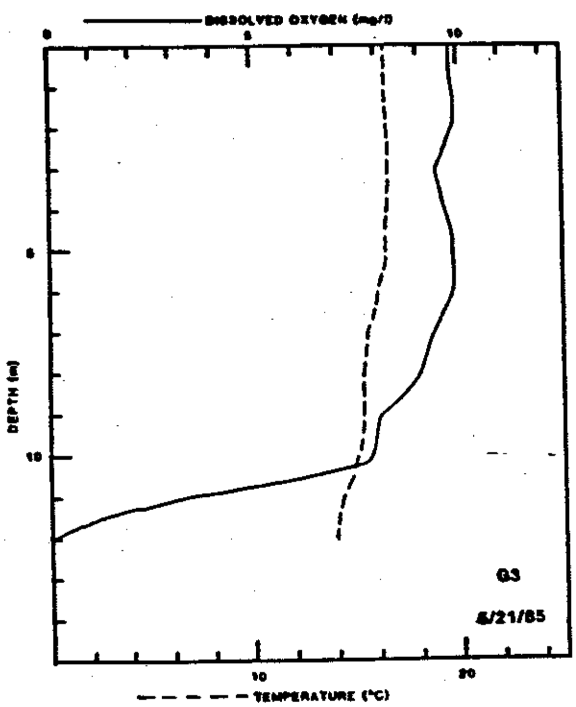
DISSOLVED OXYGEN (MG/L) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	8.9	7.2	9.9			9.7			7.8
05-21-85		5.1	9.8	9.8	.1	9.8	9.5	.1	9.2
06-06-85	4.4	2.0	8.6	8.4	0.0	8.7	8.4	.3	7.6
06-18-85		1.5	8.7	6.8	.2	8.8	6.5	.2	7.7
07-02-85		7.0	8.6	7.5	.2	8.4	7.8	0.0	8.4
07-16-85		2.1	7.8	3.6	.3	7.9	4.8	.3	6.2
07-30-85		2.7	8.0	7.6	.3	8.3	6.1	.4	6.7
08-13-85		3.7	8.5	4.9	.1	8.4	4.8	.7	7.2
08-28-85		1.6	8.4	2.3	.3	7.9	1.7	.3	8.7
09-10-85	4.7	2.2	8.7	2.6	.2	8.1	2.7	.3	8.0
10-01-85			7.8		.5	7.2		.4	7.6
12-04-85	11.2	2.6	12.6		10.0	12.0		7.2	11.8
01-14-86	11.2	4.9	14.1		13.5	14.2		1.1	14.6
02-10-86	12.5	3.3				12.2		7.6	12.5
03-11-86	12.6	4.8	13.9		13.6				13.4
04-03-86	10.6	7.6	12.3		12.6	12.0		9.2	11.4
04-16-86	11.4	10.4	11.6		10.2	11.8		6.6	10.4
MEAN	9.7	4.3	10.0	5.9	4.1	9.7	5.8	2.3	9.4
MAXIMUM	12.6	10.4	14.1	9.8	13.6	14.2	9.5	9.2	14.6
MINIMUM	4.4	1.5	7.8	2.3	0.0	7.2	1.7	0.0	6.2

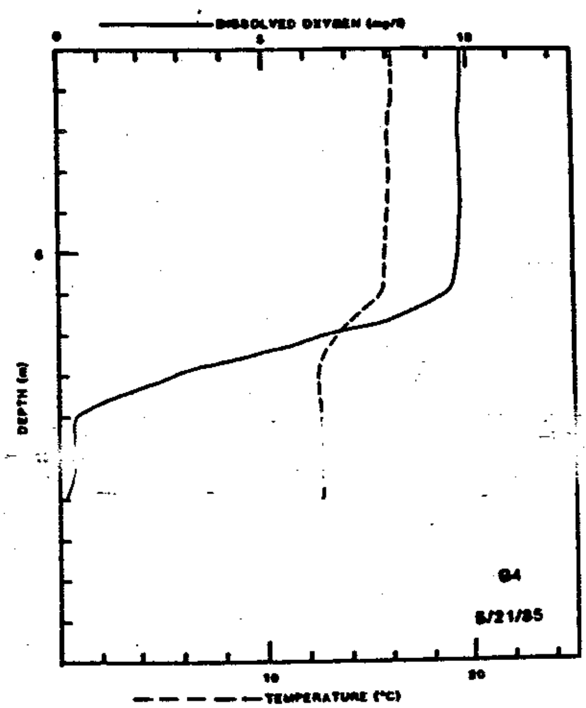
PERCENT D.O. SATURATION IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	83.9	65.1	95.4			92.9			75.5
05-21-85		48.4	100.3	99.3	1.0	99.7	95.0	.9	95.6
06-06-85	44.6	18.3	92.5	90.4	0.0	93.6	90.4	2.8	80.1
06-18-85		14.0	94.5	72.9	2.0	95.6	69.1	1.9	82.7
07-02-85		69.3	94.4	80.0	2.0	93.8	83.7	0.0	95.1
07-16-85		21.6	94.0	38.6	2.9	95.2	55.1	2.9	74.8
07-30-85		26.2	96.3	90.4	2.9	99.9	71.4	3.8	79.4
08-13-85		36.5	102.1	57.1	1.0	100.0	56.2	6.6	84.2
08-28-85		19.2	98.8	26.2	2.9	92.8	18.7	2.8	101.4
09-10-85	51.6	21.4	97.2	28.2	2.0	90.0	28.9	3.0	89.7
10-01-85			84.2		5.0	77.1		4.2	82.3
12-04-85	81.4	20.5	97.4		76.7	93.4		57.4	90.0
01-14-86	81.6	39.3	96.4		92.8	97.4		8.2	109.0
02-10-86	87.9	25.2				83.9		55.2	86.0
03-11-86	89.9	38.4	98.3		95.9				95.6
04-03-86	100.6	65.7	109.2		106.9	103.8		73.0	102.9
04-16-86	108.2	92.1	102.8		86.1	105.8		55.7	96.5
MEAN	81.1	38.8	97.1	64.8	32.0	94.7	63.2	18.6	89.5
MAXIMUM	108.2	92.1	109.2	99.3	106.9	105.8	95.0	73.0	109.0
MINIMUM	44.6	14.0	84.2	26.2	0.0	77.1	18.7	0.0	74.8

DISSOLVED OXYGEN AND TEMPERATURE VERSUS DEPTH



DISSOLVED OXYGEN AND TEMPERATURE VERSUS DEPTH



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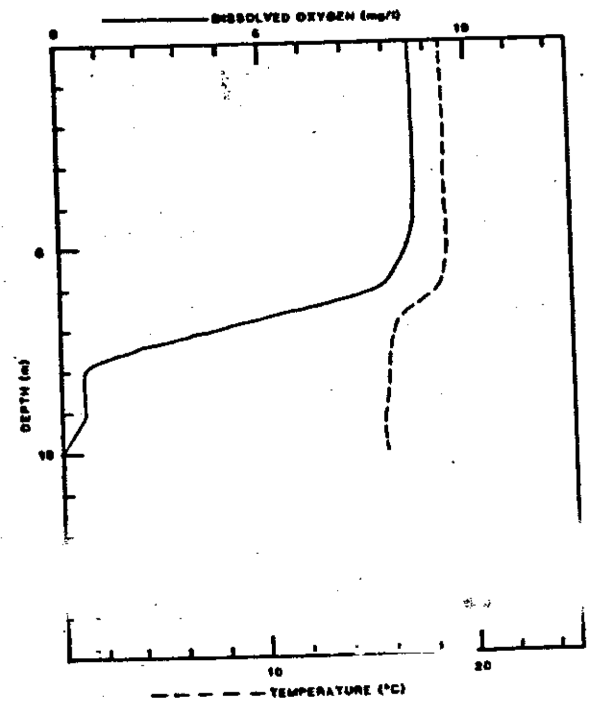
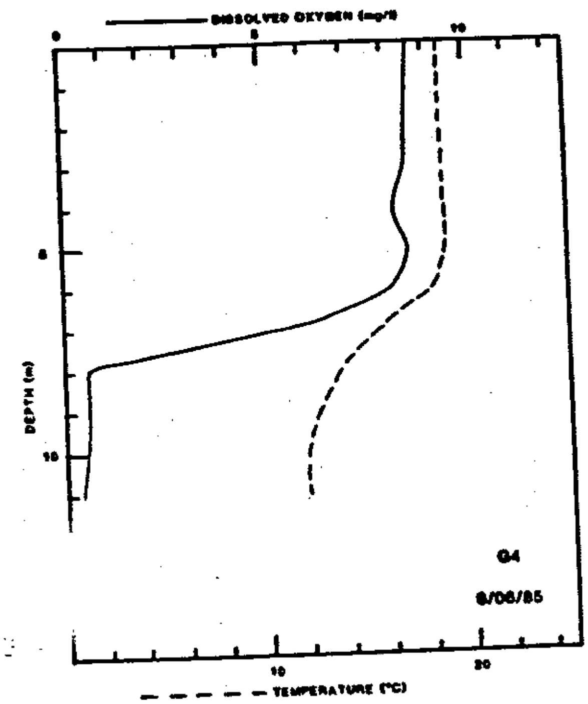


DISSOLVED OXYGEN AND TEMPERATURE VERSUS DEPTH



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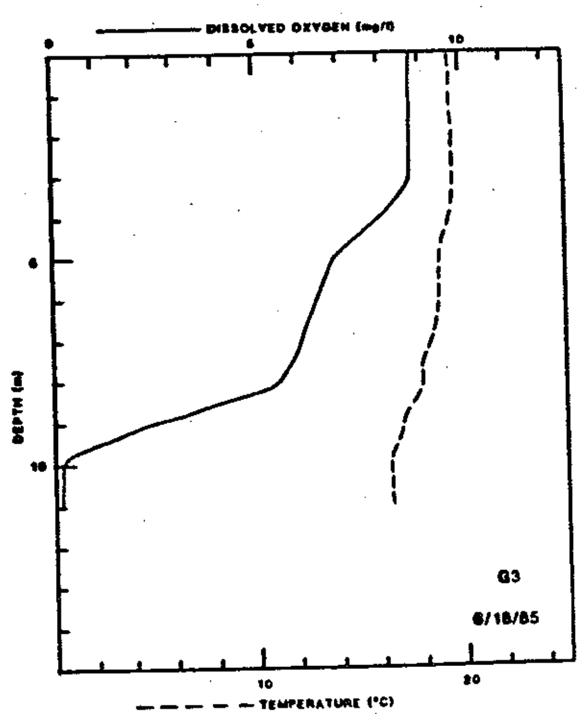

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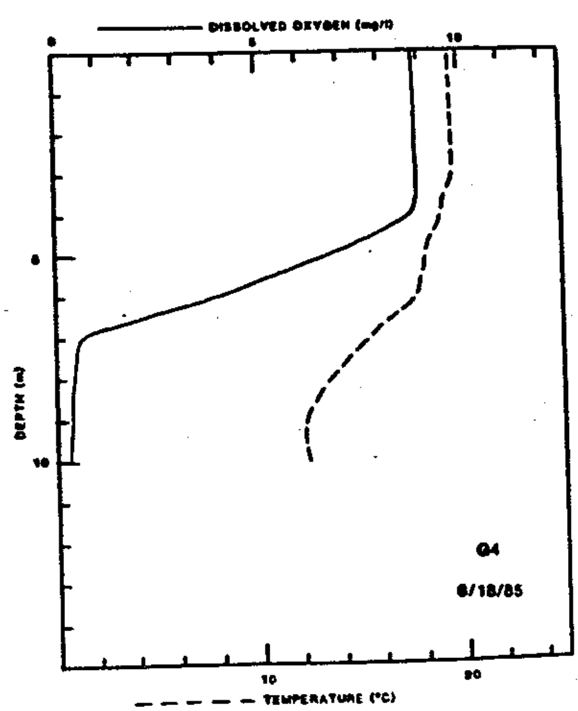
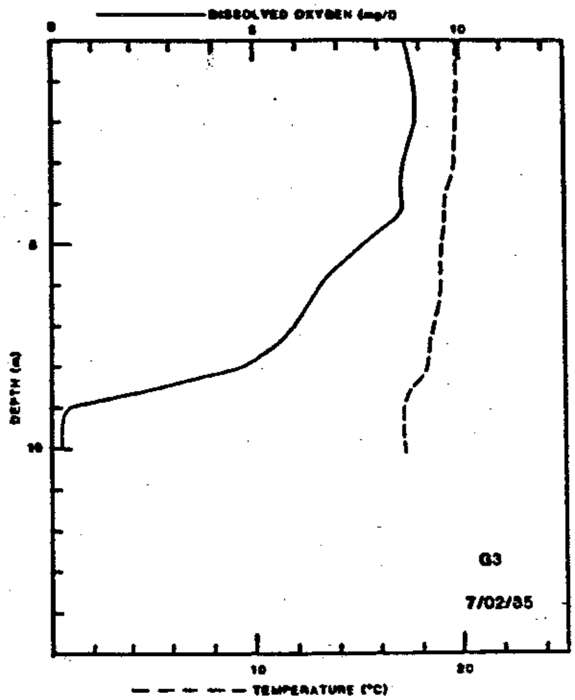


DISSOLVED OXYGEN AND TEMPERATURE VERSUS DEPTH



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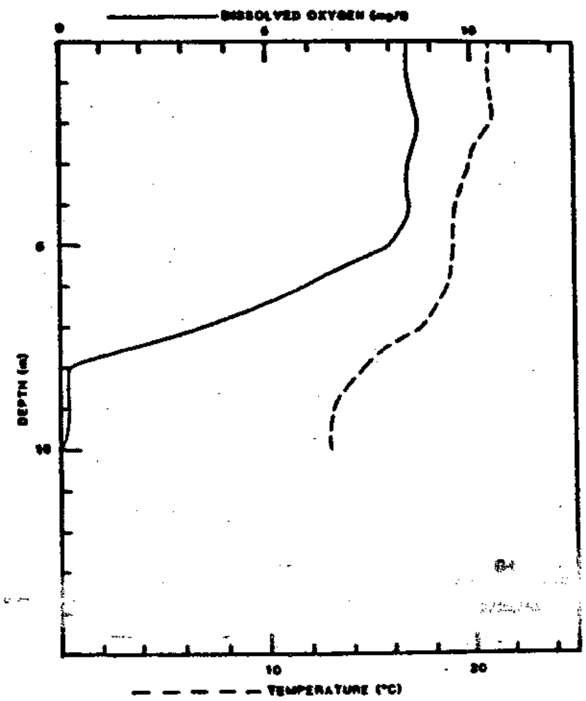

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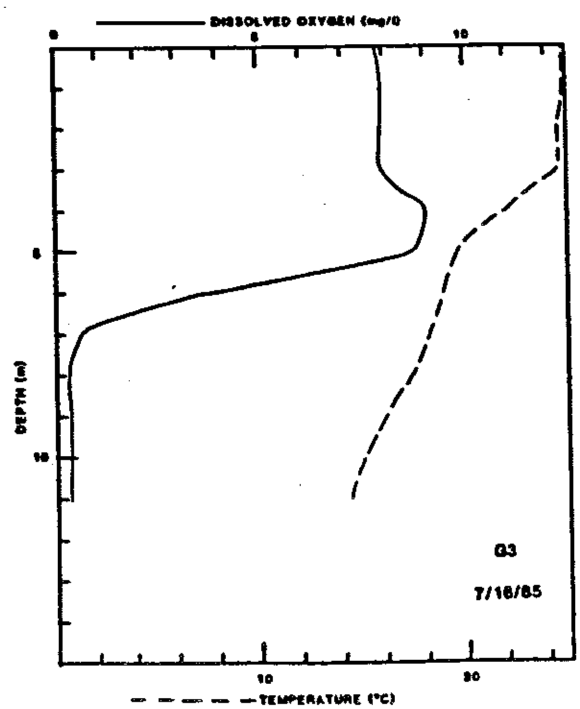

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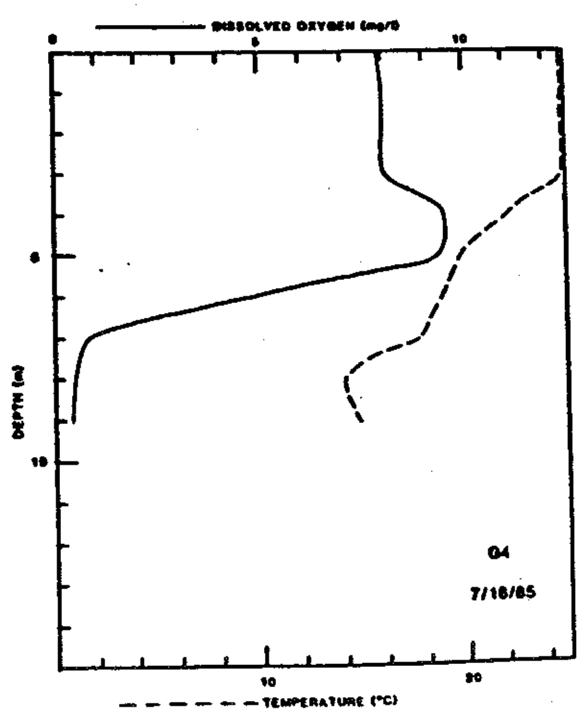

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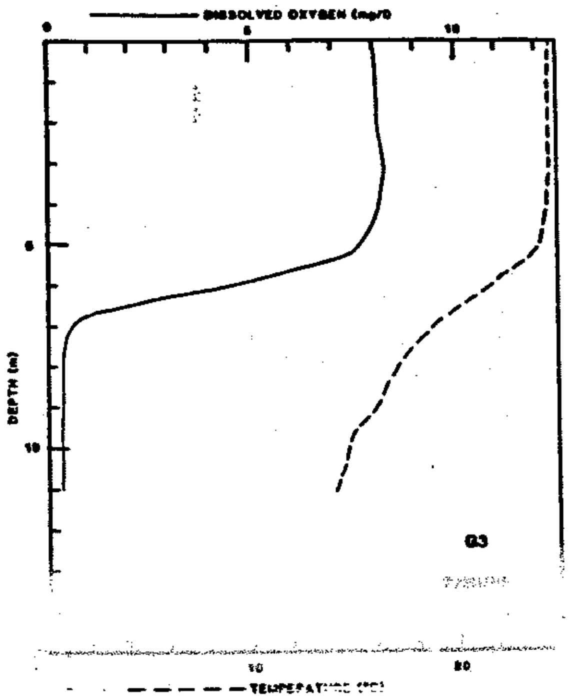

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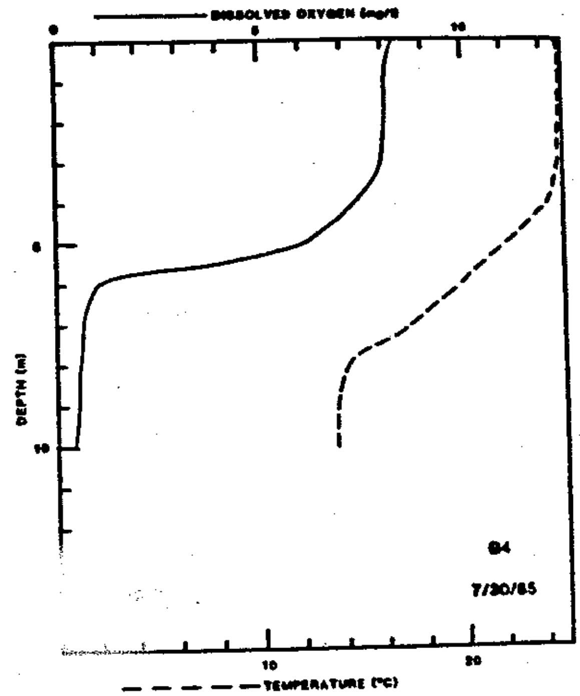

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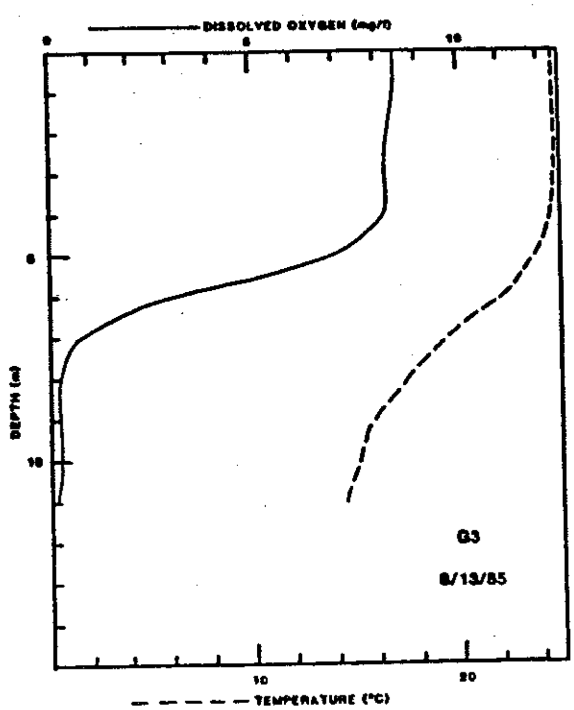

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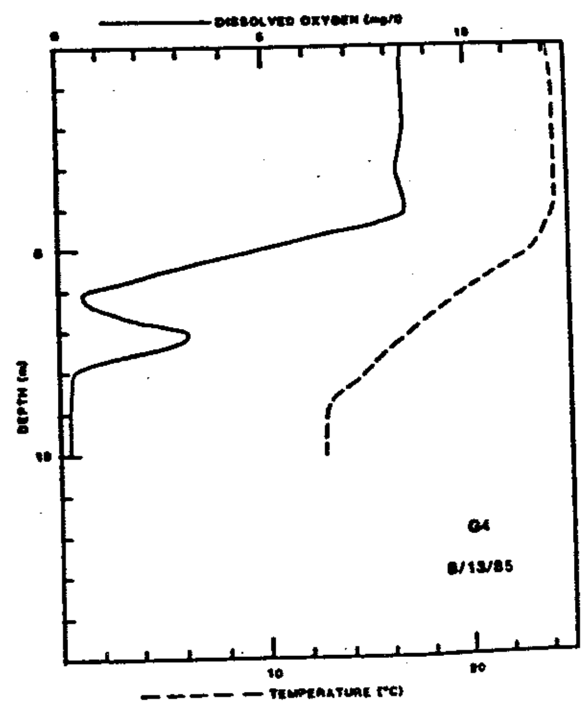

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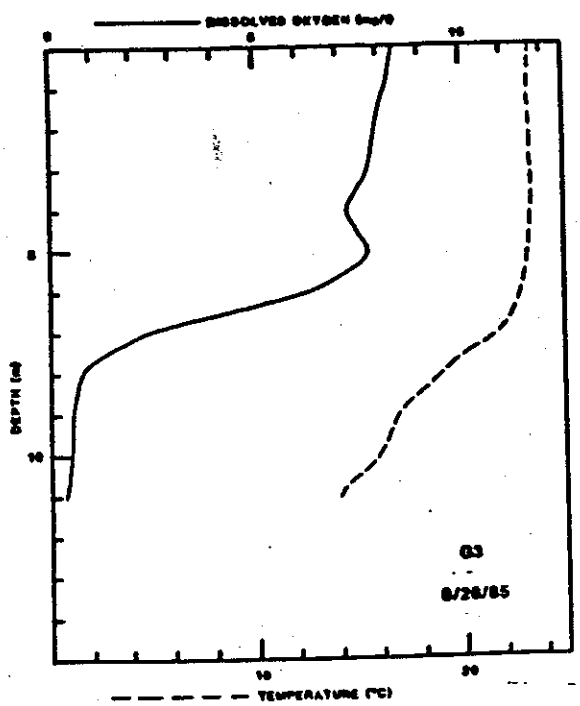

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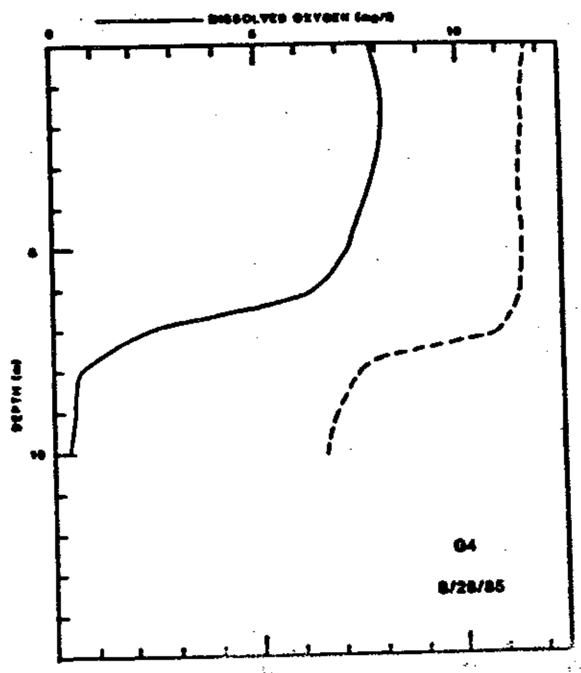

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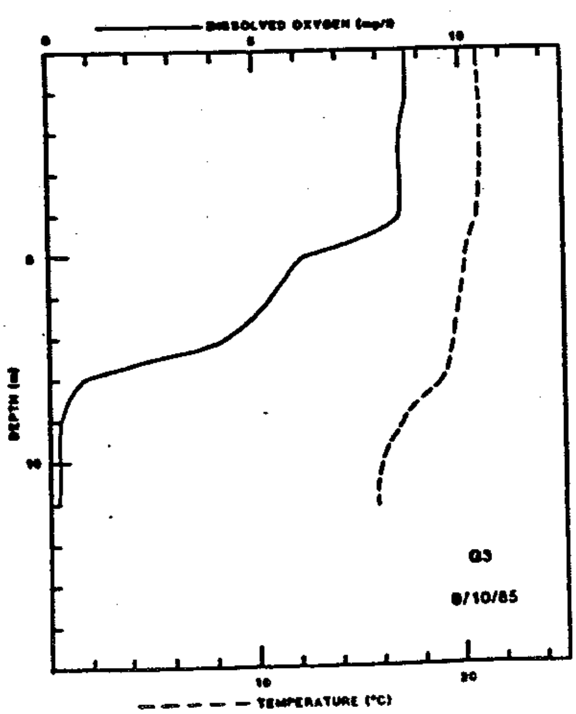

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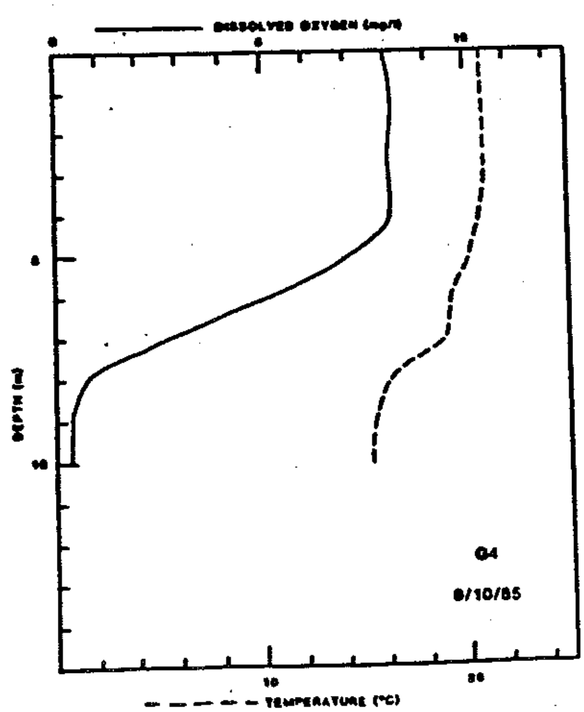

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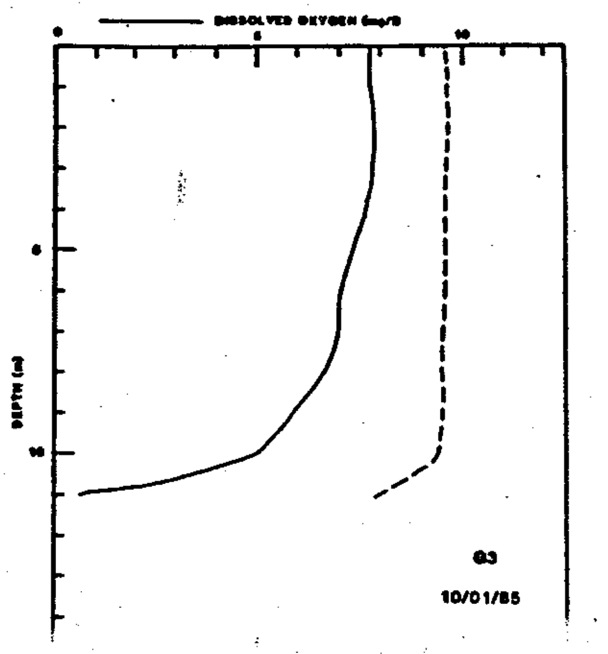

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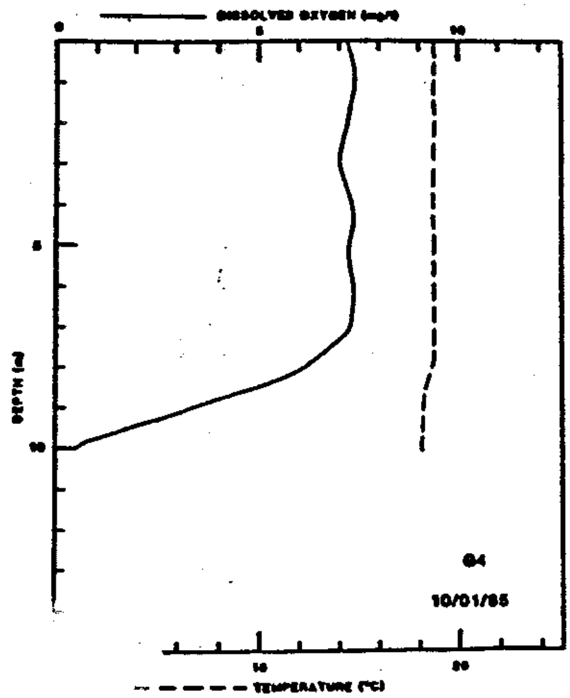

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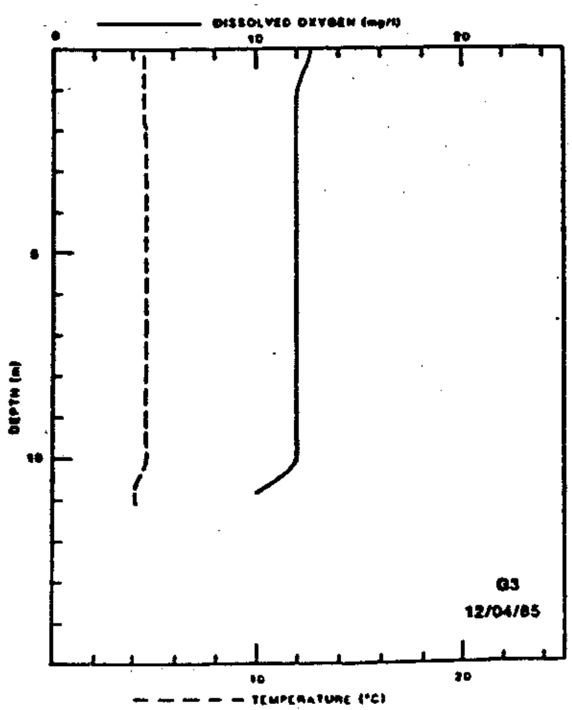

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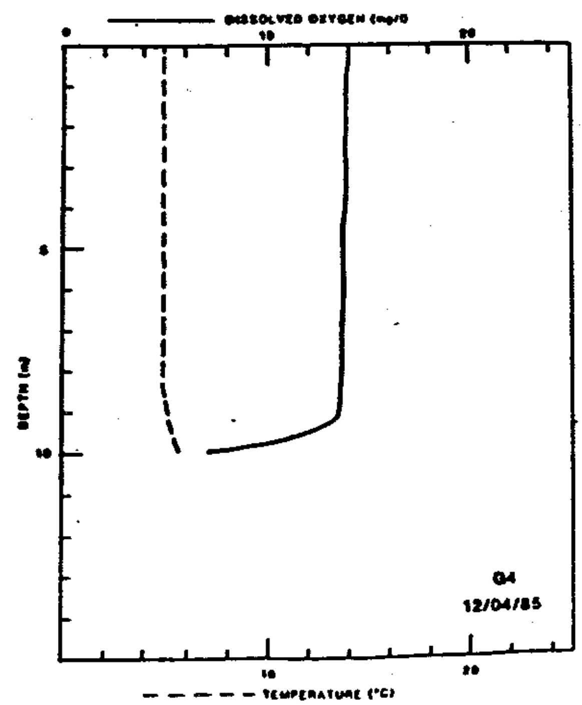

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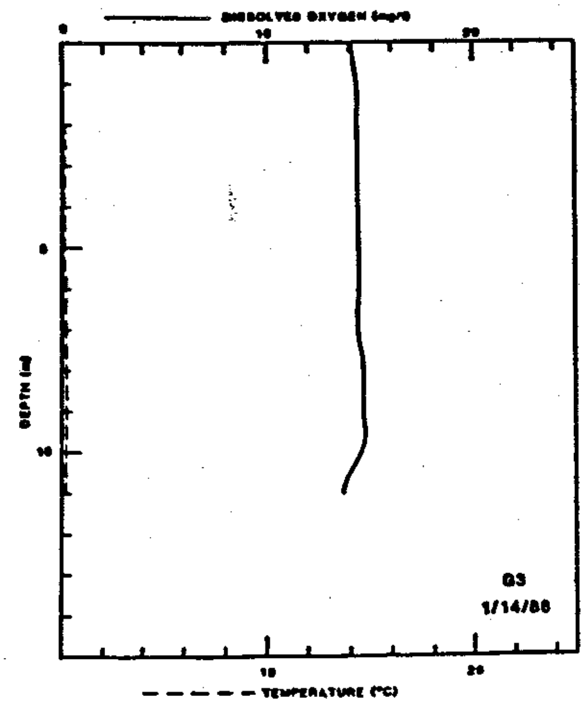

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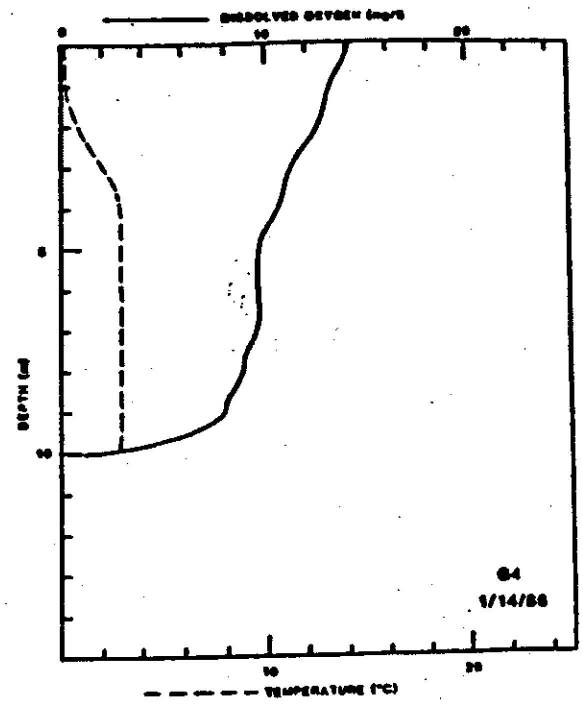

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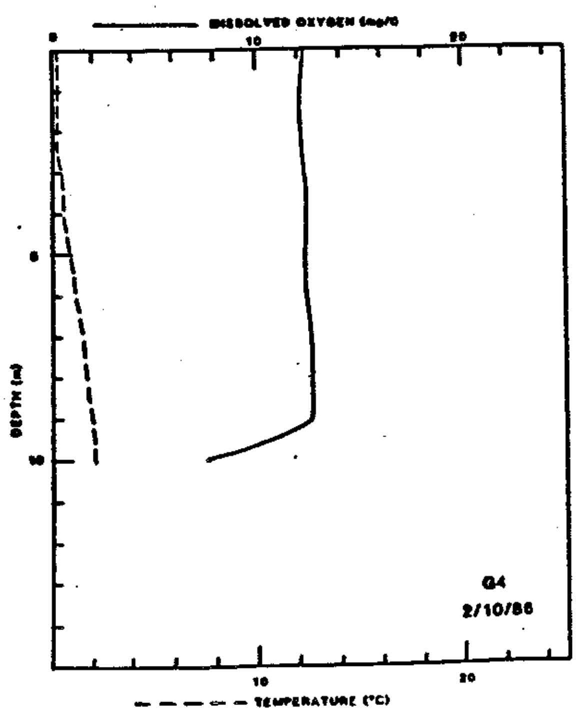

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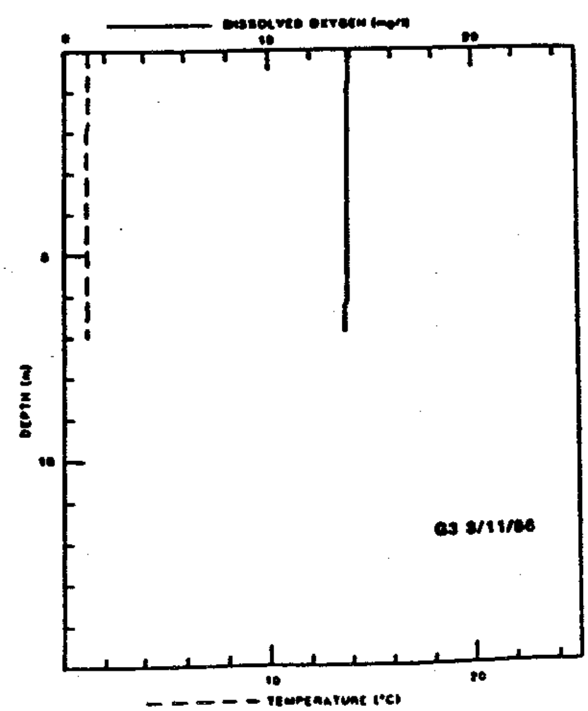
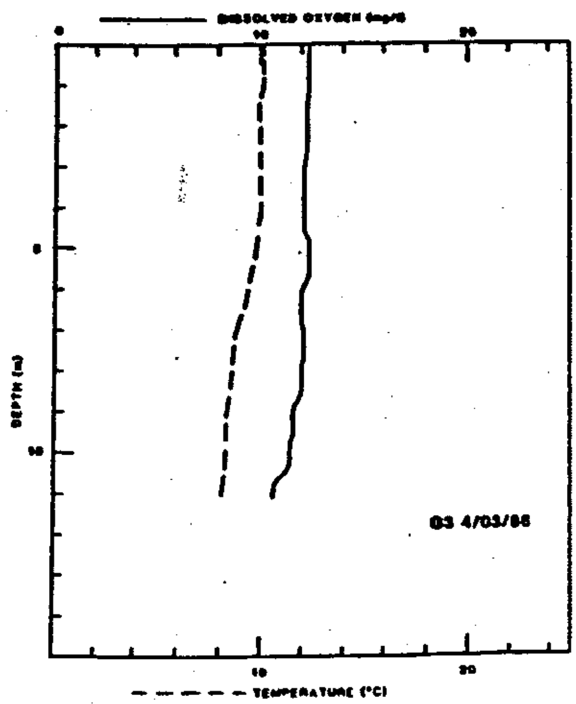
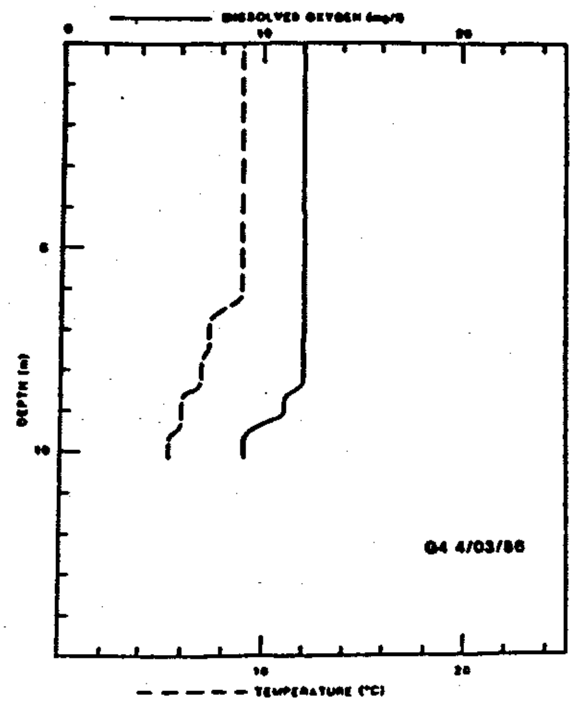


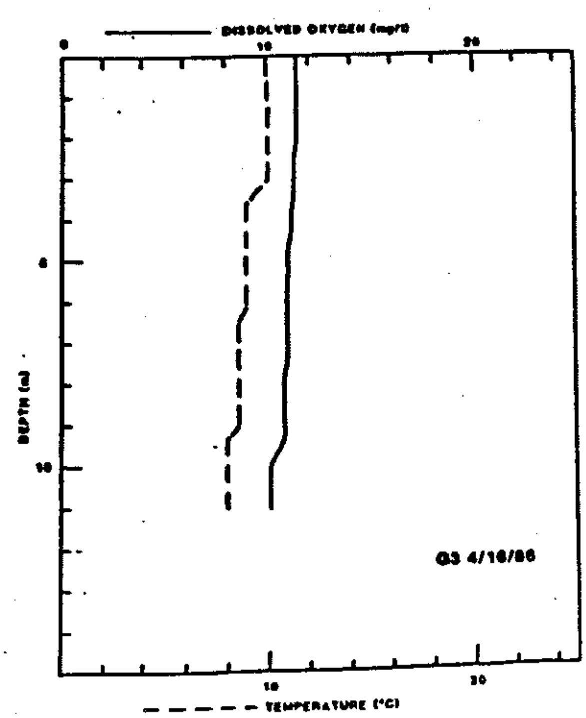
DISSOLVED OXYGEN AND TEMPERATURE VERSUS DEPTH



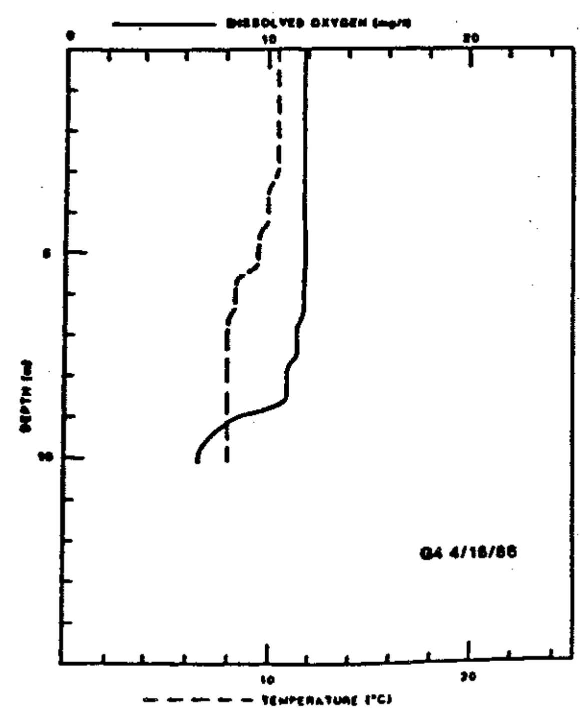
DISSOLVED OXYGEN AND TEMPERATURE VERSUS DEPTH



DISSOLVED OXYGEN AND TEMPERATURE VERSUS DEPTH



DISSOLVED OXYGEN AND TEMPERATURE VERSUS DEPTH



TOTAL SUSPENDED SOLIDS (MG/L) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	2.0	2.8	2.4			2.0			2.0
05-21-85		1.2	1.2		10.0	.8	.4	2.4	.8
06-06-85	4.8	4.8	3.2	2.0	1.2	1.6	2.0	2.4	.8
06-18-85		20.0	4.0	5.6	4.7	4.0	3.6	8.0	4.4
07-02-85		8.0	1.2	.8	2.0	.4	1.6	2.0	.4
07-16-85			7.2	6.8	6.4	4.8	3.6	13.0	2.4
07-30-85			9.6	5.2	42.0	4.0	8.0	40.0	3.2
08-13-85			8.0	3.6	44.0	3.6	6.8	46.0	4.4
08-28-85		8.0	3.6	4.0	2.8	2.0	2.8	8.0	
09-10-85	3.2	5.2	2.0	2.0	3.6	.4	3.2	1.6	.4
10-01-85			1.6		3.2	.4		.4	2.4
12-04-85	15.0	3.0	19.0		3.0	2.0		27.0	4.0
01-14-86	.8	3.2	.4		1.2	.4		8.4	3.2
02-10-86	2.8	2.8				.4		.4	1.6
03-11-86	1.7	.8	.4		4.8				.4
04-03-86	1.6	1.2	2.4		1.6	2.4		2.8	1.2
04-16-86	5.6	8.4	3.2		1.6	4.0		2.8	6.8
MEAN	4.2	5.3	4.3	3.8	8.8	2.1	3.6	11.0	2.4
MAXIMUM	15.0	20.0	19.0	6.8	44.0	4.8	8.0	46.0	6.8
MINIMUM	.8	.8	.4	.8	1.2	.4	.4	.4	.4

TOTAL DISSOLVED SOLIDS (MG/L) IN THE GREAT POND

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	81	87	83			77			77
05-21-85		73	55		64	63	55	55	57
06-06-85	72	99	61	75	21	57	61	60	45
06-18-85		152	89	68	69	53	60	91	59
07-02-85		89	69	75	69	59	64	68	76
07-16-85			33	21	24	35	36	52	55
07-30-85			84	68	100	96	57	68	49
08-13-85			116	64	119	72	75	44	21
08-28-85		139	84	80	82	72	83	77	
09-10-85	29	103	48	39	244	15	24	45	27
10-01-85			75		68	72		68	55
12-04-85	87	112	75		93	92		84	80
01-14-86	75	89	80		81	83		79	65
02-10-86	67	73				53		72	64
03-11-86	56	57	31		51				27
04-03-86	67	61	72		65	64		67	61
04-16-86	116	111	112		105	115		104	109
MEAN	72	96	73	61	84	67	57	69	58
MAXIMUM	116	152	116	80	244	115	83	104	109
MINIMUM	29	57	31	21	21	15	24	44	21

CONDUCTIVTY (UMHOS/CM) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	118	137	142			139			145
05-21-85		137	144	143	141	145	144	145	144
06-06-85	120	127	143	145	143	140	140	140	141
06-18-85		130	145	142	144	140	140	145	140
07-02-85		158	167	167	162	164	165	160	170
07-16-85		140	168	165	172	168	163	166	167
07-30-85		175	180	180	208	175	185	205	180
08-13-85		130	155	157	205	156	158	210	157
08-28-85		141	150	142	148	147	139	167	151
09-10-85	120	142	145	144	144	145	143	141	143
10-01-85			140		139	141		141	132
12-04-85	172	198	202		200	201		203	210
01-14-86	192	200	190		178	182		195	174
02-10-86	128	151				143		143	145
03-11-86	140	164	160		162				166
04-03-86	125	150	142		142	140		145	148
04-16-86	145	157	153		153	155		155	156
MEAN	140	152	158	154	163	155	153	164	157
MAXIMUM	192	200	202	180	208	201	185	210	210
[illegible]	[illegible]	[illegible]				139	139	140	132

PH (S.U.) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	6.5	6.3	6.9			6.9			6.8
05-21-85		6.3	6.9	6.9	6.7	6.9	6.8	6.8	6.9
06-06-85	5.9	5.2	6.9	6.9	6.8	6.9	6.9	6.5	6.8
06-18-85		5.2	7.0	6.9	6.4	7.1	6.9	6.7	6.8
07-02-85		5.8	7.1	6.8	6.6	7.1	6.9	6.7	6.9
07-16-85		5.4	7.0	7.0	6.8	7.0	7.1	6.5	6.3
07-30-85		5.2	7.1	6.8	6.3	7.1	6.6	6.3	6.9
08-13-85		5.2	7.1	6.7	6.7	7.1	6.7	6.7	7.0
08-28-85		5.0	6.9	6.7	6.6	6.9	6.8	6.4	6.8
09-10-85	6.4	5.2	6.9	6.4	6.3	6.9	6.8	6.3	6.9
10-01-85			6.9		6.8	6.9		6.8	6.9
12-04-85	6.0	5.3	6.9		6.9	6.9		6.9	6.9
01-14-86	5.8	5.3	6.9		6.9	6.9		6.7	6.8
02-10-86	6.4	5.0				6.9		6.8	6.9
03-11-86	6.4	5.3	6.7		6.9				6.9
04-03-86	6.7	5.3	6.9		6.8	6.9		6.9	6.9
04-16-86	6.7	5.3	6.9		6.8	6.9		6.9	6.9
MAXIMUM	6.7	6.3	7.1	7.0	6.9	7.1	7.1	6.9	7.0
MINIMUM	5.8	5.0	6.7	6.4	6.3	6.9	6.6	6.3	6.3

TOTAL ALKALINITY (MG/L AS CACO3) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	3.2	2.8	7.1			8.3			7.9
05-21-85		3.6	7.3		7.3	8.1	8.6	8.6	8.3
06-06-85	3.2	1.1	8.6	8.3	9.0	8.1	7.7	9.4	8.1
06-18-85		3.0	8.6	8.1	10.0	8.6	11.0	11.0	8.1
07-02-85		5.4	9.0	11.0	9.4	9.0	9.2	10.0	9.0
07-16-85			7.9	9.0	10.0	8.2	9.0	9.6	9.4
07-30-85			8.6	9.2	22.0	8.8	11.0	24.0	8.6
08-13-85			8.2	9.6	28.0	10.0	9.2	31.0	9.0
08-28-85		2.7	9.0	8.8	10.0	8.2	8.8	19.0	8.8
09-10-85	3.8	3.6	9.4	9.0	11.0	8.8	9.8	9.4	9.0
10-01-85			10.0		12.0	11.0		11.0	10.0
12-04-85	7.3	7.3	8.8		9.8	9.6		9.6	10.0
01-14-86	6.7	8.6	10.0		10.0	9.4		9.4	9.6
02-10-86	6.2	6.8				9.3		9.1	9.9
03-11-86	5.2	9.0	9.0		7.2				8.8
04-03-86	7.7	7.9	11.0		11.0	9.9		10.0	10.0
04-16-86	7.2	5.7	8.6		8.6	7.9		9.0	7.5
MEAN	5.6	5.2	8.8	9.1	11.7	8.9	9.4	12.7	8.9
MAXIMUM	7.7	9.0	11.0	11.0	28.0	11.0	11.0	31.0	10.0
MINIMUM	3.2	1.1	7.1	8.1	7.2	7.9	7.7	8.6	7.5

CHLORIDE (MG/L) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-3M	G-3B	G-4S	G-4M	G-4B	G-5
05-08-85	32	32	31			28			31
05-21-85		26	34		42	32	37	35	33
06-06-85	19	20	19	26	21	22	23	28	29
06-18-85		22	25	27	25	24	25	22	21
07-02-85		22	22	23	19	22	21	21	26
07-16-85			33	21	24	21	22	21	23
07-30-85			22	21	22	23	22	23	22
08-13-85			23	25	18	24	23	24	23
08-28-85		26	22	21	24	20	22	22	22
09-10-85	17	28	43	20	22	20	19	21	22
10-01-85			29		34	28		26	28
12-04-85	26	25	26		25	26		26	26
01-14-86	29	31	30		30	31		30	30
02-10-86	25	26				30		32	30
03-11-86	28	28	30		32				29
04-03-86	25	27	29		28	28		29	29
04-16-86	27	28	30		28	28		30	28
MEAN	25	26	28	23	26	25	24	26	27
MAXIMUM	32	32	43	27	42	32	37	35	33
MINIMUM	17	20	19	20	18	20	19	21	21

BIOLOGICAL DATA

FECAL STREPTOCOCCI (N/100 ML) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-4S	G-5
05-08-85	247	8	1	1	1
05-21-85		0	0	0	0
06-06-85	380	130	165	37	263
06-18-85		0	0	0	0
07-02-85		88	31	1	28
07-16-85			4	13	52
07-30-85			10	2	45
08-13-85			10	15	83
08-28-85		410	10	1	40
09-10-85	120	213	33	1	28
10-01-85			3	0	3
12-04-85	2	460	0	0	3
01-14-86	0	0	0	0	0
02-10-86	0	0		0	0
03-11-86	0	0	4		1
04-03-86	0	0	0	1	48
04-16-86	1	33	2	0	7
MEAN (GEOMETRIC)	6.6	11.9	4.3	1.8	8.3
MAXIMUM	380	460	165	37	263
MINIMUM	0	0	0	0	0

FECAL COLIFORM (N/100 ML) IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-4S	G-5
05-08-85	0	0	0	0	0
05-21-85		5	0	0	3
06-06-85	338	150	3	0	0
06-18-85		5	0	0	0
07-02-85		81	0	0	0
07-16-85			0	0	14
07-30-85			0	0	0
08-13-85			5	0	0
08-28-85		128	0	0	0
09-10-85	48	64	0	6	4
10-01-85			1	4	0
12-04-85	0	0	0	1	1
01-14-86	0	0	0	0	0
02-10-86	0	0		0	0
03-11-86	0	0	0		1
04-03-86	0	0	0	0	0
04-16-86	85	0	0	0	0
MEAN (GEOMETRIC)	4.8	5.3	1.2	1.2	1.3
MAXIMUM	338	150	5	6	14
MINIMUM	0	0	0	0	0

FECAL COLIFORM/FECAL STREPTOCOCCI IN THE GREAT POND SYSTEM

STATION DATE	G-1	G-2	G-3S	G-4S	G-5
05-08-85	1.4	18.8	3.0	0.0	0.0
05-21-85					
06-06-85	0.0	.6	0.0	0.0	0.0
06-18-85					
07-02-85		0.0	0.0	0.0	0.0
07-16-85			1.2	0.0	0.0
07-30-85			0.0	0.0	0.0
08-13-85			0.0	.4	0.0
08-28-85	0.0	0.0	.1	4.0	0.0
09-10-85		0.0	0.0	1.0	0.0
10-01-85			0.0		0.0
12-04-85	0.0	0.0			0.0
01-14-86					
02-10-86					
03-11-86			0.0		0.0
04-03-86				0.0	0.0
04-16-86	0.0	0.0	0.0		0.0
MEAN	.3	2.8	.4	.6	0.0
MAXIMUM	1.4	18.8	3.0	4.0	0.0
MINIMUM	0.0	0.0	0.0	0.0	0.0

CHLOROPHYLL A (UG/L)
IN THE GREAT POND SYSTEM

STATION DATE	G-3S	G-4S
05-08-85	2.40	5.00
05-21-85	1.60	2.50
06-06-85	6.50	4.60
06-18-85	8.00	5.40
07-02-85	5.30	6.20
07-16-85	28.00	8.40
07-30-85	4.00	21.00
08-13-85	5.90	6.10
08-28-85	5.65	5.78
09-10-85	13.00	20.00
10-01-85	7.20	8.50
12-04-85	8.50	8.90
01-14-86	4.60	7.60
02-11-86		9.00
03-11-86	9.30	
04-03-86	9.90	9.34
04-16-86	5.60	5.70
MEAN	7.84	8.38
MAXIMUM	28.00	21.00
MINIMUM	1.60	2.50

SECCHI DISK TRANSPARENCY (M)
IN THE GREAT POND SYSTEM

STATION DATE	G-3S	G-4S
05-08-85		
05-21-85	4.5	4.5
06-06-85	2.5	2.8
06-18-85	3.3	2.5
07-02-85	2.6	3.0
07-16-85	2.9	2.9
07-30-85	2.8	3.3
08-13-85	4.5	3.4
08-28-85	3.5	3.1
09-10-85	3.2	3.9
10-01-85	3.8	3.2
12-04-85	3.4	3.7
01-14-86	3.4	2.7
02-10-86		2.1
03-11-86	2.8	
04-03-86	4.8	4.3
04-16-86	4.8	4.3
MEAN	3.4	3.2
MAXIMUM	4.8	4.5
MINIMUM	2.5	2.1

PHYTOPLANKTON DENS[illegible] IN GREAT POND, EASTHAM

	050885 CELLS/ML	UG/L
BACILLARIOPHYTA		
Asterionella	3.2	.64
Cyclotella	7.6	19
Melosira	4	9.60
Nitzschia	.2	.16
Synedra	1	.8
Tabellaria	1.6	4.8
CHLOROPHYTA		
Ankistrodesmus	.4	.2
Botryococcus	9.6	6.72
Chlamydomonas	36	3.6
Closterium	.2	.8
Cosmarium	1.2	9.6
Eudorina	4.8	1.92
Staurastrum	1.2	.96
CRYPTOPHYTA		
Cryptomonas	20	20
EUGLENOPHYTA		
Trachelomonas	10.4	10.4
PYRRHOPHYTA		
Peridinium	.4	1.2
TOTAL	101.8	90.4
BACILLARIOPHYTA	17.6	35
CHLOROPHYTA	53.4	23.8
CRYPTOPHYTA	20	20
EUGLENOPHYTA	10.4	10.4
PYRRHOPHYTA	.4	1.2

	052185 CELLS/ML	UG/L
BACILLARIOPHYTA		
Asterionella	1.6	.32
Cyclotella	30	75
Melosira	3	.9
Synedra	.8	.64
Tabellaria	2.4	7.2
CHLOROPHYTA		
Chlamydomonas	24	2.4
Cosmarium	.4	.32
Oocystis	3.2	1.28
Scenedesmus	5.6	.56
Staurastrum	.4	.32
CHRYSOPHYTA		
Dinobryon	15.4	46.2
CRYPTOPHYTA		
Cryptomonas	14	14
CYANOPHYTA		
Microcystis	160	1.6
EUGLENOPHYTA		
Trachelomonas	9.6	9.6
PYRRHOPHYTA		
Ceratium	.4	16
Peridinium	.4	1.2
TOTAL	271.2	177.54
BACILLARIOPHYTA	37.8	84.06
CHLOROPHYTA	33.6	4.88
CHRYSOPHYTA	15.4	46.2
CRYPTOPHYTA	14	14
CYANOPHYTA	160	1.6
EUGLENOPHYTA	9.6	9.6
PYRRHOPHYTA	.8	17.2

	060685 CELLS/ML	UG/L
BACILLARIOPHYTA		
Cyclotella	34	85
Synedra	.6	.48
Tabellaria	2.4	7.2
CHLOROPHYTA		
Botryococcus	1.6	1.12
Chlamydomonas	4.8	.48
CRYPTOPHYTA		
Cryptomonas	9	1.8
CYANOPHYTA		
Anabaena	40	124
Chroococcus	3.2	.032
Coelosphaerium	36	.36
Microcystis	16	.16
EUGLENOPHYTA		
Trachelomonas	7.6	7.6
PYRRHOPHYTA		
Ceratium	.6	24
Peridinium	28.4	85.2
TOTAL	184.2	337.432
BACILLARIOPHYTA	37	92.68
CHLOROPHYTA	6.4	1.6
CRYPTOPHYTA	9	1.8
CYANOPHYTA	95.2	124.552
EUGLENOPHYTA	7.6	7.6
PYRRHOPHYTA	29	109.2

061885	CELLS/ML	UG/L
BACILLARIOPHYTA		
Cyclotella	52	20.8
CHLOROPHYTA		
Chlamydomonas	5	.5
Oocystis	.8	.32
Scenedesmus	.8	.08
CRYPTOPHYTA		
Cryptomonas	7.2	1.44
CYANOPHYTA		
Anabaena	9.6	3.84
Coelosphaerium	16	.16
Microcystis	220	2.2
EUGLENOPHYTA		
Trachelomonas	4.8	4.8
PYRRHOPHYTA		
Ceratium	.8	32
Peridinium	28	84
TOTAL	345	150.14
BACILLARIOPHYTA	52	20.8
CHLOROPHYTA	6.6	.9
CRYPTOPHYTA	7.2	1.44
CYANOPHYTA	245.6	6.2
EUGLENOPHYTA	4.8	4.8
PYRRHOPHYTA	28.8	116

070285	CELLS/ML	UG/L
BACILLARIOPHYTA		
Cyclotella	15.2	38
Melosira	8	2.4
Tabellaria	2.4	7.2
CHLOROPHYTA		
Chlamydomonas	16.8	1.68
CRYPTOPHYTA		
Cryptomonas	9.6	1.92
CYANOPHYTA		
Coelosphaerium	24	.24
Microcystis	48	.48
Oscillatoria	16	.16
EUGLENOPHYTA		
Euglena	.4	.2
Trachelomonas	4.8	4.8
PYRRHOPHYTA		
Peridinium	32.8	98.4
TOTAL	178	155.48
BACILLARIOPHYTA	25.6	47.6
CHLOROPHYTA	16.8	1.68
CRYPTOPHYTA	9.6	1.92
CYANOPHYTA	88	.88
EUGLENOPHYTA	5.2	5
PYRRHOPHYTA	32.8	98.4

071585	CELLS/ML	UG/L
BACILLARIOPHYTA		
Cyclotella	7.2	2.88
Gomphonema	.3	.3
Melosira	6.6	1.98
Navicula	.6	.6
CHLOROPHYTA		
Chlamydomonas	6	.6
Oocystis	1.2	.48
CRYPTOPHYTA		
Cryptomonas	3.6	.72
CYANOPHYTA		
Anabaena	72	28.8
Chroococcus	4.8	.048
Microcystis	60	.6
EUGLENOPHYTA		
Euglena	.3	.15
Trachelomonas	2.4	2.4
PYRRHOPHYTA		
Peridinium	42.9	128.7
TOTAL	207.9	168.258
BACILLARIOPHYTA	14.7	5.76
CHLOROPHYTA	7.2	1.08
CRYPTOPHYTA	3.6	.72
CYANOPHYTA	136.8	29.448
EUGLENOPHYTA	2.7	2.55
PYRRHOPHYTA	42.9	128.7

BACILLARIOPHYTA	073085 CELLS/ML	UG/L
Melosira	2.4	.72
Synedra	.2	.16
CHLOROPHYTA		
Chlamydomonas	1.2	.12
CRYPTOPHYTA		
Cryptomonas	1.6	.32
CYANOPHYTA		
Anabaena	22.4	8.96
Coelosphaerium	9.2	.092
Microcystis	41.6	.416
EUGLENOPHYTA		
Trachelomonas	.8	.8
PYRRHOPHYTA		
Peridinium	24.2	72.6
TOTAL	103.6	84.188
BACILLARIOPHYTA	2.6	.88
CHLOROPHYTA	1.2	.12
CRYPTOPHYTA	1.6	.32
CYANOPHYTA	73.2	9.468
EUGLENOPHYTA	.8	.8
PYRRHOPHYTA	24.2	72.6

BACILLARIOPHYTA	[illegible]385 [illegible]LS/ML	UG/L
Cyclotella	.8	.32
Melosira	[illegible].8	.84
CHLOROPHYTA		
Chlamydomonas	7.4	1.24
Pandorina	.8	.32
CHRYSOPHYTA		
Dinobryon	3.2	9.6
CRYPTOPHYTA		
Cryptomonas	1.2	.24
CYANOPHYTA		
Coelosphaerium	[illegible]4	.24
Microcystis	[illegible]2	.12
Oscillatoria	[illegible]	.22
EUGLENOPHYTA		
Trachelomonas	.6	.6
PYRRHOPHYTA		
Peridinium	[illegible].4	46.2
TOTAL	95.2	59.94
BACILLARIOPHYTA	3.6	1.16
CHLOROPHYTA	13.2	1.56
CHRYSOPHYTA	3.2	9.6
CRYPTOPHYTA	1.2	.24
CYANOPHYTA	58	.58
EUGLENOPHYTA	.6	.6
PYRRHOPHYTA	15.4	46.2

BACILLARIOPHYTA	082885 CELLS/ML	UG/L
Cyclotella	1.6	.64
Melosira	6.4	1.92
Synedra	.4	3.2
Tabellaria	1.2	3.6
CHLOROPHYTA		
Chlamydomonas	2.8	.28
CHRYSOPHYTA		
Dinobryon	18	54
CRYPTOPHYTA		
Cryptomonas	1.2	.24
CYANOPHYTA		
Coelosphaerium	68	.68
Microcystis	12	.12
EUGLENOPHYTA		
Trachelomonas	.4	.4
PYRRHOPHYTA		
Peridinium	14	42
TOTAL	126	107.08
BACILLARIOPHYTA	9.6	9.36
CHLOROPHYTA	2.8	.28
CHRYSOPHYTA	18	54
CRYPTOPHYTA	1.2	.24
CYANOPHYTA	80	.8
EUGLENOPHYTA	.4	.4
PYRRHOPHYTA	14	42

BACILLARIOPHYTA	091085 CELLS/ML	UG/L
Melosira	4.8	1.44
Tabellaria	3.2	9.6
CHLOROPHYTA		
Chlamydomonas	9.6	.96
Scenedesmus	3.2	.32
CHRYSOPHYTA		
Dinobryon	36	108
CRYPTOPHYTA		
Cryptomonas	11.2	2.24
CYANOPHYTA		
Coelosphaerium	16	.16
Microcystis	64	.64
EUGLENOPHYTA		
Euglena	.8	.4
Trachelomonas	6.4	6.4
PYRRHOPHYTA		
Peridinium	33.6	100.8
TOTAL	188.8	230.96
BACILLARIOPHYTA	8	11.04
CHLOROPHYTA	12.8	1.28
CHRYSOPHYTA	36	108
CRYPTOPHYTA	11.2	2.24
CYANOPHYTA	80	.80
EUGLENOPHYTA	7.2	6.8
PYRRHOPHYTA	33.6	100.8

BACILLARIOPHYTA	100185 CELLS/ML	UG/L
Melosira	10	3
Navicula	.4	.4
Synedra	1.4	1.12
Tabellaria	6.4	19.2
CHLOROPHYTA		
Chlamydomonas	5.6	.56
CHRYSOPHYTA		
Dinobryon	17.6	52.8
CRYPTOPHYTA		
Cryptomonas	9	1.8
CYANOPHYTA		
Anabaena	6.8	2.72
Microcystis	240.8	2.408
PYRRHOPHYTA		
Ceratium	.2	8
Peridinium	5.6	16.8
TOTAL	303.8	108.808
BACILLARIOPHYTA	18.2	23.72
CHLOROPHYTA	5.6	.56
CHRYSOPHYTA	17.6	52.8
CRYPTOPHYTA	9	1.8
CYANOPHYTA	247.6	5.128
PYRRHOPHYTA	5.8	24.8

BACILLARIOPHYTA	120485 CELLS/ML	UG/L
Asterionella	4.8	.96
Melosira	24	7.2
Navicula	.6	1.8
Nitzschia	.3	.24
Synedra	2.4	1.92
Tabellaria	39.6	118.8
CHLOROPHYTA		
Chlamydomonas	6	.6
Scenedesmus	1.2	.12
CHRYSOPHYTA		
Dinobryon	12	36
CRYPTOPHYTA		
Cryptomonas	6.6	1.32
CYANOPHYTA		
Microcystis	60	.6
PYRRHOPHYTA		
Peridinium	1.8	5.4
TOTAL	159.3	174.96
BACILLARIOPHYTA	71.7	130.92
CHLOROPHYTA	7.2	.72
CHRYSOPHYTA	12	36
CRYPTOPHYTA	6.6	1.32
CYANOPHYTA	60	.6
PYRRHOPHYTA	1.8	5.4

BACILLARIOPHYTA	011486 CELLS/ML	UG/L
Asterionella	2.4	.48
Tabellaria	25.8	77.4
CHLOROPHYTA		
Eudorina	3.6	1.44
Sphaerocystis	3.6	.36
Staurastrum	.6	.48
CHRYSOPHYTA		
Dinobryon	52.5	157.5
CRYPTOPHYTA		
Cryptomonas	14.4	2.88
PYRRHOPHYTA		
Peridinium	5.4	16.2
TOTAL	108.3	256.74
BACILLARIOPHYTA	28.2	77.88
CHLOROPHYTA	7.8	2.28
CHRYSOPHYTA	52.5	157.5
CRYPTOPHYTA	14.4	2.88
PYRRHOPHYTA	5.4	16.2

BACILLARIOPHYTA	021086 CELLS/ML	UG/L
Asterionella	4.4	.88
Synedra	.4	3.2
Tabellaria	13.2	39.6
CHLOROPHYTA		
Chlamydomonas	36	3.6
Cosmarium	.4	.32
CHRYSOPHYTA		
Dinobryon	16	48
CRYPTOPHYTA		
Cryptomonas	24	4.8
PYRRHOPHYTA		
Peridinium	3.2	9.6
TOTAL	97.6	110
BACILLARIOPHYTA	18	43.68
CHLOROPHYTA	36.4	3.92
CHRYSOPHYTA	16	48
CRYPTOPHYTA	24	4.8
PYRRHOPHYTA	3.2	9.6

BACILLARIOPHYTA	031186 CELLS/ML	UG/L
Asterionella	8.4	1.68
Synedra	.8	.64
Tabellaria	36.8	110.4
CHLOROPHYTA		
Chlamydomonas	44	4.4
Eudorina	4.8	1.92
Staurastrum	.4	.32
CHRYSOPHYTA		
Dinobryon	360	1080
CRYPTOPHYTA		
Cryptomonas	26.8	5.36
EUGLENOPHYTA		
Trachelomonas	4.8	4.8
PYRRHOPHYTA		
Peridinium	20.4	61.2
TOTAL	507.2	1270.72
BACILLARIOPHYTA	46	112.72
CHLOROPHYTA	49.2	6.64
CHRYSOPHYTA	360	1080
CRYPTOPHYTA	26.8	5.36
EUGLENOPHYTA	4.8	4.8
PYRRHOPHYTA	20.4	61.2

BACILLARIOPHYTA	040386 CELLS/ML	UG/L
Asterionella	11.4	2.28
Navicula	.3	.3
Nitzschia	.3	.24
Synedra	1.2	.96
Tabellaria	33.6	100.8
CHLOROPHYTA		
Chlamydomonas	57	5.7
Cosmarium	1.2	.96
Eudorina	3.6	1.44
Scenedesmus	2.4	.24
Staurastrum	1.2	.96
CHRYSOPHYTA		
Dinobryon	222	666
CRYPTOPHYTA		
Cryptomonas	12.9	2.58
EUGLENOPHYTA		
Trachelomonas	6.6	6.6
TOTAL	353.7	789.86
BACILLARIOPHYTA	46.8	104.58
CHLOROPHYTA	65.4	9.3
CHRYSOPHYTA	222	666
CRYPTOPHYTA	12.9	2.58
EUGLENOPHYTA	6.6	6.6

BACILLARIOPHYTA	041686 CELLS/ML	UG/L
Asterionella	4	.8
Cyclotella	4.4	1.76
Fragilaria	2.4	4.8
Navicula	.4	.4
Nitzschia	.2	.7
Synedra	5.2	4.16
Tabellaria	16	48
CHLOROPHYTA		
Chlamydomonas	22	2.2
Cosmarium	.8	.64
Eudorina	3.2	1.28
Pediastrum	4.8	.96
Scenedesmus	4.8	.48
Staurastrum	.8	.64
CHRYSOPHYTA		
Dinobryon	40	120
PYRRHOPHYTA		
Peridinium	12.2	297
TOTAL	121.2	483.82
BACILLARIOPHYTA	32.6	60.62
CHLOROPHYTA	36.4	6.2
CHRYSOPHYTA	40	120
PYRRHOPHYTA	12.2	297

GREAT POND ZOOPLANKTON

DATE

Taxon	5/21/85		7/15/85		8/13/85		1/14/86	
	#/l	ug/l	#/l	ug/l	#/l	ug/l	#/l	ug/l
Rotifera								
Asplanchna	0.6	7.5	0.6	0.6	3.3	3.3	0.5	1.1
Kellicottia	1.8	0.1						
Copepoda								
[illegible]	[illegible]	[illegible]			0.6	1.4	4.0	9.9
							3.2	8.3
Cladocera								
Bosmina	3.6	3.6	0.1	0.1	0.7	0.7	1.5	1.5
Ceriodaphnia	0.9	6.3	0.1	0.1				
Chydorus	0.6	0.6						
Daphnia ambigua	11.4	66.9	0.1	0.1	0.1	0.2	0.3	0.5
Holopedium	2.7	22.8						
Rotifera	2.4	1.6	0.6	0.6	3.3	3.3	0.5	1.1
Copepoda	7.8	21.0	0.4	1.1	0.6	1.4	7.2	18.2
Cladocera	19.2	100.2	0.3	0.3	0.8	0.9	1.8	2.0
TOTAL	29.4	122.8	1.3	2.0	4.7	5.6	9.5	21.2

WATER: GREAT POND
TOWN: EASTHAM

DATE SAMPLED: 7-9-85
READ BY: JGL

Species ===> YELLOW PERCH (YP)

AVERAGE LENGTH AT TIME OF ANNULUS FORMATION	I	II	III	IV	V	VI	VII	VIII	IX	X
	74									
	84	125								
	82	135	169							
	72	115	154	182						
	75	123	164	189	205					
	92	128	153	176	193	209				
	87	122	146	165	182	197	208			
	77	0	0	0	0	0	0	0		
AVE GROWTH, MM	80	123	154	176	190	200	205	194	0	0
AVE GROWTH, IN	3.2	4.8	6.1	6.9	7.5	7.9	8.1	7.7	0.0	0.0
SD,(MM)	10.7	12.0	16.5	15.5	17.6	14.8	14.1	0.0	0.0	0.0
SD,(IN)	0.4	0.5	0.7	0.6	0.7	0.6	0.6	0.0	0.0	0.0
MEAN WT., LBS	0.0	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.0	0.0
CAP. LENGTH	108	158	191	197	220	224	221	210	0	0
CFACTOR	33	50	42	47	42	41	42	50	0	0
SD OF CF	0.0	23.6	3.3	8.5	5.7	1.2	4.2	0.0	0.0	0.0
OVERALL C 43							STANDARD C		45	
NO.PER AGE CLASS	9	9	4	7	4	6	7	1	0	0
C. OF VARIATION	0.52	0.38	0.42	0.35	0.36	0.29	0.27	0.00	0.00	0.00

IF THE COEFFICIENT OF VARIATION VALUES DIFFER GREATLY, RECHECK AGING

WATER: GREAT POND
TOWN: EASTHAM

DATE SAMPLED: 7/9/85
READ BY: RPM

Species ===> WHITE PERCH (WP)

	AVERAGE LENGTH AT TIME OF ANNULUS FORMATION									
	I	II	III	IV	V	VI	VII	VIII	IX	X
	89	174								
	72	140	204							
	85	151	206	239						
	74	136	195	229	231					
	93	168	224	271	290	304				
AVE GROWTH, MM	79	145	202	236	255	304	0	0	0	0
AVE GROWTH, IN	3.1	5.7	7.9	9.3	10.0	12.0	0.0	0.0	0.0	0.0
SD,(MM)	17.0	20.4	17.5	17.7	18.2	0.3	0.0	0.0	0.0	0.0
SD,(IN)	0.7	0.8	0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.0
MEAN WT., LBS	0.0	0.3	0.4	0.6	0.6	0.9	0.0	0.0	0.0	0.0
CAP. LENGTH	0	201	235	256	261	314	0	0	0	0
CFACTOR	0	63	52	53	51	50	0	0	0	0
SD OF CF	0.0	0.0	5.2	4.0	2.0	5.7	0.0	0.0	0.0	0.0
OVERALL C 52						STANDARD C 53				
NO.PER AGE CLASS	0	1	4	10	14	2	0	0	0	0
C. OF VARIATION	0.00	0.55	0.34	0.29	0.28	0.00	0.00	0.00	0.00	0.00

IF THE COEFFICIENT OF VARIATION VALUES DIFFER GREATLY, RECHECK AGING

WATER: GREAT POND
TOWN: EASTHAM

DATE SAMPLED: 7-8-85
READ BY: RPM

Species ===> PUMPKINSEED (P)

AVERAGE LENGTH AT TIME OF ANNULUS FORMATION

	I	II	III	IV	V	VI	VII	VIII	IX	X
	55	88								
	45	84	125							
	41	79	119	156						
	47	83	114	140	156					
	52	92	128	152	164	173				
	40	67	95	116	136	151	160			
AVE GROWTH, MM	50	85	119	143	156	166	160	0	0	0
AVE GROWTH, IN	1.9	3.4	4.7	5.6	6.1	6.5	6.3	0.0	0.0	0.0
SD,(MM)	9.9	12.9	17.9	14.1	10.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SD,(IN)	0.4	0.5	0.7	0.6	0.4	0.5	0.3	0.0	0.0	0.0
MEAN WT., LBS	0.0	0.1	0.2	0.2	0.2	0.3	0.2	0.0	0.0	0.0
CAP. LENGTH	0	107	142	170	165	181	167	0	0	0
CFACTOR	0	90	102	73	75	75	76	0	0	0
SD OF CF	0.0	32.8	31.3	14.7	8.7	7.3	5.8	0.0	0.0	0.0
OVERALL C 85							STANDARD C		76	
NO.PER AGE CLASS	0	11	5	2	6	5	2	0	0	0
C. OF VARIATION	0.00	0.60	0.59	0.39	0.27	0.27	0.17	0.00	0.00	0.00

IF THE COEFFICIENT OF VARIATION VALUES DIFFER GREATLY, RECHECK AGING

WATER: GREAT POND
TOWN: EASTHAM

DATE SAMPLED: 7-9-85
READ BY: RPM&JGL

Species ===> (CP) Chain Pickerel

AVERAGE LENGTH AT TIME OF ANNULUS FORMATION

	I	II	III	IV	V	VI	VII	VIII	IX	X
	165									
	162	259								
	185	314	376							
	167	256	337	406						
AVE GROWTH, MM	169	274	360	406	0	0	0	0	0	0
AVE GROWTH, IN	6.6	10.8	14.2	16.0	0.0	0.0	0.0	0.0	0.0	0.0
SD,(MM)	32.5	41.1	35.6	19.4	0.0	0.0	0.0	0.0	0.0	0.0
SD.(IN)	1.3	1.6	1.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0
CAP. LENGTH	215	287	405	437	0	0	0	0	0	0
CFACTOR	22	18	22	23	0	0	0	0	0	0
SD OF CF	0.0	2.7	3.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0
OVERALL C 21							STANDARD C 23			
NO.PER AGE CLASS	8	14	8	6	0	0	0	0	0	0
C. OF VARIATION	0.76	0.59	0.39	0.19	0.00	0.00	0.00	0.00	0.00	0.00

IF THE COEFFICIENT OF VARIATION VALUES DIFFER GREATLY, RECHECK AGING

Length-Frequency Sheet

Date: July 8, 1985 **Location:** Great Pond, Eastham **Remarks:** Shockboat/gill nets/rod&r

Length (mm)	CP	YP	WP	P	SMB	K	Length (mm)
50-59							50-59
60-69							60-69
70-79							70-79
80-89							80-89
90-99				///			90-99
100-109		/////		///			100-109
110-119		///		/////			110-119
120-129		/		//			120-129
130-139				/			130-139
140-149		/					140-149
150-159		////		/		O	150-159
160-169		////		//////			160-169
170-179		/		///////			170-179
180-189		/		//		B	180-189
190-199	/	//////		/			190-199
200-209		///////	/				200-209
210-219	/	/////				S	210-219
220-229	////	////	//				220-229
230-239		///	//				230-239
240-249	//	/	//////			E	240-249
250-259	/	/	//////				250-259
260-269	////		//////				260-269
270-279	////		/////			R	270-279
280-289	//						280-289
290-299	/		/				290-299
300-309	/					V	300-309
310-319			//				310-319
320-329							320-329
330-339	/					E	330-339
340-349	/						340-349
350-359							350-359
360-369	/					D	360-369
370-379	///						370-379
380-389	/						380-389
390-399							390-399
400-409	/						400-409
410-419	///						410-419
420-429	/						420-429
430-439							430-439
440-449	//						440-449
450-459	/						450-459
460-469	/						460-469
470-479	/						470-479
480-489							480-489
490-499							490-499
500-509					/		500-509
510-519							510-519
520-529							520-529
530-539							530-539
Total No.	38	47	31	31	1	-	
Weight: Kg.	8.9	3.8	7.8	2.3	1.9	-	
Lbs.	19.7	8.5	17.1	5.1	4.1	-	

CALCULATION SHEETS

Calculation of Ground Water Flow into Great Pond

By Darcy's Law:

$$Q = KIA$$

Q = flow into the lake

K = permeability: >20 inches/hr (0.014 cm/s or 300 gal/d/sq. ft) according to SCS (in press)

Range = 750-3750 gal/d/sq. ft (50-250 inches/hr or 0.035-0.176 cm/s) according to Guswa and LaBlanc (1985), which gives a mean of 1600 gal/d/sq. ft (107 inches/hr or 0.075 cm/s).

For Eastham, with many clay lenses, might expect subaverage permeability (about 1000 gal/d/sq. ft = 67 inches/hr

I = hydraulic gradient: 5-10 ft/4000 ft over watershed = 0.0013-0.0025

A = seepage face: 2750 linear ft of shoreline with face extending 400-500 ft into the lake from N.E. shore = 1.1-1.4 million sq. ft = 31130-39620 sq. m.

Therefore, Q = 2.8-34.5 cu.m/min, calculated mean of 10.0 cu.m/min, adjusted estimate (for Eastham with clay lenses) of 6.3 cu.m/min.

By Empirical Values and Intuition:

Q = VA

Q = flow into the lake

V = velocity of water in ground: 2 to 10 ft/day, according to conversations with USGS personnel.

A = cross-sectional area of intersection between ground water plume and Great Pond; about 20 ft by 2750 ft = 55000 sq. ft.

Therefore, Q = 2.2-10.9 cu.m/min.

The Eastham-adjusted estimate of 6.3 cu.m/min is in the middle of this range. For further calculations, a mean ground water inflow of 6.3 cu.m/min and a range of 3 to 10 cu.m/min will be assumed.

CALCULATION OF LAND AREAS NECESSARY TO ALLOW PROPER DILUTION OF NITRATE NITROGEN FROM ON-SITE WASTEWATER DISPOSAL SYSTEMS

Areal Dilution Model (modified from Brown 1980, CCPEDC 1986)

$$\text{Req'd Ac/Person} = \frac{[Ve\ (Ce-Cq) + Vi\ (Ci)]\ (1-U)}{(Vi + Ve)\ Cq}$$

Where Ve = effluent volume (gal/person/unit time)

Ce = effluent concentration (mg/l)

Cq = target concentration (mg/l)

Vi = volume of dilution water (gal/ac/unit time)

Ci = dilution water concentration (mg/l)

U = uptake by plants (%/100)

The model assumes no dilution by the existing ground water supply, as it is not desirable to depend on this source for pollution mitigation.

This model can be modified to calculate the acceptable load per unit area.

Acceptable Load = L = (Vi + Ve) Cq

If the effluent volume is small relative to the dilution water volume, this becomes

L = (Vi) Cq

Calculations

1. Acceptable N load:

   Vi = 434,500 gal/ac/yr (CCPEDC 1986)

   Cq = 5 mg/l = 4.16 x 10 - 5 lbs/gal (CCPEDC 1986)

   L = (Vi) Cq = 18.1 lbs/ac = 20.4 kg/ha

2. Req'd Area per Person - Annual Interval

   Ve = 24,000 gal/person/yr (Brown 1980)

   Ce = 45 mg/l (NO_3-N) (Brown 1980)

$Cq = 5$ mg/l (NO_3-N) (CCPEDC 1986)

$Ci = 0.67$ mg/l (NO_3-N) (Reckhow et al. 1980)

$U = 0.05$ (Brown 1980)

$$Ac/Person = \frac{[24{,}000\ (45-5) + 435{,}500\ (0.67)]\ (0.95)}{(458{,}500)\ (5)} = 0.52$$

With an advanced treatment disposal system, expect to add a term for removal efficiency to the dilution equation; (1-E).

The highest value for E will be 0.83, representing 83% removal of N by the disposal system.
Req'd ac/person would then drop to (1-E) (0.52), or (0.17) (0.52) =0.09 ac/person.

SAMPLE SURVEY QUESTIONAIRE

BAYSTATE ENVIRONMENTAL CONSULTANTS, INC.

BEC

296 NORTH MAIN STREET • EAST LONGMEADOW, MASSACHUSETTS 01028 • TELEPHONE (413) 525-3822

Dear Watershed Resident:

Baystate Environmental Consultants, Inc. of East Longmeadow, MA was selected by a committee from Eastham to perform a study on Great Pond to determine the causes of perceived water related problems and recommend measures to improve the situation. This study began in May of 1985 and will continue through next May (1986). We recently held a public meeting at the Eastham Town Hall to discuss our findings to date and solicit comments from watershed residents. We are now moving into the next phase of the study with renewed vigor, and hopefully with your support.

As a part of the study we are attempting to assess the needs of residents and their impact on Great Pond. The attached questionaire will greatly aid us in this effort, and we would appreciate your cooperation in filling it out and returning it. [illegible] le time on paperwork [illegible] mation really is [illegible] stionaire to the person who delivered it or directly to BEC, Inc. at the return address by September 15, 1985. All responses will be kept confidential and will become part of a statistical data base for evaluation. Specific information will not be used for or against individual respondents.

The goal of the entire study is to make Great Pond a better facility for you. We can do little without your support and guidance. This questionaire represents an important way in which you can help us to help you. We look forward to hearing from you.

Very truly yours,

BEC, INC.

Ken Wagner

Kenneth J. Wagner, Ph.D.
Principal Biologist

QUESTIONNAIRE FOR WATERSHED RESIDENTS
GREAT POND

Name________________________ Phone____________________

Street Address (Not Mailing)______________________________

Nearest Lake or Waterway__________________________________

1. Number of people in household?

2. Number of months in full time residency?

3. Distance of property from lake?

4. Do you make use of Great Pond?

   At Least Daily? At Least Weekly? Monthly or Less?

5. Preferred activities on Great Pond?

   1.____
   2.____
   3.____

6. Where do you get your drinking water?

7. Where do you get your washing water?

8. Do you have an in-ground waste disposal system? (If not, where are wastes disposed?)

9. If you have a well and/or in-ground waste disposal system:

   a. What kind of disposal system do you have (i.e. cesspool, tank and leachfield, pipe to lake, etc.)?

   b. Approximate age of disposal system?

   c. Distance of disposal system from lake?

   d. What kind of well do you have?

   e. Approximate depth of well?

   f. Distance of well from lake?

g. Distance between well and disposal system?

h. Is well upslope, downslope, or alongside of disposal system?

i. When was well water last tested?

j. When was disposal system last inspected/maintained?

k. Any known problems (quantity or quality) with well or disposal system?

10. Do you use a washing machine on the premises?

11. Do you use a garbage disposal on the premises?

12. What kind of detergent do you use?
    a. For clothes?

    b. For dishes?

13. Do you fertilize your lawn?

14. Do you have any questions or comments? Please feel free to use space on this page or an additional sheet to respond.

DATA FROM OTHER EASTHAM PONDS

Characteristics of Eastham P[illegible] Other Than Great Pond

Pond	Date Sampled	Secchi Disk Transparency (m)	Total Alkalinity (mg/l)	Surface pH (units)	Surface Conductivity (umhos/cm)	Surface Temperature (°C)	Surface Dissolved Oxygen (mg/l)	[illegible]tom [illegible]perature (°C)	Bottom Dissolved Oxygen (mg/l)	NH_3-N (mg/l)	NO_3-N (mg/l)	TKN (mg/l)	Ortho Phosphorus (ug/l)	Total Phosphorus (ug/l)
Bridge	8-28-85	1.1	8.6	7.1	143	26.0	9.8	—	—	0.02	0.02	1.10	10	18
Deborah	8-28-85	1.9	3.8	6.5	113	26.3	8.7	22.9	2.1	0.02	0.02	0.46	10	15
Depot	8-28-85	2.2	1.7	6.3	94	23.0	7.[illegible]	21.9	6.2	0.01	0.02	0.25	10	20
Herring	9-10-85	2.7	19.0	7.5	830	21.2	8.9	20.2	2.6	0.24	0.06	0.76	10	13
Jemima	8-28-85	2.5	1.5	6.7	83	26.2	9.2	—	—	0.01	0.04	0.95	10	30
Long	8-28-85	4.6	3.1	6.5	130	23.5	7.5	[illegible]1.8	3.2	0.02	0.02	0.20	10	15
Minister	9-10-85	2.0	5.0	5.9	200	20.8	7.3	[illegible].7	4.5	0.46	0.01	0.67	10	20
Widow Harding	8-28-85	3.2	2.1	6.5	92	24.9	8.3	[illegible].7	6.4	0.01	0.04	0.58	10	15

Pond	Date Sampled	Fecal Coliform (#/100ml)	Fecal Streptococcus (#/100ml)	[illegible]	% Cover by Macrophytes Surface	% Cover by Macrophytes Bottom	Macrophyte Species Seen (in order of abundance)
Bridge	8-28-85	1	1		< 5	< 5	Peripheral Dv, Hv
Deborah	8-28-85	0	2	2.[illegible]	40	40	Ut, Bs, Nu, My, No, Mg, Dv, T
Depot	8-28-85	71	57	2.2	5	10	Hv, No, My, Mg
Herring	9-10-85	0	8	10	< 5	< 5	None Seen
Jemima	8-28-85	21	196	9	10	15	My, No, Nu
Long	8-28-85	6	5	10	10	25	Nf, Ut, Ld, Mg, Pc, S
Minister	9-10-85	0	23	7	10	20	Ut, No, Cd, Dv, Pc
Widow Harding	8-28-85	0	17	3.2	10	50	Ut, No, Ld, El, Cd, Nu, Hv

Key For Macrophyte Species

Bs = Brasenia schreberi
Cd = Ceratophyllum demersum
Dv = Decodon verticillatus
El = Eleocharis sp.
Hv = Hydrocotyle verticillata
Ld = Lobelia dortmanna
Mg = Myrica gale
My = Myriophyllum sp.
Nf = Najas flexilis
No = Nymphaea odorata
Nu = Nuphar sp.
Pc = Pontderia cordata
S = Scirpus sp.
T = Typha sp.
Ut = Utricularia sp.

PHYTOPLANKTON DENSITIES IN EASTHAM PONDS

	BRIDGE 82785 CELLS/ML
BACILLARIOPHYTA	
CHLOROPHYTA	
Pediastrum	13
Scenedesmus	39
Staurastrum	1
CHRYSOPHYTA	
CRYPTOPHYTA	
Cryptomonas	75
CYANOPHYTA	
Aphanizomenon	16335
Chroococcus	6
EUGLENOPHYTA	
Euglena	3
Trachelomonas	14
PYRRHOPHYTA	
Ceratium	1
Peridinium	21
TOTAL	16513
CHLOROPHYTA	54
CRYPTOPHYTA	75
CYANOPHYTA	16341
EUGLENOPHYTA	18
PYRRHOPHYTA	23

	UG/L
BACILLARIOPHYTA	
CHLOROPHYTA	
Pediastrum	2
Scenedesmus	3
Staurastrum	1
CHRYSOPHYTA	
CRYPTOPHYTA	
Cryptomonas	15
CYANOPHYTA	
Aphanizomenon	163
EUGLENOPHYTA	
Euglena	1
Trachelomonas	14
PYRRHOPHYTA	
Ceratium	44
Peridinium	618
TOTAL	887
CHLOROPHYTA	7
CRYPTOPHYTA	15
CYANOPHYTA	163
EUGLENOPHYTA	16
PYRRHOPHYTA	684

	DEBORAH 082785 CELLS/ML
BACILLARIOPHYTA	
CHLOROPHYTA	
Closterium	1
Eudorina	10
Spirogyra	1
Staurastrum	1
CHRYSOPHYTA	
CRYPTOPHYTA	
Cryptomonas	80
CYANOPHYTA	
EUGLENOPHYTA	
Euglena	3
Trachelomonas	10
PYRRHOPHYTA	
Peridinium	72
TOTAL	179
CHLOROPHYTA	12
CRYPTOPHYTA	80
EUGLENOPHYTA	14
PYRRHOPHYTA	72

	UG/L
BACILLARIOPHYTA	
CHLOROPHYTA	
Closterium	[illegible]
Eudorina	32
Spirogyra	17
Staurastrum	5
CHRYSOPHYTA	
CRYPTOPHYTA	
Cryptomonas	16
CYANOPHYTA	
EUGLENOPHYTA	
Euglena	1
Trachelomonas	10
PYRRHOPHYTA	
Peridinium	216
TOTAL	344
BACILLARIOPHYTA	5
CHLOROPHYTA	99
CRYPTOPHYTA	16
EUGLENOPHYTA	12
PYRRHOPHYTA	216

	DEPOT 082785 CELLS/ML
BACILLARIOPHYTA	
Asterionella	7
Melosira	7
Synedra	1
CHLOROPHYTA	
Kirchneriella	614
CHRYSOPHYTA	
CRYPTOPHYTA	
Cryptomonas	10
CYANOPHYTA	
Anabaena	10
Chroococcus	7
Microcystis	7
EUGLENOPHYTA	
Euglena	2
Trachelomonas	3
PYRRHOPHYTA	
Peridinium	4
TOTAL	667
BACILLARIOPHYTA	1
CHLOROPHYTA	619
CRYPTOPHYTA	10
CYANOPHYTA	18
EUGLENOPHYTA	5
PYRRHOPHYTA	4

	UG/L
BACILLARIOPHYTA	
CHLOROPHYTA	
Actinastrum	1
Botryococcus	1
Kirchneriella	308
Staurastrum	10
CHRYSOPHYTA	
CRYPTOPHYTA	
Cryptomonas	3
CYANOPHYTA	
Anabaena	7
EUGLENOPHYTA	
Euglena	1
Trachelomonas	3
PYRRHOPHYTA	
Peridinium	78
TOTAL	412
BACILLARIOPHYTA	1
CHLOROPHYTA	318
CRYPTOPHYTA	3
CYANOPHYTA	7
EUGLENOPHYTA	4
PYRRHOPHYTA	78

BACILLARIOPHYTA	HERRING 091085 CELLS/ML
Asterionella	7
Fragilaria	28
CHLOROPHYTA	
Chlamydomonas	2340
Staurastrum	1
CHRYSOPHYTA	
CRYPTOPHYTA	
Cryptomonas	10
CYANOPHYTA	
Anabaena	558
Chroococcus	21
Microcystis	54
EUGLENOPHYTA	
Trachelomonas	3
PYRRHOPHYTA	
Peridinium	3
TOTAL	3029
BACILLARIOPHYTA	36
CHLOROPHYTA	2341
CRYPTOPHYTA	10
CYANOPHYTA	633
[illegible]	[illegible]

BACILLARIOPHYTA	JEMTHA 082885 CELLS/ML
CHLOROPHYTA	
Chlamydomonas	7
Eudorina	21
CHRYSOPHYTA	
Dinobryon	10
CRYPTOPHYTA	
Cryptomonas	33
CYANOPHYTA	
Chroococcus	7
EUGLENOPHYTA	
Trachelomonas	11
PYRRHOPHYTA	
Peridinium	198
TOTAL	311
BACILLARIOPHYTA	21
CHLOROPHYTA	28
CHRYSOPHYTA	10
CRYPTOPHYTA	33
CYANOPHYTA	7
[illegible]	

BACILLARIOPHYTA	LONG 082785 CELLS/ML
Synedra	1
CHLOROPHYTA	
Closterium	1
Cosmarium	1
Staurastrum	1
CHRYSOPHYTA	
CRYPTOPHYTA	
Cryptomonas	12
CYANOPHYTA	
EUGLENOPHYTA	
Trachelomonas	4
PYRRHOPHYTA	
Peridinium	6
TOTAL	25
BACILLARIOPHYTA	1
CHLOROPHYTA	1
CRYPTOPHYTA	12
EUGLENOPHYTA	4
...NOPHYTA	6

BACILLARIOPHYTA	UG/L
Asterionella	1
Fragilaria	57
CHLOROPHYTA	
Chlamydomonas	234
Staurastrum	1
CHRYSOPHYTA	
CRYPTOPHYTA	
Cryptomonas	2
CYANOPHYTA	
Anabaena	1729
Chroococcus	8
Microcystis	1
EUGLENOPHYTA	
Trachelomonas	3
PYRRHOPHYTA	
Peridinium	10
TOTAL	2051
BACILLARIOPHYTA	59
CHLOROPHYTA	235
CRYPTOPHYTA	2
CYANOPHYTA	1740
EUGLENOPHYTA	3
PYRRHOPHYTA	10

BACILLARIOPHYTA	UG/L
Melosira	4
CHLOROPHYTA	
Chlamydomonas	2
Eudorina	28
CHRYSOPHYTA	
Dinobryon	32
CRYPTOPHYTA	
Cryptomonas	6
CYANOPHYTA	
Chroococcus	2
EUGLENOPHYTA	
Trachelomonas	11
PYRRHOPHYTA	
Peridinium	8910
TOTAL	9001
BACILLARIOPHYTA	4
CHLOROPHYTA	31
CHRYSOPHYTA	32
CRYPTOPHYTA	7
CYANOPHYTA	3
EUGLENOPHYTA	12
PYRRHOPHYTA	8910

BACILLARIOPHYTA	UG/L
Synedra	1
CHLOROPHYTA	
Closterium	1
Cosmarium	3
Staurastrum	11
CHRYSOPHYTA	
CRYPTOPHYTA	
Cryptomonas	2
CYANOPHYTA	
EUGLENOPHYTA	
Trachelomonas	4
PYRRHOPHYTA	
Peridinium	39
TOTAL	60
BACILLARIOPHYTA	1
CHLOROPHYTA	14
CRYPTOPHYTA	2
EUGLENOPHYTA	4
PYRRHOPHYTA	39

BACILLARIOPHYTA	MINISTER 091085 CELLS/ML
Asterionella	35
Melosira	1188
Synedra	2
CHLOROPHYTA	
Ankistrodesmus	4
Botryococcus	26
CHRYSOPHYTA	
CRYPTOPHYTA	
Cryptomonas	48
CYANOPHYTA	
Chroococcus	52
EUGLENOPHYTA	
Euglena	13
Trachelomonas	11
PYRRHOPHYTA	
Peridinium	4
TOTAL	3029
BACILLARIOPHYTA	26
CHLOROPHYTA	2341
CRYPTOPHYTA	10
CYANOPHYTA	633
EUGLENOPHYTA	3
PYRRHOPHYTA	3

	MIDOW HARDING 082085 CELLS/ML
BACILLARIOPHYTA	
CHLOROPHYTA	
Botryococcus	22
Spirogyra	2
CHRYSOPHYTA	
Dinobryon	79
CRYPTOPHYTA	
Cryptomonas	5
CYANOPHYTA	
Anabaena	52
EUGLENOPHYTA	
Euglena	1
Trachelomonas	5
PYRRHOPHYTA	
Peridinium	6
TOTAL	174
CHLOROPHYTA	25
CHRYSOPHYTA	79
CRYPTOPHYTA	5
CYANOPHYTA	52
EUGLENOPHYTA	5
PYRRHOPHYTA	[illegible]

BACILLARIOPHYTA	UG/L
Asterionella	7
Melosira	356
Synedra	1
CHLOROPHYTA	
Ankistrodesmus	2
Botryococcus	5
CHRYSOPHYTA	
CRYPTOPHYTA	
Cryptomonas	48
CYANOPHYTA	
Chroococcus	21
EUGLENOPHYTA	
Euglena	330
Trachelomonas	11
PYRRHOPHYTA	
Peridinium	13
TOTAL	794
BACILLARIOPHYTA	365
CHLOROPHYTA	7
CRYPTOPHYTA	48
CYANOPHYTA	21
EUGLENOPHYTA	341
PYRRHOPHYTA	13

BACILLARIOPHYTA	UG/L
CHLOROPHYTA	
Botryococcus	15
Spirogyra	52
Staurastrum	5
CHRYSOPHYTA	
Dinobryon	237
CRYPTOPHYTA	
Cryptomonas	1
CYANOPHYTA	
Anabaena	21
EUGLENOPHYTA	
Euglena	1
Trachelomonas	5
PYRRHOPHYTA	
Peridinium	16
TOTAL	357
CHLOROPHYTA	73
CHRYSOPHYTA	237
CRYPTOPHYTA	1
CYANOPHYTA	21
EUGLENOPHYTA	5
PYRRHOPHYTA	18

EASTHAM PONDS ZOOPLANKTON

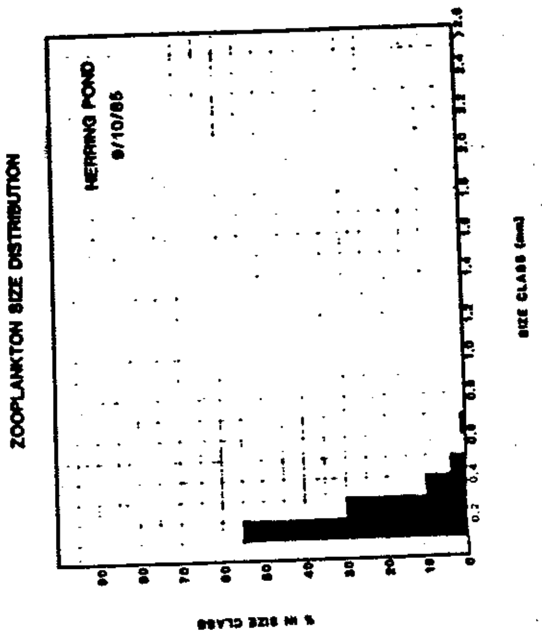
Pond (Date)

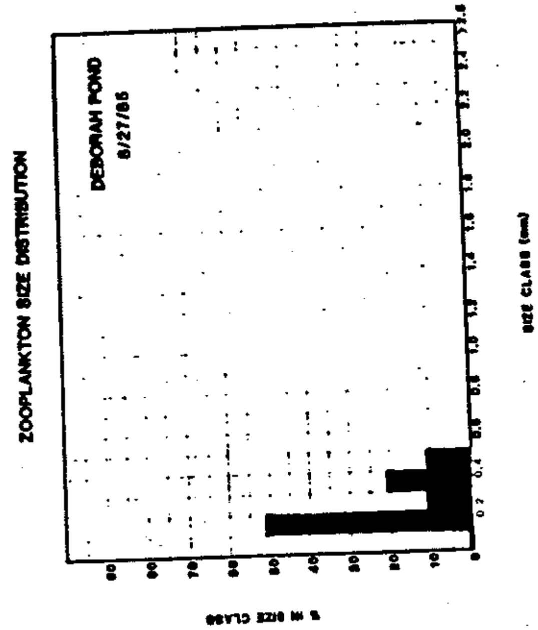
Taxon	Depot (8/27/85)		Long (8/27/85)		Deborah (8/27/85)		Bridge (8/27/85)	
	#/l	ug/l	#/l	ug/l	#/l	ug/l	#/l	ug/l
Rotifera								
Asplanchna	0.4	0.8	4.8	9.6			0.1	0.2
Kellicottia	1.6	0.06						
Keratella	0.3	0.03					0.4	0.03
Polyarthra								
Cyclops	[illegible]	[illegible]	[illegible]	[illegible]	0.2	0.4	0.05	0.1
Diaptomus	4.8	17.8	0.5	1.9	0.03	0.01	0.05	0.02
Nauplii	0.6	1.6			0.06	0.2	0.05	0.1
Cladocera								
Alona							0.02	0.07
Bosmina	0.5	0.5	3.4	3.3	0.03	0.03	0.05	0.05
Ceriodaphnia	0.2	0.5						
Chydorus	0.4	0.4						
Eurycercus	0.2	2.7						
Holopedium								
Sida								
Rotifera	2.3	0.9	4.8	9.6	0.0	0.0	0.5	0.5
Copepoda	6.2	21.3	1.0	3.1	1.1	0.7	0.2	0.2
Cladocera	1.3	4.1	3.4	3.3	0.03	0.03	0.1	0.1
TOTAL	9.8	26.3	9.2	16.0	1.1	0.7	0.8	0.8

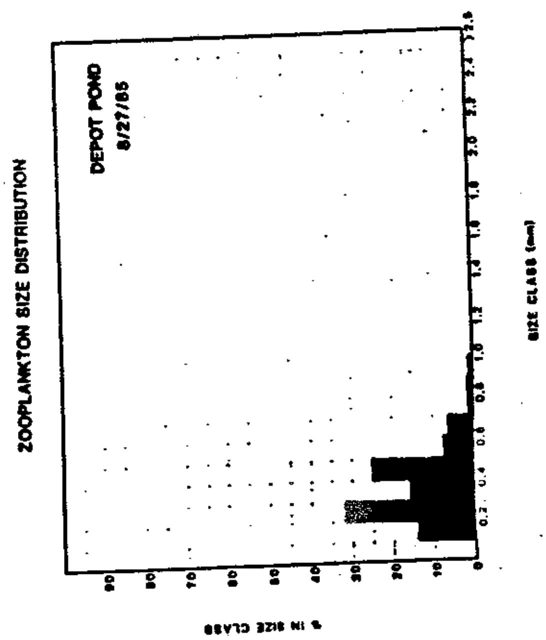
EASTHAM PONDS ZOOPLANKTON

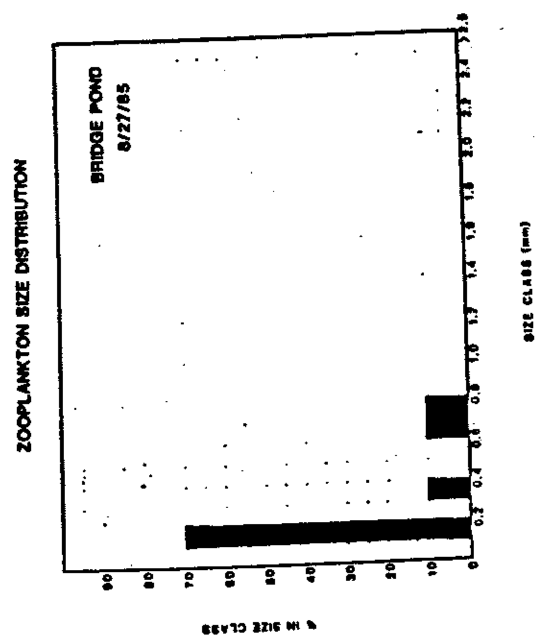
Pond (Date)

Taxon	Jemima (8/28/85)		Widow Harding (8/28/85)		Minister (9/10/85)		Herring (9/10/85)	
	#/l	ug/l	#/l	ug/l	#/l	ug/l	#/l	ug/l
Rotifera								
Asplanchna								
Kellicottia			0.4	0.01	2.1	0.1		
Keratella			0.5	0.04	0.5	0.04		
Polyarthra					0.3	0.03		
Copepoda								
Cyclops	0.2	0.4			2.6	6.2	0.6	1.6
Diaptomus	0.6	0.8	2.8	15.9	3.6	13.3	0.3	1.0
Nauplii	0.2	0.4	4.2	11.1	2.9	7.6	1.0	2.8
Cladocera								
Alona								
Bosmina	0.1	0.1	0.2	0.2	3.9	3.8	0.9	0.9
Ceriodaphnia					0.6	1.6	0.3	0.7
Chydorus								
Eurycercus								
Holopedium					0.9	7.5		
Sida					1.4	19.8	0.04	0.2
Rotifera	0.0	0.0	0.9	0.05	2.9	0.2	0.0	0.0
Copepoda	1.0	1.6	7.0	27.0	9.1	27.1	1.9	5.4
Cladocera	0.1	0.1	0.2	0.2	6.8	32.7	1.2	1.8
TOTAL	1.1	1.7	8.1	27.3	18.8	60.0	3.1	7.2


ZOOPLANKTON SIZE DISTRIBUTION
HERRING POND
9/10/85
SIZE CLASS (mm)
% IN SIZE CLASS


ZOOPLANKTON SIZE DISTRIBUTION
DEBORAH POND
8/27/85
SIZE CLASS (mm)
% IN SIZE CLASS


ZOOPLANKTON SIZE DISTRIBUTION
DEPOT POND
8/27/85
SIZE CLASS (mm)
% IN SIZE CLASS


ZOOPLANKTON SIZE DISTRIBUTION
BRIDGE POND
8/27/85
SIZE CLASS (mm)
% IN SIZE CLASS