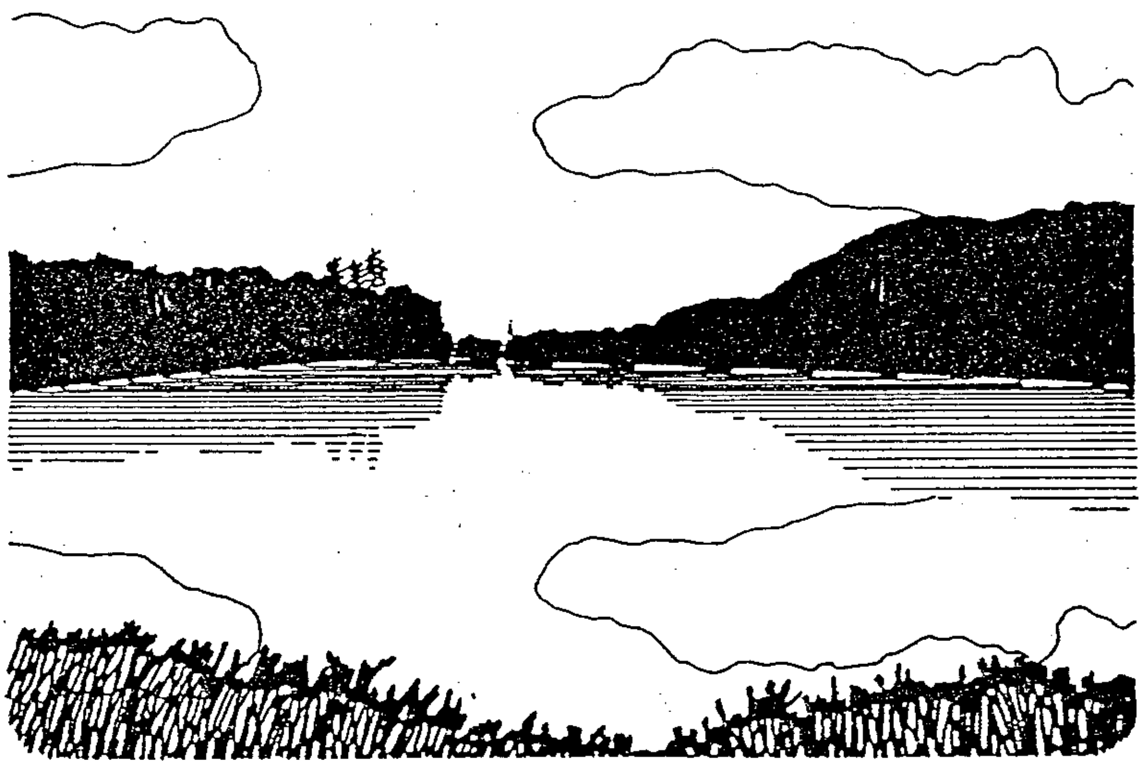
A DIAGNOSTIC/FEASIBILITY STUDY FOR THE MANAGEMENT OF HERRING POND EASTHAM, MASSACHUSETTS



BAYSTATE ENVIRONMENTAL CONSULTANTS INC.

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

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

UNDER
MGL CHAP. 628
MASSACHUSETTS CLEAN LAKES PROGRAM

BY
BAYSTATE ENVIRONMENTAL CONSULTANTS, INC.
296 NORTH MAIN STREET
EAST LONGMEADOW, MASSACHUSETTS

DECEMBER, 1991

DISCLAIMER

This report was funded under a cost sharing Substate Agreement between the Commonwealth of Massachusetts through its Division of Water Pollution Control (Division), Clean Lakes Program (Chapter 628, Acts of 1981), and the Town of Eastham. As stated in the Substate Agreement (Paragraph A.3.4), the Town is required to submit a draft Final Report for the Division's review and comment. Subsequently, the Town must submit a Final Report that incorporates the Division's comments and corrections. Final payment of a 10% retainage would be released upon acceptance of the Final Report by the Division (Paragraph 1.7 of the Substate Agreement).

Prior to the completion of this Phase I project, most of the resources and staff of the Clean Lakes Program were reallocated by the Department of Environmental Protection. As one consequence of these actions, a thorough and timely review of this report was not feasible. Since the Town and its subcontractor, Baystate Environmental Consultants, Inc., should not be burdened unduly, the Division adopted an interim procedure of checking draft final reports solely to determine whether the scope of work (Appendix A of the Substate Agreement) had been met. This Draft Final Report has been checked by the Division, any discrepancies have been rectified by Baystate Environmental Consultants, Inc. and, at a minimum, it does fulfill all requirements specified in the scope of work. The Division has, therefore, accepted this report in accordance with Paragraphs 1.7 and A.3.4 of the Town for subsequent reimbursement to Baystate Environmental Consultants, Inc.

It should be emphasized, however, that this report has <u>not</u> been subjected to a full and thorough review by the Division as in the past, and therefore, the quality and completeness of this report, and the assessments and recommendations contained therein, represent primarily the work and judgements of Baystate Environmental Consultants, Inc.

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PROJECT SUMMARY

Herring Pond and its watershed were the subjects of a Phase I Diagnostic/Feasibility Study, conducted under the M.G.L. Chapter 628 Clean Lakes Program. This study was performed by the firm of Baystate Environmental Consultants, Inc. for the Town of Eastham. The Diagnostic/Feasibility study's primary goals were to investigate water quality in the pond, identify major sources of nutrient loadings in the watershed, and provide appropriate recommendations for improvement and protection of the water resource. The major concerns expressed by the Town were increases in aquatic macrophytes in the pond, their impact on the recreational utility and visual aesthetics of the pond, and the future protection of the pond as a desirable resource.

The results of the Diagnostic portion of the study indicate that Herring Pond is a mesotrophic pond, moderately impacted by its residential setting, but suitable for a wide variety of uses. Phosphorus was the most critical limiting nutrient for primary production in Herring Pond. The most important sources of phosphorus to Herring Pond are groundwater (46%) and internal loading, or recycling within the pond (38%). The biological community which exists under these conditions includes a modest, but increasing macrophyte community, and a flourishing panfish community. The major recreational problem with the rooted aquatic plants is their peripheral distribution, not their overall density.

The Feasibility portion of the study considered available management options and recommended lake management techniques most appropriate for Herring Pond. The recommended options were environmental education of watershed residents, particularly with reference to groundwater protection, and selected macrophyte removal/control. Implementation of all management options would reduce the phosphorus budget by 5 to 22%. This is not a large decrease in phosphorus content, but the real value of the management program lies in its protection of the water resource and potential improvement of recreational utility. A detailed description and cost estimate for each recommended option is provided. Costs of the recommended management options and a corresponding monitoring program total to $45,562, with minimum required local support (Eastham's portion) of $18,141 under the Massachusetts Clean Lakes Program. Presently, however, the MA Clean Lakes Program has no funds allocated to new projects, making it a very unlikely source of financial support in the near future. While Herring Pond is in a condition acceptable for all current uses, the Town of Eastham should consider improvement and protection actions in the near future, as the cost of restoration is likely to be far greater than the cost of prevention.

PART 1

DIAGNOSTIC EVALUATION

INTRODUCTION

The establishment of the Massachusetts Clean Lakes Program under Chapter 628 of the Acts of 1981 enabled many municipalities 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 Herring Pond. After being awarded the grant, the Town contracted Baystate Environmental Consultants, Inc. to conduct the study.

Concern over the present and future status of Herring Pond has prompted the request for a study. The water quality impacts of domestic activities in the Herring Pond watershed were largely unknown, and the aesthetic value and recreational status of Herring Pond was perceived to be gradually deteriorating, although it remains a popular recreational facility. Maintenance of the pond through mitigation of present negative influences and the prevention of major degradation of this water resource in the future are desired.

DATA COLLECTION METHODS

Previous studies of Herring Pond were reviewed, and historic conditions were discussed with local residents and other parties concerned with the pond. 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), the Barnstable County soil survey information provided by SCS (unpublished), and aerial infrared photographs obtained from the National Cartographic Information Center (1985). 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.

Historical lake and land use were investigated through conversations with watershed residents, previous reports and maps, state agency correspondence, and field inspection. There is relatively little documentation of historic events at Herring Pond. The aid of Mrs. Crosby of Crosby Village Road is acknowledged in accessing historic information.

A bathymetric map was generated along cross-lake transects with the aid of an electronic depth finder. Soft sediment depth was assessed by driving a probe to first refusal; these measurements were performed by divers.

A comprehensive monitoring and investigative research program was implemented to assess the physical, chemical, and biological characteristics of Herring Pond. Sampling stations were selected from topographic maps and field inspection. These stations are described in Table 1 and shown in Figure 1. The in-lake station was sampled with a Scott bottle at the surface and bottom. Samples were collected approximately monthly between April 1988 and March 1989.

Sixteen parameters were routinely assessed at regular sampling locations (non-storm stations) (Table 1). Temperature and dissolved oxygen levels were measured with a YS1 model 57 meter, with vertical profiles obtained at the in-lake stations (1.0 m intervals). The pH was measured with an Orion model SA 250 pH meter. Conductivity was assessed with a YSI model 33 S-C-T meter. Turbidity was measured with a Hach model 1860 turbidimeter. A one gallon water sample was taken at each sampling location and transported to Arnold Greene Testing Laboratories in Natick, MA for analysis of suspended solids, total alkalinity, iron, chlorides, total Kjeldahl nitrogen, nitrate nitrogen, ammonia nitrogen, total phosphorus, and orthophosphorus by accepted standard methods (e.g., Kopp and

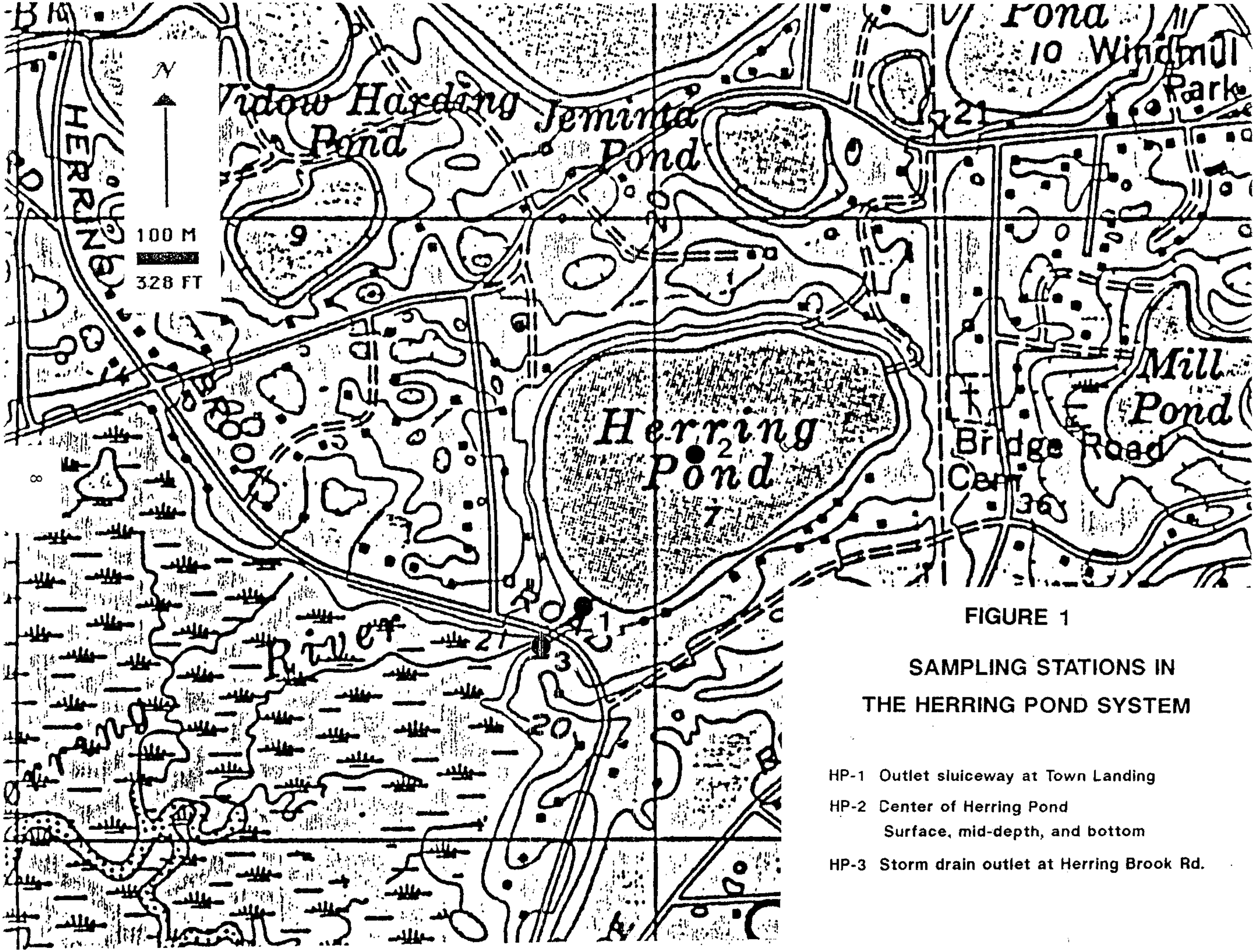


FIGURE 1

SAMPLING STATIONS IN THE HERRING POND SYSTEM

HP-1 Outlet sluiceway at Town Landing

HP-2 Center of Herring Pond
Surface, mid-depth, and bottom

HP-3 Storm drain outlet at Herring Brook Rd.

TABLE 1

HERRING POND DIAGNOSTIC/FEASIBILITY STUDY
EASTHAM

Station No.	Location	Sample Description
HP-1	Outlet/occasional inlet at boat launch off Herring Road.	
HP-2s	In-lake station, central area, surface.	
HP-2m	In-lake station, central area, mid-depth.	
HP-2b	In-lake station, central area, near bottom.	

Parameters to be assessed by lab:

In-lake/outlet:

Total phosphorus	Alkalinity	Fecal coliform
Orthophosphorus	Total suspended solids	Fecal streptococci
Ammonia nitrogen	Chlorides	
Nitrate nitrogen	Total iron	
Total Kjeldahl nitrogen		

Storm drains:

All of the above, plus

Cadmium	Iron	Zinc
Chromium	Lead	Oil and grease
Copper	Manganese	

BEC to do:

Temperature	Conductivity	Secchi disk transparency
Dissolved oxygen	Turbidity	Chlorophyll
pH	Flow	Phytoplankton
	Rainfall	Zooplankton (seasonal)

Date Sampled ____________ by ______________________________

Transferred to ______________________________ on ____________

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).

A 20 cm Secchi disk was lowered on the shaded side of the boat to evaluate water transparency at the in-lake station. Analyses of chlorophyll concentration and features of the phytoplankton and zooplankton communities were conducted for that location as well. Phytoplankton samples were obtained from a depth integrated 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.

Groundwater interaction with Herring Pond was assessed through direct measurement of seepage into and out of the pond, and sampling of porewater near its point of entry or exit from the pond (Mitchell et al. 1988). Seasonal influences were investigated by conducting groundwater seepage surveys in late spring and late summer of the study year.

Seepage measurements were accomplished with meters constructed from 208 liter barrels cut in half and modified to accept a fitting to which a bag with a predetermined volume of water is attached. The meter is set into the sediment, open end down. After several hours in situ, the bag will have accumulated detectable additional water if there is seepage into the open end of the barrel, and the bag loses water if there is seepage into the groundwater from the pond.

Porewater samples were collected with a littoral interstitial porewater (LIP) sampler (Mitchell et al. 1989), which functions as a miniature well when inserted into the groundwater near the shoreline. A hand pump draws water into an intermediate glass trap, yielding a sample of groundwater near the pond. LIP samples are processed at the laboratory in the same manner as other water quality samples, but for a reduced set of parameters.

Additional groundwater investigations were conducted by installing five permanent monitoring wells in various locations around the pond. These wells allow for the determination of local groundwater elevation as well as water quality. Knowledge of groundwater elevations is useful in determining the horizontal direction of groundwater flow. Domestic wells from residences around the pond were also sampled during the study. Although domestic wells do not provide information regarding groundwater elevation, they do provide for water quality analysis. All well samples were analyzed for ammonia nitrogen, nitrate nitrogen, total filterable phosphorus, orthophosphorus, pH, specific conductance, chloride, iron, and fecal coliform.

Sediment samples were obtained from the in-lake station (Figure 1) with an Ekman dredge. The sample was 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), and oil and grease.

Macrophyte species composition and areal extent of cover were assessed by visual inspection by divers. The distribution of summer bottom cover was mapped, noting dominant species in each area. Observations were made of the subsurface density, composition, and distribution of macrophyte stands.

Benthic macroinvertebrate composition was examined several times during this study, most carefully in association with the macrophyte survey. Samples collected with a D-net and an Ekman dredge were analyzed in the field to the level of family, and a semi-quantitative assessment of abundance was made.

A fishery survey of Herring Pond was performed by BEC personnel in August, 1988. This survey included an evening seining operation at the public beach. A fishery survey was also conducted by the Massachusetts Division of Fisheries and Wildlife (MDFW). Sampling methods of this survey included day and night electroshocking and setting of three gill nets set overnight. Captured fish were placed in holding tanks until they could be measured and scale-sampled, after which they were returned to the pond. Collected scales were assessed in the laboratory to facilitate age and growth determinations. Additionally, herring collected from the pond outlet during herring runs were provided by Mr. Henry Lind, Natural Resource Officer for the Town of Eastham. These fish were analyzed for egg content.

A detailed listing of all field and laboratory methods is included in Appendix A. Equipment, instrumentation, techniques, and any specific handling requirements are listed.

LAKE AND WATERSHED DESCRIPTION AND HISTORY

Lake Description

Herring Pond is located in the Town of Eastham, Barnstable County, Massachusetts. It lies at latitude 47°49'30" and longitude 69°59'00", encompassing an open water area of 17.7 ha (43.7 ac) (Table 2). Herring Pond has a pear shape (Figure 1), with a ratio of the shoreline length to the circumference of a circle having the same area as the pond (known as the shoreline development factor) of 1.06.

Depth contours in Herring Pond reveal a deep central depression (Figure 2). The mean depth is 6.2 m (20.2 ft) and the maximum depth is 10.9 m (36 ft), with the deepest point in the center of the pond. The hypsograph for Herring Pond (Figure 3), suggests a rather gradual deepening from the shoreline to maximum depth.

Herring Pond contains a total volume of approximately 1,085,200 cu.m of water. Based on study year data, the long-term detention time for water in Herring Pond is estimated at 2.81 years (1,024 days). The variability of the detention time is largely a function of weather pattern. Assuming that detention in Herring Pond is a function of annual precipitation, long-term detention time ranges from 1.6 to 4.2 years (584 to 1,533 days). Precipitation during the study year (96.4 cm) was well below the long-term mean value (114.3 cm). Consequently, the detention time observed during the study year falls in the upper portion of the range of detention times based on long-term precipitation values. Flushing rate is simply the inverse of detention time; for Herring Pond, a flushing rate of 0.36 times per year is calculated from observed data, while a range of 0.24 to 0.63 times per year could be expected. The quality of water in Herring Pond is therefore likely to be a function of both input quality and natural processes within the pond.

Direct precipitation, direct runoff, groundwater seepage, and rare inflow due to storm tides are the only sources of water for Herring Pond. The pond lies in a natural depression shaped largely by glacial action. The pond has a single inlet/outlet channel, but inflow is quite rare. During the BEC study, only 10 minutes of inflow from a very high storm tide was recorded by Town officials. During dry periods of the year (i.e., summer), the pond level drops, rendering the outlet inactive.

The shoreline of Herring Pond is primarily of sandy nature and in most areas slopes steeply. Much of the land area along the shoreline is developed, but vegetation is maintained, thereby reducing serious erosion damage commonly associated with steeply sloping shorelines. Herring Pond is an aesthetically important feature of the environment to the residents of the Herring Pond

TABLE 2

CHARACTERISTICS OF HERRING POND AND ITS WATERSHED

Lake Parameters

Location: Barnstable County, Town of Eastham,	47°49'30" lat. 69°59'00" long.	
Area:	17.7 ha	(43.7 acres)
Depth: Mean	6.2 m	(20.2 ft.)
Maximum	10.9 m	(35.8 ft)
Volume:	1,085,158 cu.m	(879 acre-ft.)
Detention Time: Mean	2.81 yr	(1,026 days)
Range	1.6-4.2 yr	(584-1,533 days)
Maximum Length	0.55 km	(1,820 ft)
Maximum Width	0.40 km	(1,300 ft)
Shoreline Length	1.58 km	(5,200 ft)
Shoreline Development	1.06	

Watershed Parameters

Area (Excluding Herring Pond):	35.3 ha	(87.2 acres)
Watershed Area/Lake Area	2.0	
Land Use: % Residential (Low Density)	66.6	
% Recreation	1.8	
% Forest	22.1	
% Cemetery	1.8	
% Open	7.7	

FIGURE 2
HERRING POND
BATHYMETRIC MAP
(All contours given in meters)

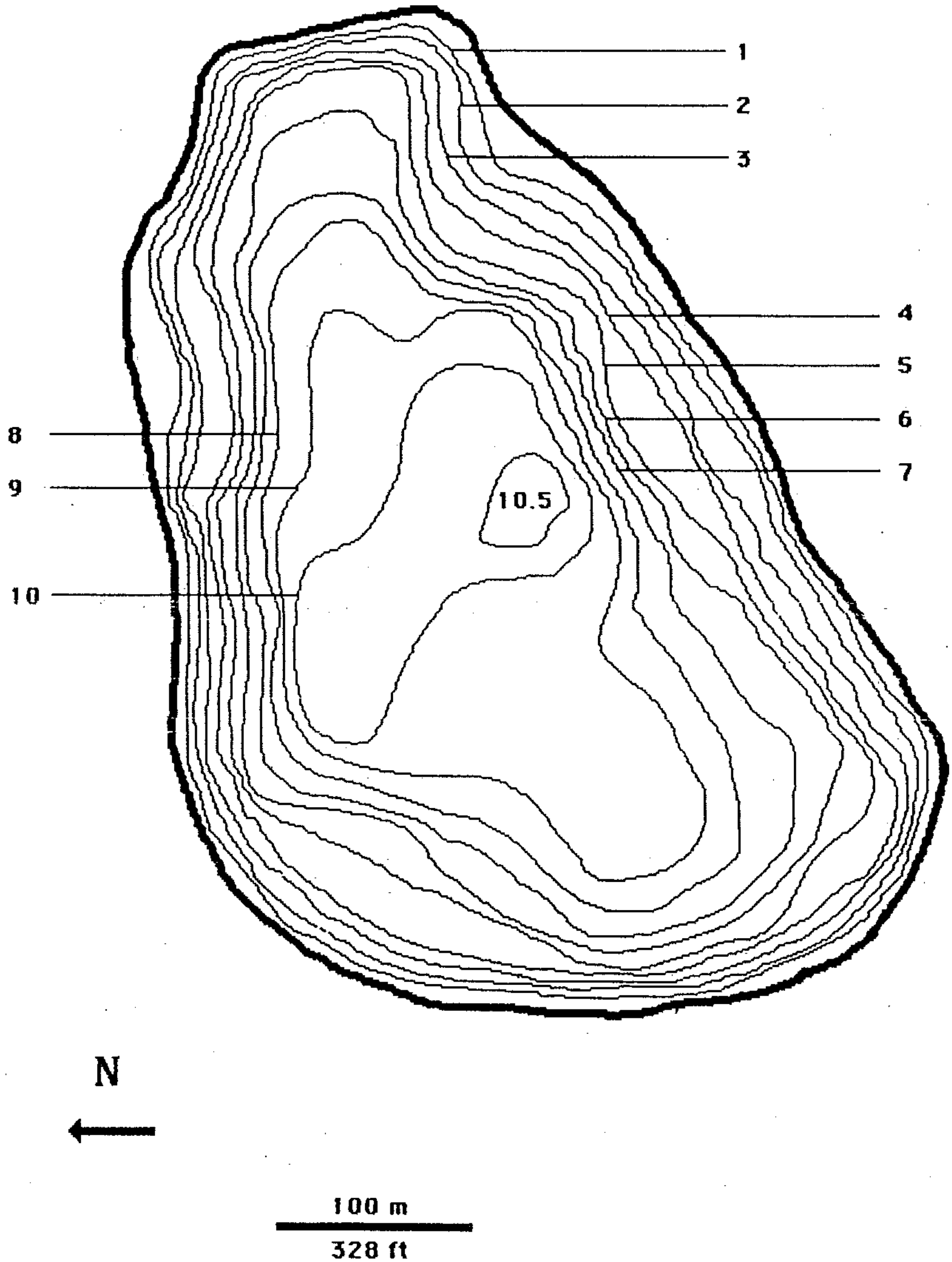
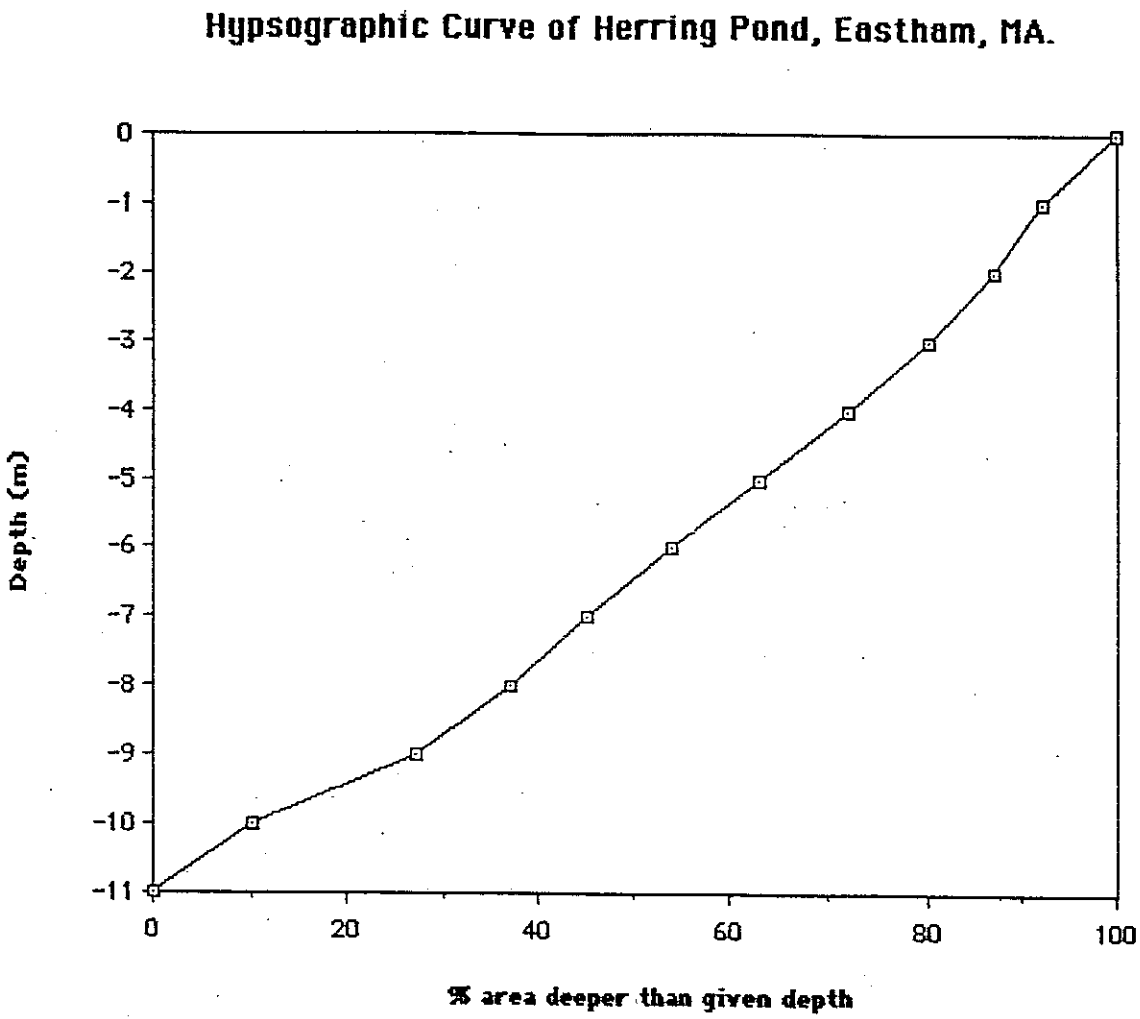


FIGURE 3


Hypsographic Curve of Herring Pond, Eastham, MA.
Depth (m)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
% area deeper than given depth

watershed and the Town of Eastham. Popular activities associated with the pond include swimming, fishing, and boating (primarily non-motorized).

There is currently only one developed beach on Herring Pond, with some public parking available for beach-goers. The bathing area itself is limited and is characterized by sandy hydrosoils. Boating on Herring Pond is limited to motorized craft of less than 10 h.p., and public access is possible from the beach area itself. This beach is under ownership and management of the Town of Eastham.

Watershed Description

The watershed of Herring Pond covers 53.0 hectares (130.9 ac), including the open water area of the pond itself (Figure 4), and is located in a primarily residential setting (Figure 5). This is not large in an absolute or relative sense; the resultant watershed to pond area ratio is a low 2 to 1. In our aquatic survey work throughout Massachusetts and the Northeast U.S. in general, BEC, Inc. has found that ratios of around 10:1 or less indicate great potential for successful watershed management and desirable pond condition. Given the residential nature of the Herring Pond watershed, the potential for water quality degradation exists, however. There are no point sources of pollution (registered discharges) in the watershed of Herring Pond, but non-point sources do exist.

Low density residential areas (e.g., 1.0 ac lots) account for almost 67% of the watershed area, exclusive of the pond, with forested land comprising another 22.1% (Table 2, Figure 5). Open area constitutes 7.7% of the watershed, and recreation areas and cemetery accounting for the remaining 3.6%. Stormwater inputs to Herring Pond are minimized due to the minute amount of impervious surface more typically associated with more urban watersheds. Sources of surface water inputs to Herring Pond are restricted primarily to overland drainage and the rare reversal of flow through the outlet structure during storm tides.

The estimated groundwater drainage basin of Herring Pond is presented in Figure 4. The drainage basin was determined through interpretation of a groundwater elevation map prepared by the Cape Cod Planning and Economic Developement Commission (CCPEDC). BEC used this same source in estimating the groundwater drainage basin of neighboring Great Pond in Eastham during the Diagnostic/Feasibility Study of Great Pond.

Groundwater in the northern portion of the groundwater drainage to some extent resides in Jemima Pond allowing purification. Freshwater groundwater appears to flow in a northeast to southwest direction. There is an apparent interaction with

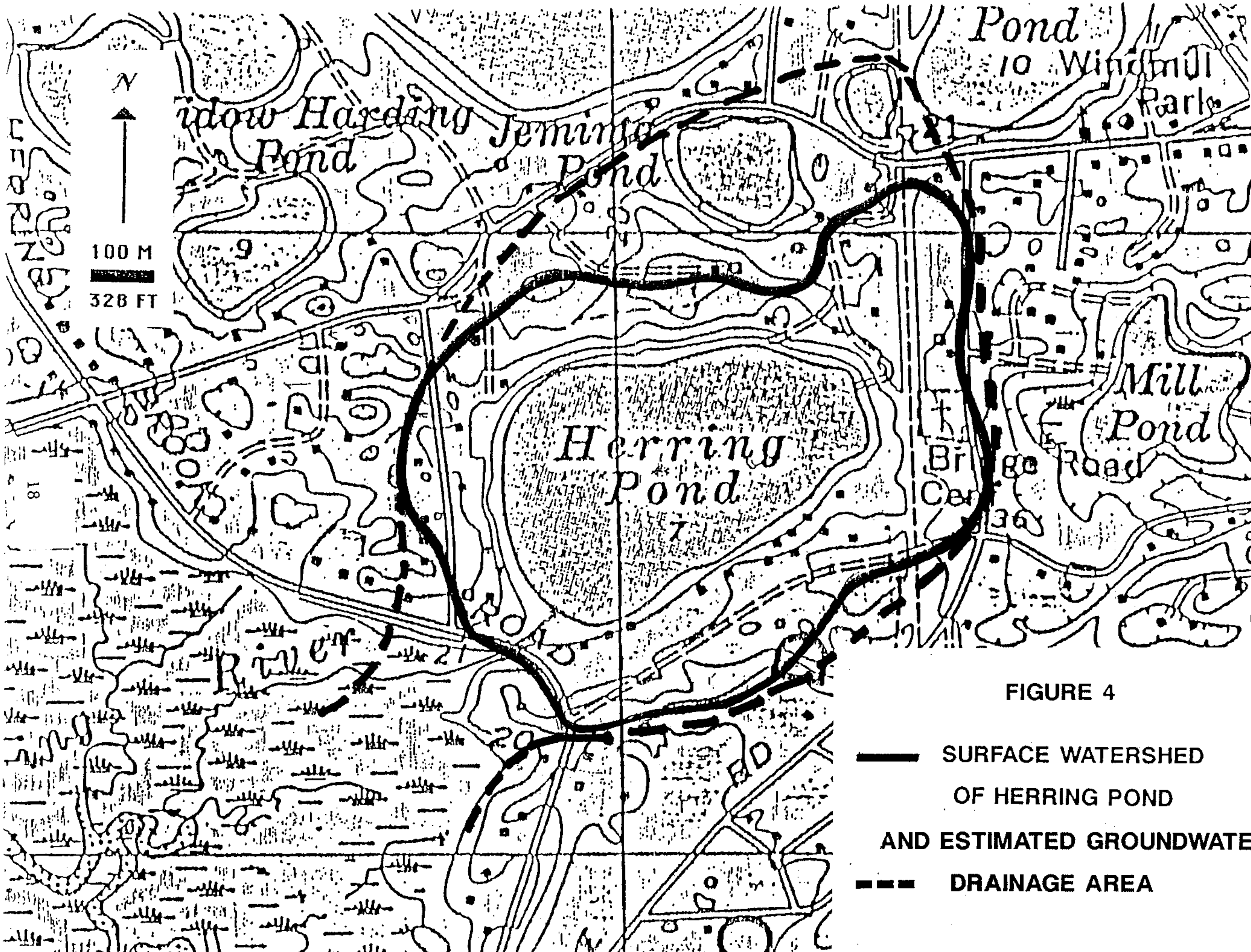


FIGURE 4

SURFACE WATERSHED OF HERRING POND AND ESTIMATED GROUNDWATER DRAINAGE AREA

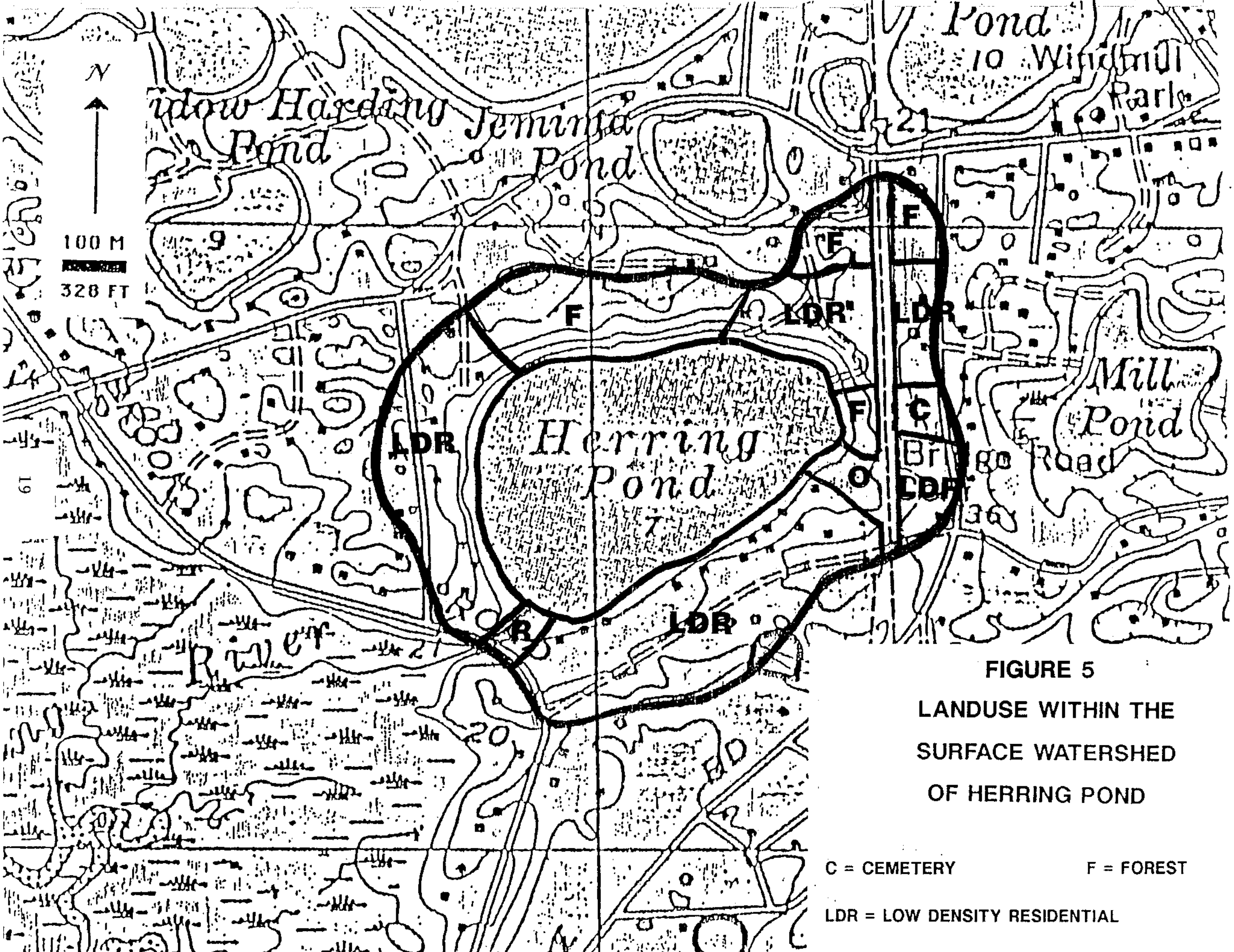


FIGURE 5

LANDUSE WITHIN THE

SURFACE WATERSHED

OF HERRING POND

C = CEMETERY F = FOREST

LDR = LOW DENSITY RESIDENTIAL

O = OPEN LAND R = RECREATIONAL

saltwater in the southern portion of the drainage. The exact extent of this source is not known. It is likely tidally influenced, but does appear to be constant (i.e., non-seasonal).

Watershed Geology and Soils

The Generalized Geologic Map of Cape Cod (Oldale 1985) shows most of Eastham and all of the Herring 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 of 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. The soils of the Herring Pond watershed consist exclusively of Carver coarse sands (Figure 6) (Soil Conservation Service 1987). These soils are excessively drained, droughty soils which have a water table usually extending greater than 6 feet below the surface. Permeability of these soils is very rapid (>20 in/hr) in the subsoil and substratum, allowing minimal runoff.

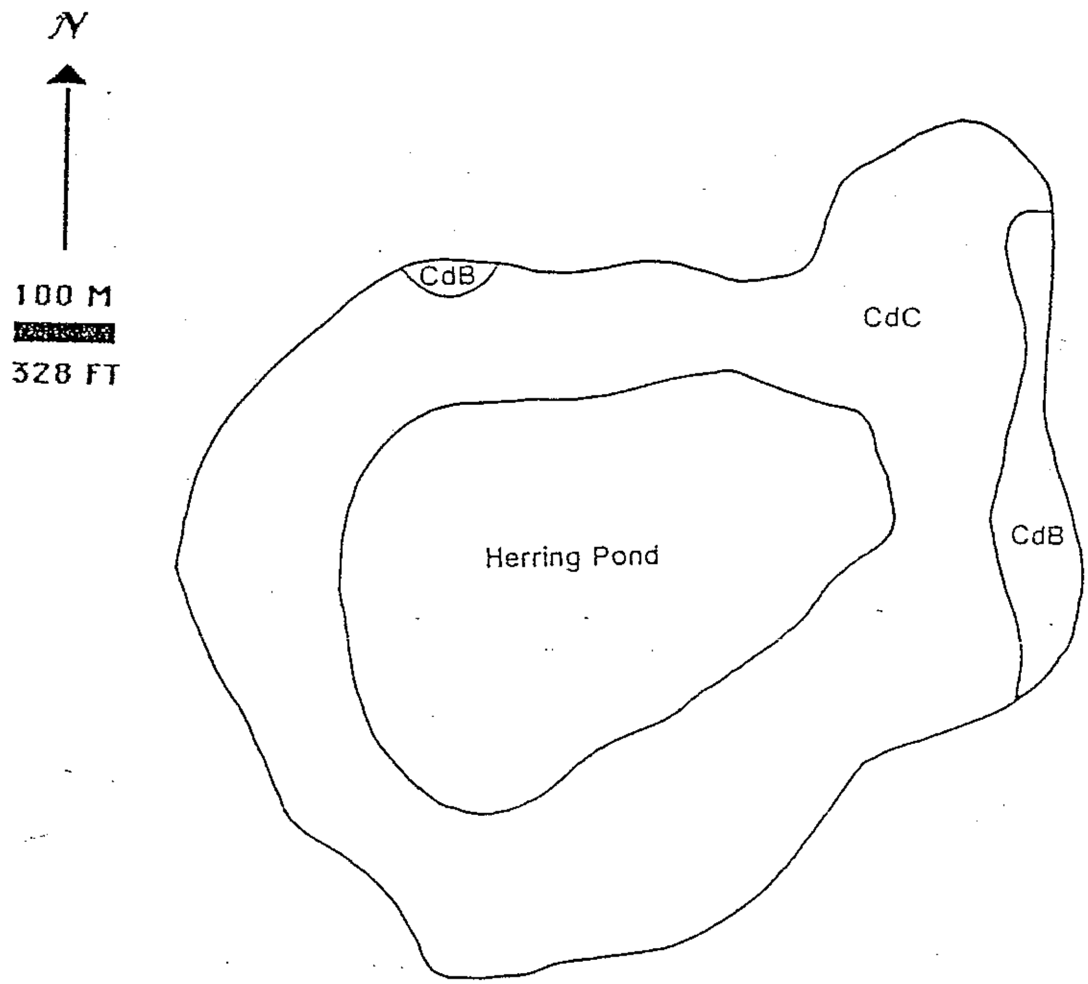
The Carver coarse sands of the Herring Pond watershed rate very poorly as septic tank absorption field soils. The effluent filtering properties of these soils are considered so unfavorable or so difficult to overcome that special designs and/or increased maintenance are required. Problems stem from rapid percolation and low phosphorus adsorptive capacity, making septic systems in these soils a groundwater contamination hazard.

Historical Lake and Land Use

From the late 1800's to early 1900's, landuse in the Herring Pond watershed was dedicated primarily to agricultural practices, although there did exist a cement block factory about a quarter-mile south of the pond. Crops inlcuded white turnips, potatoes, carrots and spinach. There were very few trees in the watershed during this period, although pine trees became reestablished during the 1920's and 1930's.

During this early period, the land was primarily owned by a few inter-related families; the Crosbys, Hortons, and Foresters. The majority of the land to the south and east of the pond was under ownership of the Crosby family. All of the property north of the pond belonged to the Hortons, cousins of the Crosbys and Foresters. Other related families recieved lots and built homes after property prices dropped in the 1930's. During the 1930's,

FIGURE 6



SOILS IN THE WATERSHED OF HERRING POND

SYMBOL	NAME/DESCRIPTION
CdB	Carver coarse sand; 3 to 8 percent slope
CdC	Carver coarse sand; 8 to 15 percent slope

there were three houses in the Herring Pond watershed. By the 1970's, there were from eighteen to twenty shorefront homes on Herring Pond. Presently, there are twenty-four shorefront homes, with additional lots for sale just off the shoreline.

During the War of 1812, prisoners were kept at Crosby Tavern, now a private residence located near the Bridge Street Cemetery. The old meeting house, now gone, was located near the Crosby Tavern.

The original beach on Herring Pond was located south of the existing beach, and was built by the Crosbys. The current beach property was sold to the Town of Eastham in 1952 by the Crosbys and the owners of the property immediately north of the outlet. The outlet channel has been there since pre-Crosby times, and has been modified for an alewife run multiple times over the last one-hundred years. The road accessing the southern shore area of the pond, Crosby Village Road, was named Damond Road prior to the 1950's.

LIMNOLOGICAL DATA BASE

Limnological data were collected for one year in an effort to assess pond conditions and evaluate temporal and spatial variability in physical, chemical and biological parameters. Through this data collection, Baystate Environmental Consultants, Inc. (BEC) seeks to understand the Herring Pond ecosystem and to identify those factors which are critical to its maintenance. A considerable data base is generated through the course of this year-long monitoring, not all of which is of equal importance. It is necessary to distinguish between the critical items and those of more general interest or minimal utility in the management of the system. Therefore, much of the raw data has been incorporated into Appendix B of this report. Included in Appendix C are calculation sheets which detail the derivation of useful values and other information of secondary importance, as well as the quality data evaluation program results.

Flow and Water Chemistry

The waters of Herring Pond are a composite of the dilute mixture of chemical substances introduced by the weathering of rock in the watershed, from seasonal precipitation, and from cultural use of the landscape (e.g., housing), including the infrastructure (e.g., roads) which supports this culture. The importance of these various sources to Herring Pond is dependent on both their concentration and the measured volume of water containing these substances which enters the pond from both surface and sub-surface pathways.

Herring Pond is a natural feature of the environment and the amount of surface waters draining into the pond are minimal. This study revealed a single combined inlet/outlet structure (HP-1), which services Herring Pond (Figure 1). This was active as an inlet only during a rare storm tide. Additional water enters the pond from precipitation, groundwater and overland runoff. Losses from the lake include evaporation, groundwater outseepage, and one outflow (HP-1), which was active only from fall to late spring (September to June). The raw, time-weighted annual mean for the outflow was 0.062 cu. m/min. (0.036 cfs). Derivation of groundwater and precipitation inputs, as well as evaporative and groundwater losses, are detailed in the Hydrologic Budget section of this report.

The chemical constituents of water samples were assayed and summary statistics, including mean (average), minimum and maximum values, were established (Table 3). To compensate for differences in flow volumes and sampling intervals, the annual mean of the following chemical parameters were appropriately flow- and time-weighted (HP-1) or time-weighted (HP-2S, HP-2M,

TABLE 3

VALUES OF MONITORED PARAMETERS IN THE HERRING POND SYSTEM

PARAMETER	UNITS	STATISTIC	HP-1	HP-2S	HP-2M	HP-2B
FLOW	CU.M/MIN	MEAN	.06	-	-	-
		MAXIMUM	.17	-	-	-
		MINIMUM	0	-	-	-
TOTAL PHOSPHORUS	UG/L	MEAN	27	27	38	31
		MAXIMUM	110	60	60	90
		MINIMUM	10	10	20	10
ORTHOPHOSPHORUS	UG/L	MEAN	10	10	12	12
		MAXIMUM	10	10	20	30
		MINIMUM	10	10	10	10
AMMONIA NITROGEN	MG/L	MEAN	.04	.03	.02	.08
		MAXIMUM	.24	.10	.04	.52
		MINIMUM	.01	.01	.01	.01
NITRATE NITROGEN	MG/L	MEAN	.06	.02	.03	.02
		MAXIMUM	.31	.07	.05	.07
		MINIMUM	.01	.01	.01	.01
TOTAL KJELDAHL NITROGEN	MG/L	MEAN	.42	.50	.56	.56
		MAXIMUM	.49	.80	.70	.78
		MINIMUM	.33	.31	.46	.36
NITROGEN:PHOSPHORUS RATIO	NONE	MEAN	32	28	19	31
		MAXIMUM	51	65	32	73
		MINIMUM	4	8	10	8
TEMPERATURE	CELSIUS	MAXIMUM	24.0	27.8	24.5	18.0
		MINIMUM	1.0	1.5	17.2	1.1
DISSOLVED OXYGEN	MG/L	MEAN	10.4	10.3	7.8	3.6
		MAXIMUM	12.6	13.7	9.6	9.6
		MINIMUM	8.6	7.6	6.8	.2
D.O. SATURATION	%	MEAN	-	98	87	30
		MAXIMUM	-	113	107	82
		MINIMUM	-	87	79	2
TOTAL SUSPENDED SOLIDS	MG/L	MEAN	2.4	2.4	1.5	3.5
		MAXIMUM	6.0	8.0	3.0	15.0
		MINIMUM	0.0	0.0	1.0	.4
TURBIDITY	NTU	MEAN	1.1	1.1	1.0	1.9
		MAXIMUM	2.4	3.8	1.4	6.6
		MINIMUM	.3	.2	.6	.3

TABLE 3 - CONTINUED

VALUES OF MONITORED PARAMETERS IN THE HERRING POND SYSTEM - CONTINUED

PARAMETER	UNITS	STATISTIC	HP-1	HP-2S	HP-2M	HP-2B
CONDUCTIVITY	UMHOS/CM	MEAN	618	628	732	630
		MAXIMUM	710	800	800	800
		MINIMUM	501	362	700	305
PH	S.U.	MAXIMUM	6.6	7.1	6.9	6.8
		MINIMUM	5.2	5.4	5.9	5.6
TOTAL ALKALINITY	MG/L	MEAN	14.6	15.3	16.1	17.0
		MAXIMUM	17.0	17.0	17.0	26.3
		MINIMUM	12.0	12.0	14.8	12.0
CHLORIDE	MG/L	MEAN	207.5	205.1	205.2	205.4
		MAXIMUM	278.0	263.0	213.0	267.0
		MINIMUM	172.9	173.3	201.1	147.7
IRON	MG/L	MEAN	.08	.07	.09	.27
		MAXIMUM	.20	.18	.21	1.49
		MINIMUM	.02	.02	.02	.02
FECAL COLIFORM	N/100ML	MEAN*	14	7	-	-
		MAXIMUM	40	10	-	-
		MINIMUM	10	0	-	-
FECAL STREPTOCOCCI	N/100ML	MEAN*	11	9	-	-
		MAXIMUM	30	2000	-	-
		MINIMUM	10	0	-	-
CHLOROPHYLL A	UG/L	MEAN		2.1		
		MAXIMUM		4.6		
		MINIMUM		.7		
SECCHI DISK TRANSPARENCY	METERS	MEAN		4.4		
		MAXIMUM		6.6		
		MINIMUM		3.0		

* GEOMETRIC MEAN APPLIED INSTEAD OF ARITHMETIC MEAN.

and HP-2B): total phosphorus, orthophosphorus, ammonia nitrogen, nitrate nitrogen, Kjeldahl nitrogen, and chloride. These values were used in calculating nutrient loadings to the pond (kg/yr). Also analyzed were total suspended solids, total alkalinity, iron, and instantaneous measurements such as dissolved oxygen, temperature, pH, chlorophyll a, conductivity, turbidity and secchi disk transparency. Mean values for these parameters are given as unweighted averages of sampling dates, as were the derived values of percent saturation and nitrogen to phosphorus ratios. Mean values of fecal coliform and fecal streptococci were reported as geometric means instead of arithmetic means.

It is appropriate to begin a discussion of the chemical composition of Herring Pond with the elements that are considered critical for lake productivity, namely phosphorus and nitrogen. Phosphorus is considered the element "limiting" primary productivity in most temperate zone lakes, as it is most often the element in shortest supply in relation to the needs of plants (phytoplankton or rooted aquatic plants). It is also more easily controlled than most of the other essential plant nutrients. The level of total phosphorus in a lake is a good indicator of the degree of fertilization or eutrophication that the lake is undergoing (Wetzel, 1983; Goldman and Horne, 1983).

Total phosphorus, as the term implies, refers to all the phosphorus in a volume of water, including dissolved and particulate forms. Total phosphorus in the open waters of Herring Pond (HP-2S, HP-2M, and HP-2B) averaged approximately 31 ug/l, with the greater concentration in the metalimnetic (HP-2M) sample. Water exiting the system (HP-2), was somewhat lower at 21 ug/l. The greatest in-lake concentrations were observed during the summer months, during which time the outlet was inactive (i.e., not flowing), accounting for the observed differences. The observed increase in total phosphorus concentrations during the summer months is largely attributed to internal loading and is discussed in greater detail in the Nutrient Budget section of this report.

Orthophosphate is the form of phosphorus most readily available for biological assimilation, and the turnover (recycling) rate of this fraction is important in determining levels of lake productivity. In Herring Pond, levels rarely rose above the level of detectability (10 ug/l); this is not uncommon for an inland lake, and indicates that there is no substantial reserve pool of phosphorus. Algal production is likely to be a function of phosphorus recycling

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 taken as the difference between Kjeldahl nitrogen (a digestion-based test result) and ammonia nitrogen. Ammonia and nitrate are readily available for uptake by plants. Both forms can cause toxicity problems at high concentrations. Ammonia nitrogen is toxic to most animals at concentrations dependent on temperature, pH, and dissolved solids levels. Nitrate can be toxic to humans at concentrations above 10 mg/l (as N). Nitrogen inputs to aquatic systems are very difficult to control as a consequence of high nitrogen concentration in the atmosphere and the high mobility of nitrogen in the soil (Martin and Goff, 1972). The interconversion of various forms of nitrogen is readily accomplished by bacterial action as well.

Ammonia is sequentially converted to nitrite and then to nitrate in the presence of oxygen by naturally occurring bacteria. In general, the decline of oxygen during the summer in the hypolimnia of lakes, or in wetland areas, promotes the buildup of ammonia through decay processes. In Herring Pond, which thermally stratifies during the summer period, the time-weighted hypolimnetic (HP-2B) ammonia concentrations were nearly four-fold greater than in surface waters (0.11 and 0.03 mg/l, respectively). However, these differences appear to be attributable to outlying values observed in bottom samples during periods of mixis. There are no obvious explanations for these anomolously high values, as they do not exhibit any apparent trend. In the Herring Pond system, ammonia values ranged from 0.01 to 0.52 mg/l, with most values occurring in the lower end of the range. Based on the levels of ammonia, in conjunction with pH and oxygen values, ammonia toxicity does not appear to be a threat to vertebrates found in Herring Pond.

Nitrate nitrogen was found in moderately low concentrations in Herring Pond during the study year. Time-weighted mean values for the year ranged from 0.02 to 0.03 mg/l within the lake. The outlet (HP-1) however, exhibited a time and flow- weighted mean nitrate value of 0.10 mg/l. Typical values for this station ranged from 0.01 to 0.05 mg/l, with one value of 0.31 mg/l. Aside from this outlying value, nitrate values from outlet samples were similar to other in-lake values. Total Kjeldahl nitrogen (TKN) exhibited in-lake mean values in the range of 0.52 to 0.57 mg/l, being rather evenly distributed throughout the study year. Nitrogen dynamics and loading are more fully discussed in the Nutrient Budget Section of this report.

The nitrogen:phosphorus ratio, calculated as (TKN + nitrate nitrogen / total phosphorus), indicates potential shifts in the chemical resources important to the primary producers. The time-weighted annual mean surface in-lake ratio was almost 28:1, and was found to be less than 10:1 on only two ocassions, although it approached this value on a few occasions. Bottom N:P values were similar to surface values, with no discernible trend in variations between surface and bottom N:P ratios. These ratios have important implications for the lake and its biological community. Concentration of chlorophyll a is generally dependent on total phosphorus at TN:TP ratios greater than 17:1, while nitrogen levels are usually more influential at ratios of 10:1 or less (Smith, 1982). In themselves, nutrient ratios do not necessarily indicate whether phosphorus or nitrogen-deficiency will limit phytoplankton. Other factors need to be considered such as nutrient and light availability, grazing, flushing rate, as well as in-lake concentrations of a host of trace metals, any of which may be in relative short supply. The observed TN:TP ratios of Herring Pond would tend to support the hypothesis that phosphorus is more limiting to primary production than is nitrogen, however.

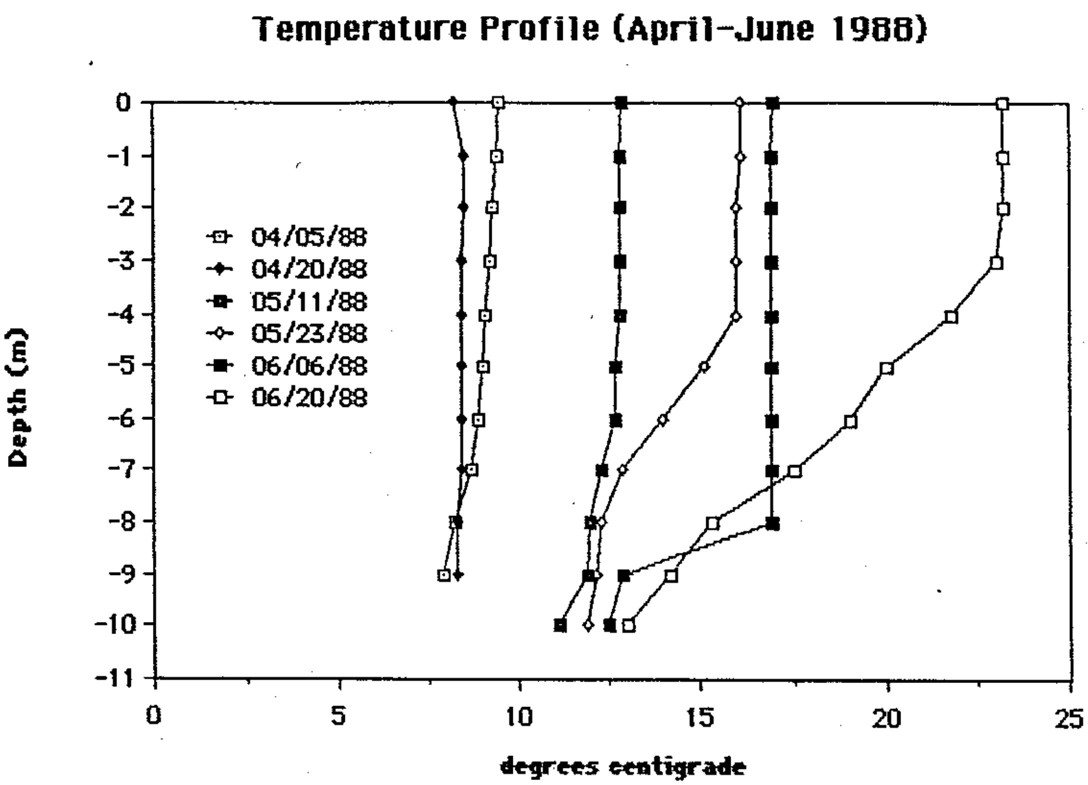
While nutrient ratios do not provide conclusive proof of limiting factors, other potentially limiting factors, such as light availability, flushing rate or grazing appear unlikely to provide the primary control of biological growth in this system. Thus, phosphorus remains the most appropriate target element for control in a lake management program. It is far easier to reduce or eliminate phosphorus inputs than to attempt to control other possible influences.

The water temperature and oxygen profiles in Herring Pond demonstrated a typical temperate zone seasonal pattern (Figure 7a-c). The study year started with isothermal conditions in March. With increasing solar insolation and gradual spring warming, the onset of thermal stratification became noticeable in May. There was an observed deepening of the zone of thermal discontinuity (thermocline) throughout the summer months. In general, mid-thermocline was detected at depths of about 6 to 7 meters. Below the thermocline, hypolimnetic oxygen values declined largely as a result of isolation from the mixed surface layer (epilimnion), and the rate of decomposition of organic matter (bacterial respiration) exceeding primary productivity (photosynthesis).

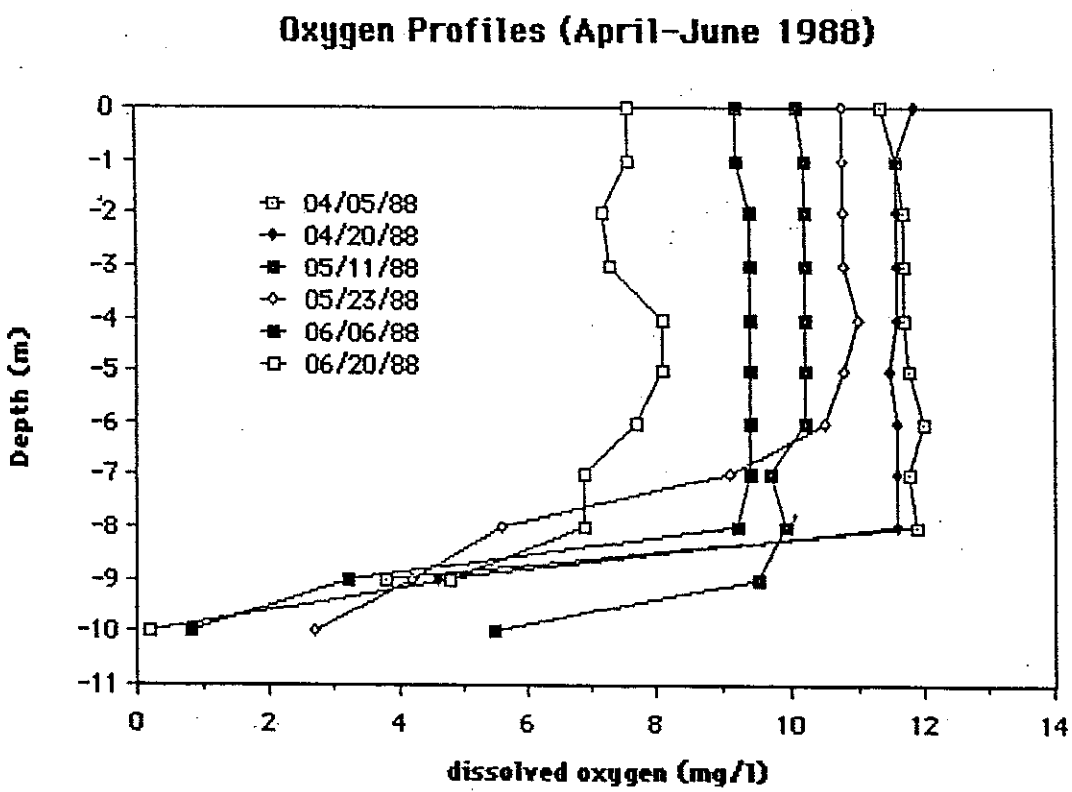
By October, the thermocline had completely degraded, and temperature profiles were isothermal. Temperature profiles remained isothermal throughout the fall and winter months, exhibiting continuous cooling. As expected, oxygen values increased with decreasing water temperatures at all depths except at the very bottom (@ 10 m), where sediment oxygen demand depressed oxygen levels in the overlying water.

Oxygen in the water column of Herring Pond displayed considerable seasonal variation, due to water temperature change and biotic activity (Figure 7a-c). The amount of oxygen which will dissolve in water is dependent on temperature, dissolved substances and

FIGURE 7a

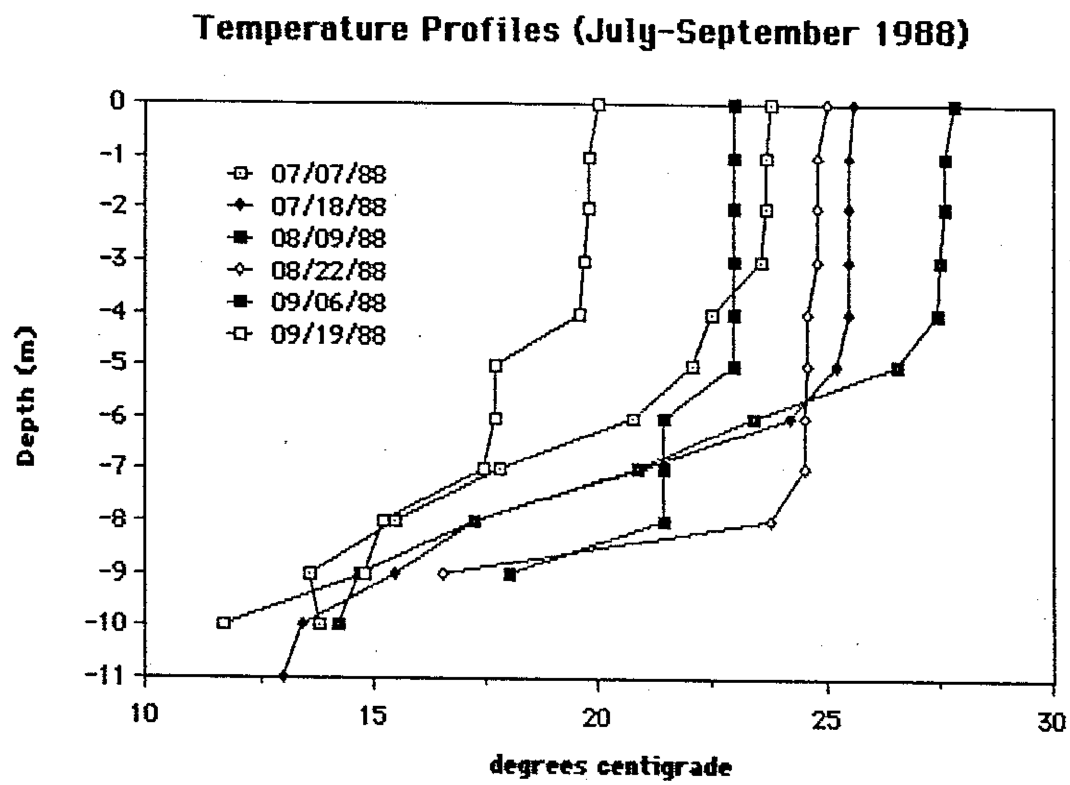


Temperature Profile (April-June 1988)
Depth (m)
degrees centigrade
04/05/88
04/20/88
05/11/88
05/23/88
06/06/88
06/20/88
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
5
10
15
20
25

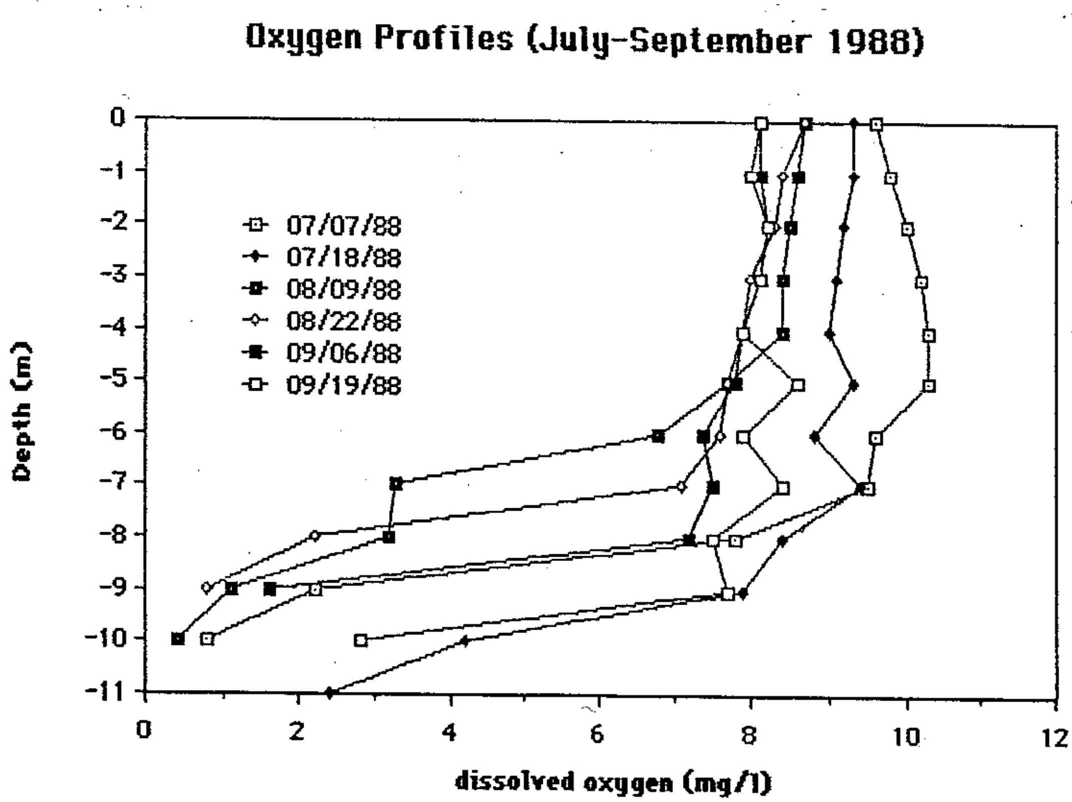


Oxygen Profiles (April-June 1988)
Depth (m)
dissolved oxygen (mg/l)
04/05/88
04/20/88
05/11/88
05/23/88
06/06/88
06/20/88
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
2
4
6
8
10
12
14

FIGURE 7b

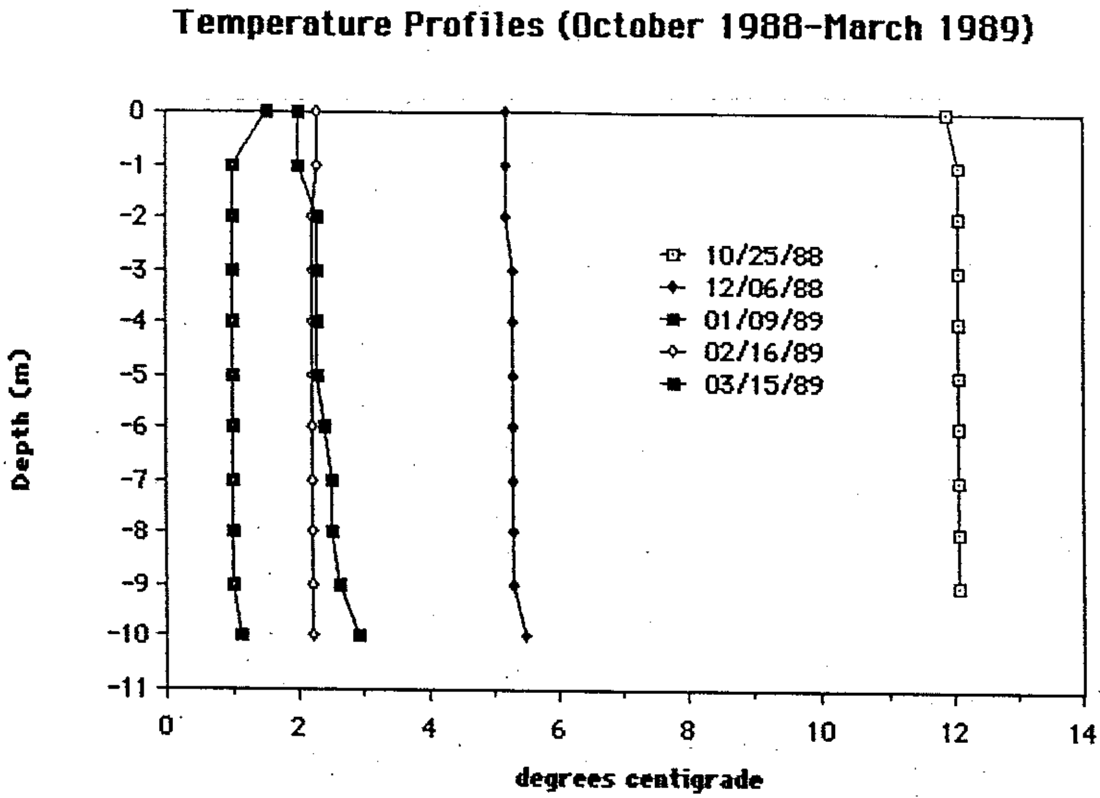


Temperature Profiles (July-September 1988)
07/07/88
07/18/88
08/09/88
08/22/88
09/06/88
09/19/88
Depth (m)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
10
15
20
25
30
degrees centigrade

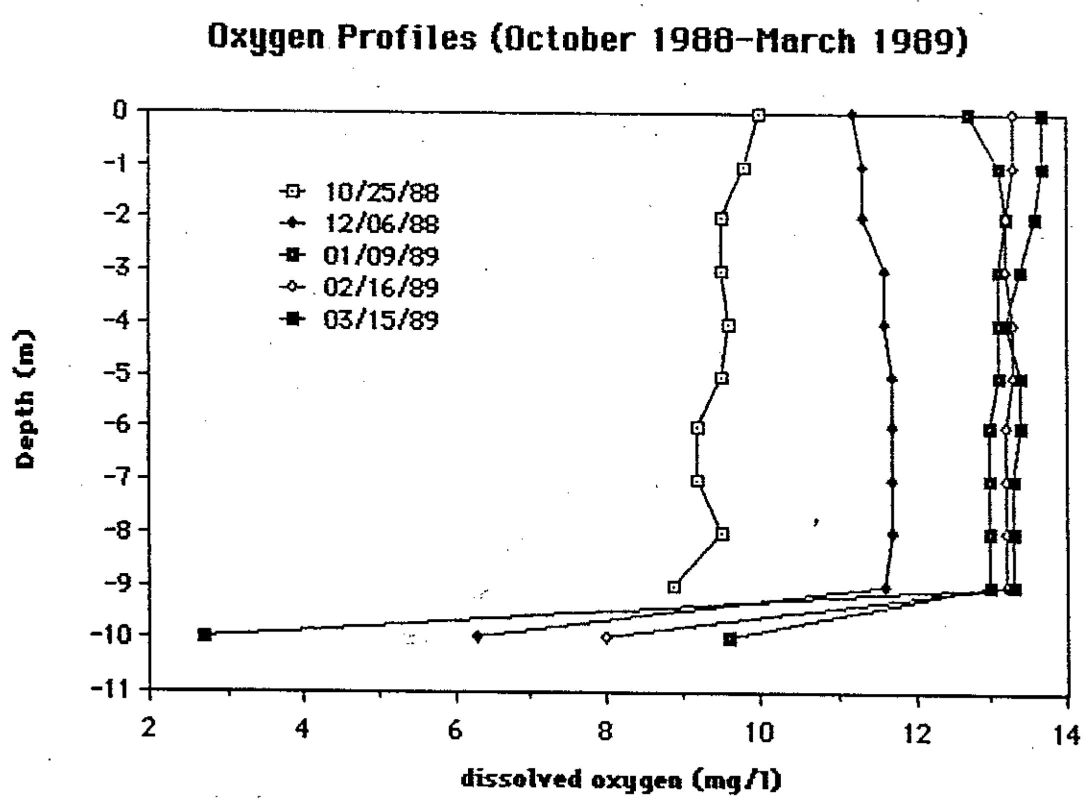


Oxygen Profiles (July-September 1988)
07/07/88
07/18/88
08/09/88
08/22/88
09/06/88
09/19/88
Depth (m)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
2
4
6
8
10
12
dissolved oxygen (mg/l)

FIGURE 7c



Temperature Profiles (October 1988-March 1989)
10/25/88
12/06/88
01/09/89
02/16/89
03/15/89
Depth (m)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
2
4
6
8
10
12
14
degrees centigrade



Oxygen Profiles (October 1988-March 1989)
10/25/88
12/06/88
01/09/89
02/16/89
03/15/89
Depth (m)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
2
4
6
8
10
12
14
dissolved oxygen (mg/l)

atmospheric pressure. The relation of the actual oxygen level to the maximum possible concentration is called the percent saturation and reveals much about lake metabolism.

Dissolved oxygen was generally found to be uniformly distributed throughout the water column during periods when the pond was mixed (i.e., unstratified). During periods of thermal stratification, however, there was a marked decline in hypolimnetic oxygen concentrations. In surface waters, the percent saturation was never observed to be less than 80 percent with respect to temperature during the study year. In bottom samples, however, particularly during periods of thermal stratification, percent oxygen saturation approached 0 percent. In addition to isolation from the air-water interface, the depletion of hypolimnetic oxygen is a function of decreased solar insolation and the concommittant reduction in photosynthetic activity in the face of continued decomposition in bottom waters. The severely low oxygen concentrations were restricted to the very deepest layers of Herring Pond. Generally, oxygen values immediately beneath the thermocline were similar to epilimnetic values, tapering to minimal values near the bottom.

Other chemical parameters monitored on a routine basis include total suspended solids, turbidity, conductivity, total alkalinity, pH, chloride and iron (Table 1). Chlorophyll a and secchi disk transparency are discussed in the phytoplankton section and bacteria are considered separately.

Total suspended solids exhibited an in-lake range of 0.0 to 15.0 mg/l, with the bottom samples more often containing higher totals of particulate matter, most likely from sinking and resuspension. The outlet values ranged from 0.0 to 6.0 mg/l. Overall, these levels of suspended materials are considered low to moderate.

Turbidity in the Herring Pond system was relatively low throughout the study year. In-lake values ranged from 0.2 to 6.6 NTU, with the highest values observed in bottom samples. Mean values for all stations ranged from 1.0 to 1.9 NTU.

Specific conductance (conductivity) is an indirect measure of the dissolved solids content and chemical fertility of water. Low fertility is usually indicated by conductivity values less than 100 umhos/cm (USEPA, 1976). By comparison, conductivity values in the Herring Pond system are extremely high. Mean values ranged from 618 to 732 umhos/cm. These very high values appear to be a consequence of Herring Pond's proximity to the Atlantic Ocean. As will be discussed in the groundwater section of this report, it is quite apparent that Herring Pond is subject to sub-surface saltwater intrusions. These intrusions do not promote excessive productivity, and lessen the meaning of observed conductivity readings in terms of overall system fertility.

Chloride values in the Herring Pond system were very high and were reflective of the very high conductivity values. Chloride concentrations were consistent throughout the study year, and exhibited a range of mean values of 205.2 to 207.5 mg/l for all stations. The means are below the limits recommended for drinking water (250 mg/l), although on one occasion (04/22/88) this limit was exceeded. Suggested sodium levels (usually about 2/3 of the chloride conc.) were assumed to always exceed the drinking water standard of 20 mg/l.

Total alkalinity provides a measure of the buffering capacity of Herring Pond. Mean values were typically in the range of 14.6 to 17.0 mg/l as $CaCO_3$. The ability of the pond to withstand acidic additions without pH change, would be considered moderate. The low buffering capacity of the soils found in the watershed provides little protection against acid precipitation. The pH values from the Herring Pond stations ranged from 5.2 to 7.1 over the study year. Higher values were typically observed during the summer months. On all but one occasion the pH values were below neutral (7.0 S.U.), with values typically observed in the 6.0 to 6.5 range, classifying the pond as slightly acidic.

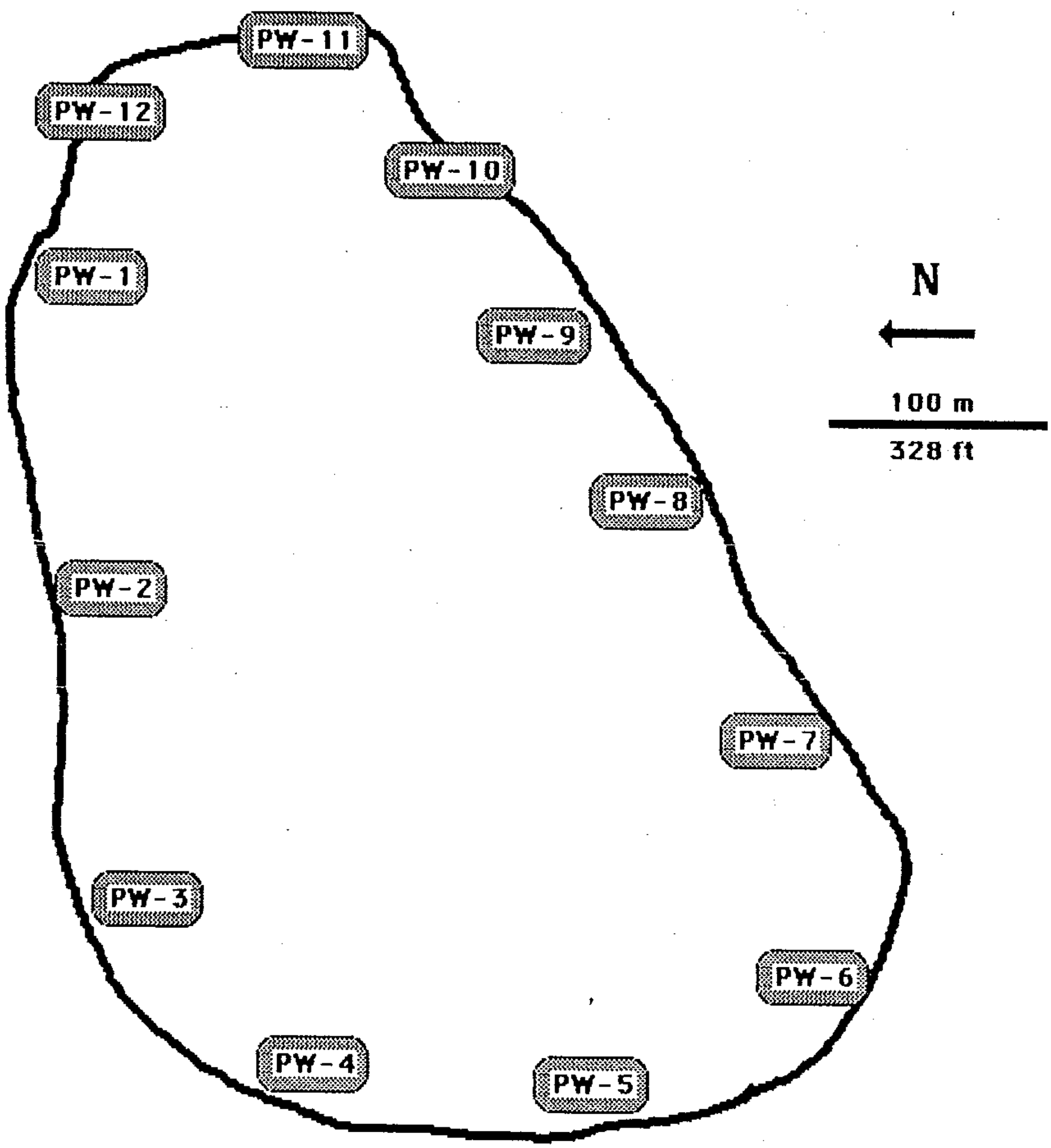
Groundwater Assessment

Routine water quality sampling was supplemented by sampling of local wells and the interstitial porewater in littoral (shallow water) sections of Herring Pond. Positions of the porewater sampling stations are indicated in Figure 8. Porewater samples were collected in May and August 1988. Domestic well samples were collected in conjunction with porewater sampling and the locations of these wells are shown on Figure 9. Water quality data from these sample stations are presented in Table 4 and Table 5, respectively. Additionally, five permanent monitoring wells were installed in the Herring Pond watershed to aid in assessing the elevation of the groundwater table in the watershed, and to investigate the quality of the groundwater further from the pond's edge and independently of domestic supply systems. The location of these monitoring wells and associated water quality data are shown in Figure 10 and Table 6, respectively.

There were apparent seasonal variations noted in both porewater and domestic well water quality with respect to phosphorus concentrations. Both of these sources exhibited higher concentrations of total filterable phosphorus during the spring survey, but there was no discernible correlation between porewater and well water quality. Orthophosphorus exhibited similar trends, but of lesser magnitude. The highest total filterable phosphorus value (3,070 ug/l) came from Well F, located on the southern shore of the pond during the spring

FIGURE 8

LOCATION OF L.I.P. SAMPLE STATIONS IN HERRING POND



Note: For quality control purposes, additional samples (PW-13 and PW-14) were collected from the same shoreline vicinity as PW-12 in August, 1988.

TABLE 4

HERRING POND PORE WATER SAMPLES (5/23/88)

PARAMETER	UNITS	PH-1	PH-2	PH-3	PH-4	PH-5	PH-6	PH-7	PH-8	PH-9	PH-10	PH-11	PH-12	PH-13	PH-14
ORTHO P	(ug/l)	60	140	70	80	100	60	100	190	260	40	80	100	50	100
TOTAL FILT. P	(ug/l)	290	300	390	350	270	240	360	390	280	170	220	210	180	390
AMMONIA N	(mg/l)	.01	.22	.02	.01	.28	.24	.07	.46	.01	.01	.54	.01	.01	4.00
NITRATE N	(mg/l)	.32	.02	.09	.02	.02	.02	.02	.02	.02	.02	.02	.46	.21	.03
PH	(su)	6.2	6.3	6.3	6.3	6.1	6.1	6.0	5.9	5.8	6.0	5.8	5.9	5.9	5.6
CONDUCT	(umhos/cm)	113	158	140	690	705	520	775	755	238	95	253	98	110	271
CHLORIDE	(mg/l)	24.9	32.1	37.5	209.0	222.0	155.0	209.0	211.0	57.4	19.5	35.7	19.5	19.5	73.7
IRON	(mg/l)	1.70	3.82	2.45	2.47	2.66	1.93	5.57	6.97	9.49	1.67	5.76	2.44	1.63	4.44
FEC COLI	(#/100 ml)	10	10	10	10	10	10	10	10	10	10	10	10	10	10

HERRING POND PORE WATER SAMPLES (08/10/88)

PARAMETER	UNITS	PH-1	PH-2	PH-3	PH-4	PH-5	PH-6	PH-7	PH-8	PH-9	PH-10	PH-11	PH-12
ORTHO P	(ug/l)	90	10	100	20	40	70	50	20	20	20	20	40
TOTAL FILT. P	(ug/l)	150	20	130	90	50	90	50	30	30	20	40	80
AMMONIA N	(mg/l)	1.90	.11	.23	.41	.06	.99	.82	.20	.18	.16	.17	.66
NITRATE N	(mg/l)	.12	.92	.02	.02	.02	.02	.02	.04	.25	.03	.02	.51
PH	(su)	5.8	5.8	6.0	5.9	6.4	6.8	6.7	6.3	5.8	6.0	5.8	5.7
CONDUCT	(umhos/cm)	305	347	150	360	750	790	760	780	192	210	452	398
CHLORIDE	(mg/l)	73.0	69.0	31.0	76.0	208.0	213.0	213.0	218.0	41.0	51.0	127	81
IRON	(mg/l)	5.01	1.92	4.65	3.40	2.91	3.29	3.77	7.88	3.54	5.13	3.20	5.90
FEC COLI	(#/100 ml)	10	10	30	10	10	10	10	10	10	20	60	20

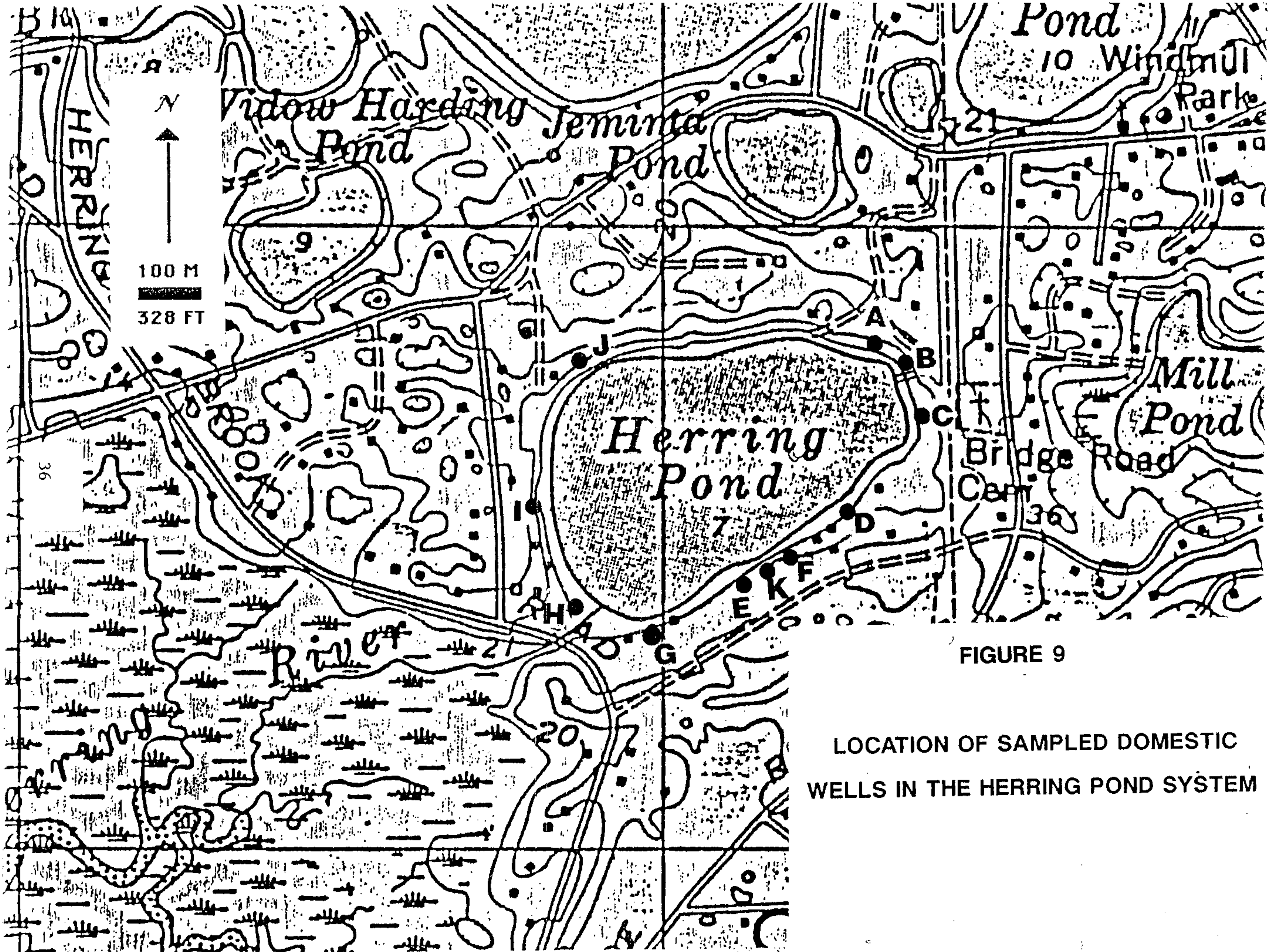


FIGURE 9

LOCATION OF SAMPLED DOMESTIC WELLS IN THE HERRING POND SYSTEM

TABLE 5

HERRING POND WELL WATER SAMPLES (5/23/88)

ANALYSIS	UNITS	WA	WB	WC	WD	WE	WF	WG	WH	WI	WJ
FEC COLI	(/100mls)	10	10	10	10	10	10	10	10	10	10
IRON	(mg/l)	.05	.02	.8	.04	.09	.69	.14	11.84	3.62	.12
TOTAL FILT. P	(ug/l)	10	120	150	200	290	3070	190	340	270	170
ORTHO P	(ug/l)	10	10	10	10	10	1710	20	220	200	10
AMM N	(mg/l)	.01	.07	.04	.01	.06	.01	.06	.51	.15	.02
NITRATE N	(mg/l)	.04	.67	.04	1.00	.06	.11	.06	.02	.02	.02
CHLORIDE	(mg/l)	33.9	30.3	43.0	32.1	28.5	37.5	23.1	39.4	227.0	37.5
PH	(su)	6.3	6.3	6.2	6.2	6.3	6.2	6.4	6.4	6.2	6.3
CONDUCT	(umhos/cm)	125	118	148	132	105	137	110	160	700	117

HERRING POND WELL WATER SAMPLES (08/09/88)

ANALYSIS	UNITS	WA	WB	WC	WD	WE	WF	WG	WH	WI	WJ	WK	WL
FEC COLI	(/100mls)	10	10	10	10	10	10	10	10	10	10	10	10
IRON	(mg/l)	.07	.08	1.73	.29	.21	.17	.33	.34	.77	.00	.24	1.47
TOTAL FILT. P	(ug/l)	20	10	20	10	10	1830	50	70	40	20	10	150
ORTHO P	(ug/l)	10	10	10	10	10	340	10	40	10	20	10	10
AMM N	(mg/l)	.02	.01	.02	.02	.02	.02	.02	.32	.15	.02	.02	.03
NITRATE N	(mg/l)	.09	1.70	.09	1.20	1.12	.18	.05	.02	.02	.19	1.40	.02
CHLORIDE	(mg/l)	27.0	24.0	26.0	30.0	30.0	34.0	21.0	38.0	217.0	34.0	33.0	25.0
PH	(su)	6.0	6.3	5.8	5.8	5.5	6.3	6.6	9.2	6.3	6.2	6.1	7.7
CONDUCT	(umhos/cm)	135	132	127	151	141	160	108	272	780	190	184	135

survey. This particular well contained a high total filterable phosphorus value (1,830 ug/l) during the summer survey as well, but the source of this high value is unknown. In most cases, the concentration of total filterable phosphorus in domestic well samples from around Herring Pond were lower than interstitial porewater values, although there were a few exceptions. The biological availability of groundwater phosphorus is dependent on incoming (or outgoing) groundwater concentration, season (accumulation), soil type (adsorption), the degree of oxygenation (remineralization) and the bacterial flora (uptake or release) connected with the layer. The relationship of porewater phosphorus to lake loading is poorly understood, so it is difficult to equate high interstitial values with contributions to the overlying water. It is possible, however, to identify and classify those shoreline segments with respect to groundwater loading potential, based on interstitial porewater total phosphorus concentrations.

Concentration of total iron was assessed in interstitial porewater and domestic well samples. Under oxygenated conditions ferrous iron, Fe(II), is hydrolyzed to ferric iron, Fe(III), and may react with phosphate, forming an iron phosphate precipitate. If under these conditions the Fe:P ratio is sufficiently high (2:1 to 5:1), this reaction is efficient in removing phosphate from solution (Armstrong et al., 1987; Stauffer, 1981). Porewater iron concentrations ranged from 1.63 to 9.49 mg/l. Although these concentrations are not unusually high compared to other studies, they may be sufficient to retain phosphate at the sediment-water interface under oxic conditions. This scavenging of phosphate by iron at the sediment level would minimize the potential influence that inseeping groundwater exerts on the water quality of Herring Pond. This may be of major importance in the Herring Pond system, as approximately one-half of the pond is associated with epilimnetic (oxic) water on an areal basis during periods of stratification. In addition, only the deepest portions of the hypolimnion were observed to be anoxic (i.e., less than 1.0 mg/l O_2), which would tend to further reduce the sediment-water interface potentially releasing phosphorus in large quantities. Overall, domestic well samples contained low to moderate levels of iron, ranging from 0.02 to 11.84 mg/l. In general, there was a tendency for higher values in wells along the southwestern periphery of the pond.

Ammonia values ranged from 0.01 to 0.51 mg/l in the wells and from 0.01 to 4.00 mg/l in interstitial porewater. The highest well value (from Well H) corresponded to the highest ammomnia value among well samples on both survey dates. This particular well is located adjacent to the public beach. Analysis of Porewater samples from this vicinity revealed relatively high values of ammonia on both occasions. It appears that the significant areas of potential nitrogen loading, based on

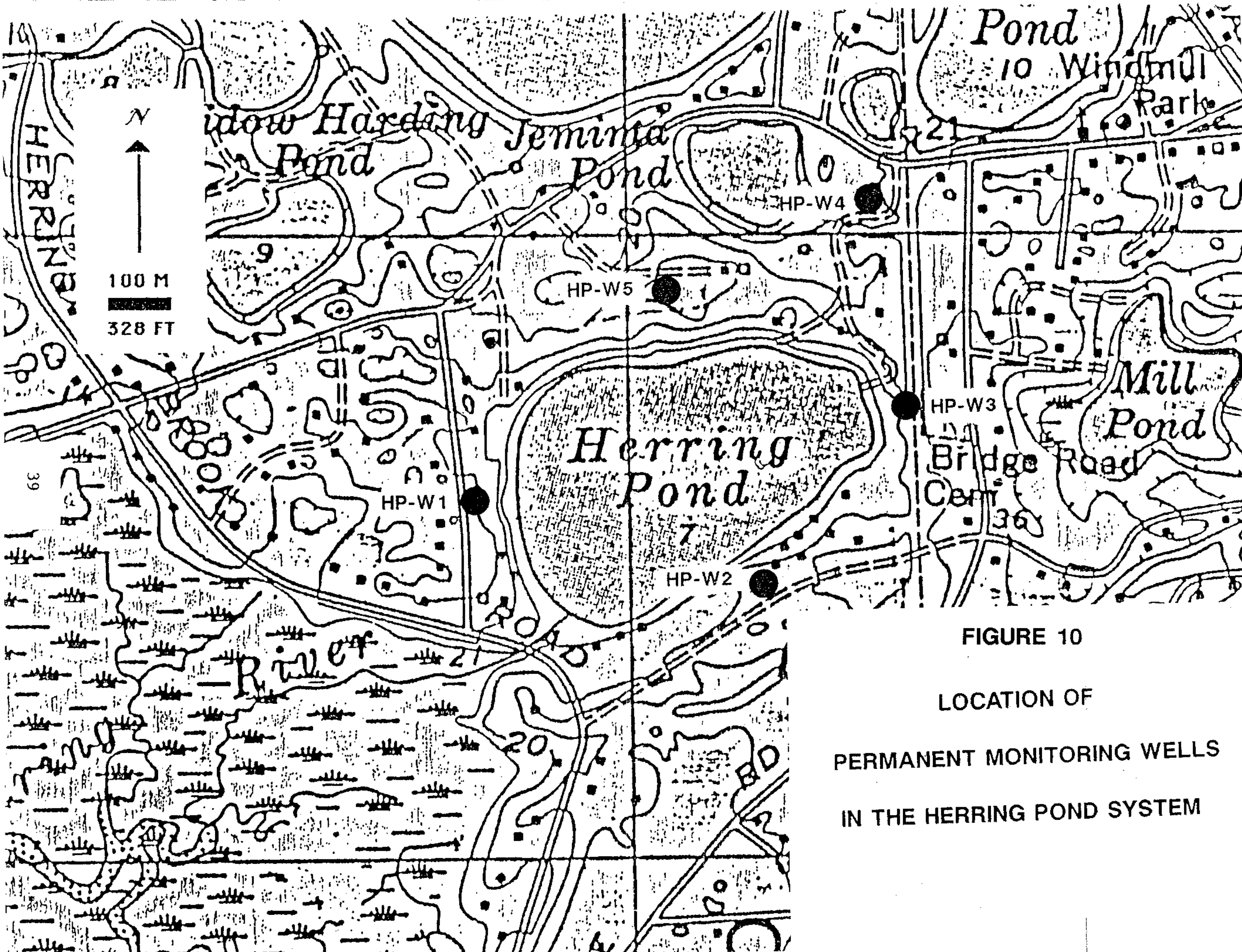


FIGURE 10

LOCATION OF

PERMANENT MONITORING WELLS

IN THE HERRING POND SYSTEM

TABLE 6

HERRING POND PERMANENT MONITORING WELL SAMPLES (5/10/89)

ANALYSIS	UNITS	HP-W1	HP-W2	HP-W3	HP-W4	HP-W5
FEC COLI	(/100mls)	10	10	10	10	10
IRON	(mg/l)	4.1	4.2	19.4	.75	.33
TOTAL FILT. P	(ug/l)	2700	220	180	70	80
ORTHO P	(ug/l)	1900	150	80	70	60
AMMONIA N	(mg/l)	.11	.09	.05	.07	.05
NITRATE N	(mg/l)	.09	.04	.14	.41	.07
CHLORIDE	(mg/l)	131.0	55.9	27.4	11.8	40.2
PH	(su)	6.4	6.3	6.3	6.5	6.8
CONDUCT	(umhos/cm)	390	159	109	70	125
TURBIDITY	(NTU)	1.4	2.3	5.0	3.3	1.5
ELEVATION	(ft)	7.42	7.98	8.29	9.89	8.46

porewater analysis, are the southwest and northeast areas of the pond. Nitrate was found in relatively high concentrations along the northeast shoreline only, however. Although domestic wells and porewater quality did not appear to correspond with respect to phosphorus, there was a semblance of a relationship with respect to nitrogen. For instance, nitrate as a source of nitrogen was observed in relatively high concentrations in porewater and well samples primarily from the southeastern shoreline along with an occasional high ammonia value. This was especially apparent in porewater samples PW-2 and PW-12, and in well samples WB, WD, WE, and WK. Ammonia, on the other hand, was the predominant form of nitrogen in well and porewater samples along the western shoreline (Well WH, PW-5, PW-6, and PW-7), although it was found in similar concentrations in porewater samples from other areas of the pond as well.

Conductivity averaged 202 umhos/cm in the well samples and 401 umhos/cm in the porewater samples (relative to in-lake of around 650 umhos/cm). Conductivity values in porewater samples from the southwestern area of the pond and in Well WI ranged from about 520 to 790 umhos/cm. These extremely high conductivity values corresponded with very high chloride values (@ 200-220 mg/l), and stongly suggest that intrusion of saltwater via groundwater in the southwestern portion of the pond influences in-lake water quality as demonstrated by the similarly high in-lake chloride and conductivity values.

Values for pH in well samples ranged from 6.2 to 6.4 in the May well survey, and from 6.2 to 9.2 in August. Wells WG and WH exhibited the higher values during both surveys. The unusually high value in well WH (9.2) is unexplainable, but may be related to its proximity to the alleged zone of saltwater intrusion. Porewater pH values ranged from 5.6 to 6.3 during the May survey, and 5.7 to 6.8 during the August survey. As in the well sample results, the higher values observed during the August porewater survey were observed in samples from the southwest periphery of the pond (i.e., PW-5, PW-6, PW-7, and PW-8).

Measurement of fecal coliform in well water indicated no ecological or health hazard in any of the well samples. Values were consistently no greater than 10/100 ml. Fecal coliform levels in porewater samples only exceeded 10/100 ml in three samples, all from the western shoreline of the pond. These values were not high however, and ranged from 20/100 ml to 60/100 ml. The contact recreation standard of 200/100 ml was never exceeded.

Stormwater Assessment

Herring Pond is topographically situated within a moderately sloped watershed. However, there are no existing storm drain systems in the watershed to direct the stormwater to the pond, and much of the water reaching Herring Pond must do so as overland flow or as groundwater. There is, however, a catch basin west of the pond that occasionally discharges into Herring Brook. Only during storm tides, which are very rare, will this act as a potential source of pollutant loading to Herring Pond. Following a steady rain on 5/11/88, BEC personnel collected water from the catch basin in an effort to characterize the nature of its contents. This station was designated HP-3, and the results of the analyses are included with routine survey data in Appendix B. Not once during the course of this study was this source observed to be an active contributor to the pond. As the water quality in the catch basin was better than most runoff samples collected by BEC over the past few years in other systems, there is no cause for concern.

In the Herring Pond watershed, the runoff coefficient is likely to be quite low due to the minimal amount of impervious surface. As a result Herring Pond receives only moderate amounts of overland storm water flow from the watershed. Owing to the permeable nature of the sandy soils in the watershed, much of the precipitation percolates into the soil and ultimately recharges the groundwater.

Bacteria

Fecal coliform (FC) and fecal streptococci (FS) were assessed during this study (Table 3). These bacteria come from the digestive tract of all warm-blooded animals, human and non-human, and do not in themselves represent a serious health threat. However, as they are occasionally accompanied by pathogens, they are considered indicators of potential health hazard if present in substantial numbers. The FC values obtained during this study were below the Massachusetts standards for contact recreation, which are 200/100 ml for multiple sample geometric means and 400/100 ml for single samples (or 10% of monthly samples). The geometric mean of the in-lake station was 9/100 ml and 14/100 ml for the outlet.

Values for fecal streptococci were similar to coliform counts except on 4/05/88 when fecal streptococci counts reached 2000/100 ml in the in-lake sample. There are no bathing standards for streptococci, however. The geometric mean for the in-lake samples was 12/100 ml, while the outlet mean was 11/100 ml. Potential sources of bacteria to Herring Pond include waterfowl and possibly septic system inputs via groundwater.

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 FC:FS ratio for humans is more than 4.0, whereas the ratio for domestic animals is less than 1.0 (Tchobanoglous and Schroder, 1985) If ratios are obtained in the ranges of 1 to 2, interpretation is less certain. The confidence of this interpretation is also less sure when FC counts are low (<200/100 ml). This would exclude all of the routine Herring Pond data from consideration. However, the very low bacterial counts suggest the conclusion that raw human septage is not coming into the pond.

Phytoplankton

Phytoplankton, or microscopic algae suspended in the water column, are an important component of aquatic food webs, but may also impart detectable color and odor to lake water as well as a reduction in water clarity. Phytoplankton abundance is often approximated by measuring the concentration of chlorophyll a, a pigment used in photosynthesis. It is the same pigment responsible for making grass and leaves green. Chlorophyll a usually represents 0.5 to 2% of total phytoplankton biomass and has been correlated with production and standing crop at various levels of the food web, water clarity, and phosphorus concentration (e.g., Jones and Bachmann, 1976; Oglesby and Schaffner, 1978; Hanson and Leggett, 1982; Vollenweider, 1982).

Measured chlorophyll a concentrations in Herring Pond ranged from 0.7 to 4.6 ug/l (Table 3, Appendix B). The mean value was 2.1 ug/l. Based on equations which relate chlorophyll a concentration to total phosphorus concentrations, expected chlorophyll a values in Herring Pond would range from 2.6 to 14.3 ug/l, with a mean value of 6.6 ug/l (Jones and Bachman 1976, Oglesby and Schaffner 1978). For calculations, see Appendix C.

These predicted values are substantially greater than those observed in Herring Pond. Among the possible explanations for the lower values observed in Herring Pond is that a large portion of the total phosphorus pool may be refractory (i.e., unavailable), or that chlorophyll values for late summer underestimate true algal biomass as the nature of the cyanophyte cell wall commonly poses difficulties during pigment extraction. Substituting the mean orthophosphorus value observed in Herring Pond (10 ug/l) into the equation yields an expected chlorophyll concentration of 2.6 ug/l. This agrees more closely with observed values.

Chlorophyll a values are often considered indicators of the trophic state of a lake. Fitting a lake or reservoir into any classification system is a subjective process with no single parameter capable of fully "defining" the trophic status of a lake. However, chlorophyll *a* levels are among the more telling parameters. The mean and range of chlorophyll *a* values from Herring Pond correspond to a meso-oligotrophic or moderately fertilized condition (Wetzel 1983).

Chlorophyll and non-living suspended solids are important determinants of water clarity. Secchi disk transparency, a measure of water clarity, ranged from 3.0 to 6.6 m in Herring Pond, with a mean of 4.4 m (Table 3, Appendix B). The predicted mean value for transparency, based on the observed mean chlorophyll value, would be 6.4 m (Appendix C) (Oglesby and Schaffner 1978, Vollenweider 1982). This suggests that observed turbidity in Herring Pond is largely a function of algal densities.

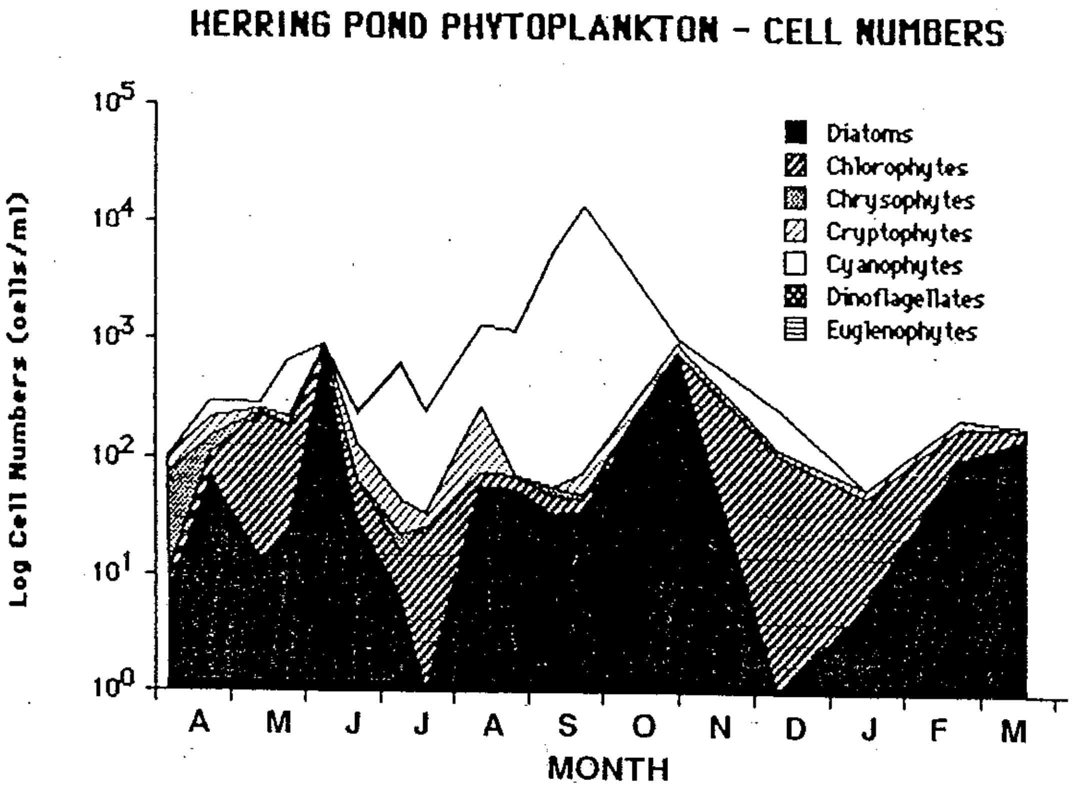
The nature of the phytoplankton community in Herring Pond varied with time over the course of the study year and included members from seven major algal divisions. The seasonal patterns of abundance (cell numbers and cell biomass) are shown in Figure 11. Secchi disk transparency should have been expected to exhibit a pattern inversely related to algal abundance, although it does appear to be inversely related to chlorophyll concentrations.

The most numerous taxa were blue-green algae (Cyanophyta), diatoms (Bacillariophyceae), green algae (Chlorophyceae), golden-brown algae (Chrysophyceae), and cryptophtes (Cryptophyceae). Euglenophytes and dinoflagellates (Pyrrophyta) were also present, but in relatively low numbers, although the latter contributed substantially to the biomass on several occasions. The seasonal progression of dominants was diatoms (winter), dinoflagellates, diatoms, and green algae (spring), green and blue-green algae (summer), and diatoms and green algae (fall). Blue-green algae tend to be dominant at low nitrogen:phosphorus (N:P) ratios (Smith, 1983). The lowest N:P values were observed during the summer months and began to rise during the early fall during which diatom populations became dominant. This pattern is common to many temperate lakes, and reflects the response of the phytoplankton community to changing physical, chemical, and biotic factors (Wetzel 1983, Reynolds 1980).

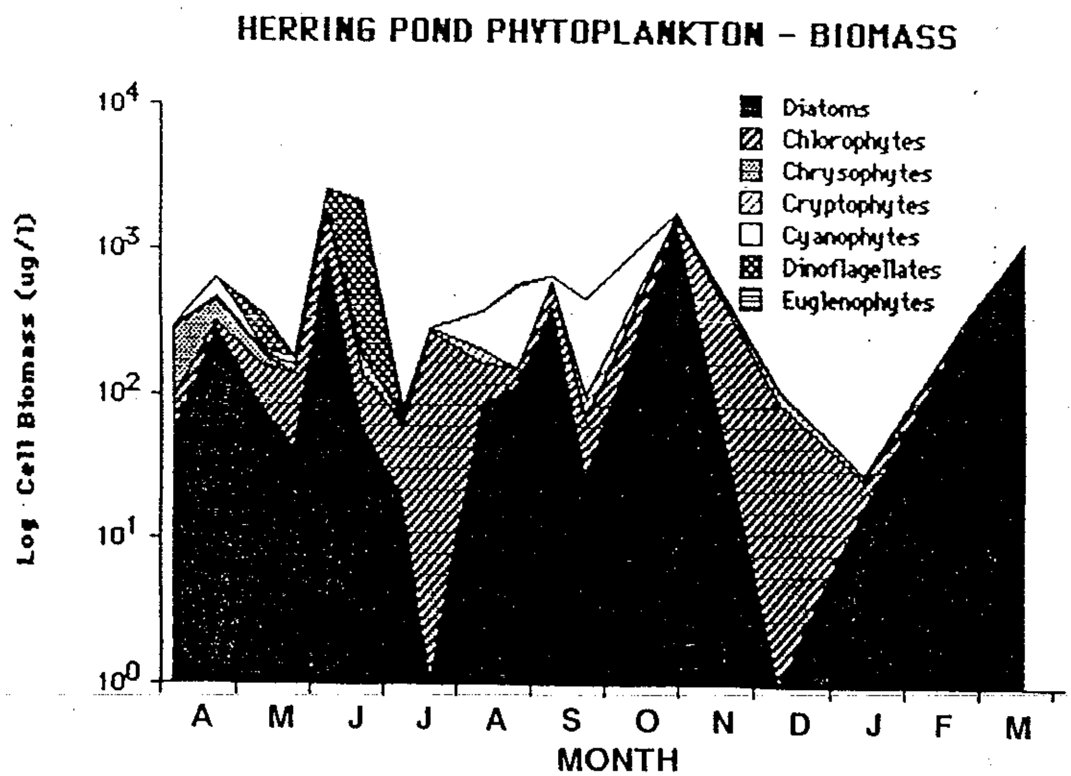
Some of the more numerous algal genera were: cyanophytes, *Anabaena*, *Oscillatoria*, and *Chroococcus*; chrysophytes, *Dinobryon*; cryptophytes, *Cryptomonas*; chlorophytes, *Staurastrum*, *Elakatothrix*, and *Oocystis*; and the diatoms, *Fragilaria*, *Synedra*, and *Asterionella*. The summer blue-green community was dominated primarily by *Anabaena*.

Overall, the phytoplankton community structure and abundance are representative of a meso-oligotrophic system. The limiting factors in Herring Pond are likely to be nutrients (primarily phosphorus) and, less importantly, light, particularly during winter months. Grazing by zooplankton may also subtly influence algal community structure through size-selective grazing.

FIGURE 11



HERRING POND PHYTOPLANKTON - CELL NUMBERS
Log Cell Numbers (cells/ml)
10^5
10^4
10^3
10^2
10^1
10^0
Diatoms
Chlorophytes
Chrysophytes
Cryptophytes
Cyanophytes
Dinoflagellates
Euglenophytes
A M J J A S O N D J F M
MONTH



HERRING POND PHYTOPLANKTON - BIOMASS
Log Cell Biomass (ug/l)
10^4
10^3
10^2
10^1
10^0
Diatoms
Chlorophytes
Chrysophytes
Cryptophytes
Cyanophytes
Dinoflagellates
Euglenophytes
A M J J A S O N D J F M
MONTH

Macrophytes

An extensive in-lake macrophyte and sediment survey was conducted on August 8, 1988. A team from BEC visually inspected the lake bottom via snorkel and SCUBA diving. Macrophytes (large aquatic plants) were identified and their density was mapped.

The taxonomic composition of the macrophytes of Herring Pond is shown in Figure 12. A total of 17 submerged and emergent species were found in Herring Pond or on its shoreline. Identification was according to Fassett (1957). The most widely distributed genera were Ceratophyllum, Potamogeton, Eleocharis, and Najas. Filamentous green algae (chlorophytes) were also observed during this survey, and were observed primarily in the eastern portion of the pond. The central, deep portion of the pond was generally devoid of rooted aquatic plant life. The nearshore zone was inhabited by a variety of plants with the deeper, more offshore zones dominated primarily by Ceratophyllum and Najas.

The density of these plants is indicated in Figure 13. Macrophyte density was generally greatest (50% - 100% cover) from 10 to 100 meters from the shore, decreasing drastically beyond this point. The peripheral shoreline zone was characterized by minimal macrophyte coverage which appeared linked to sandy areas overlain by minimal organically rich sediment.

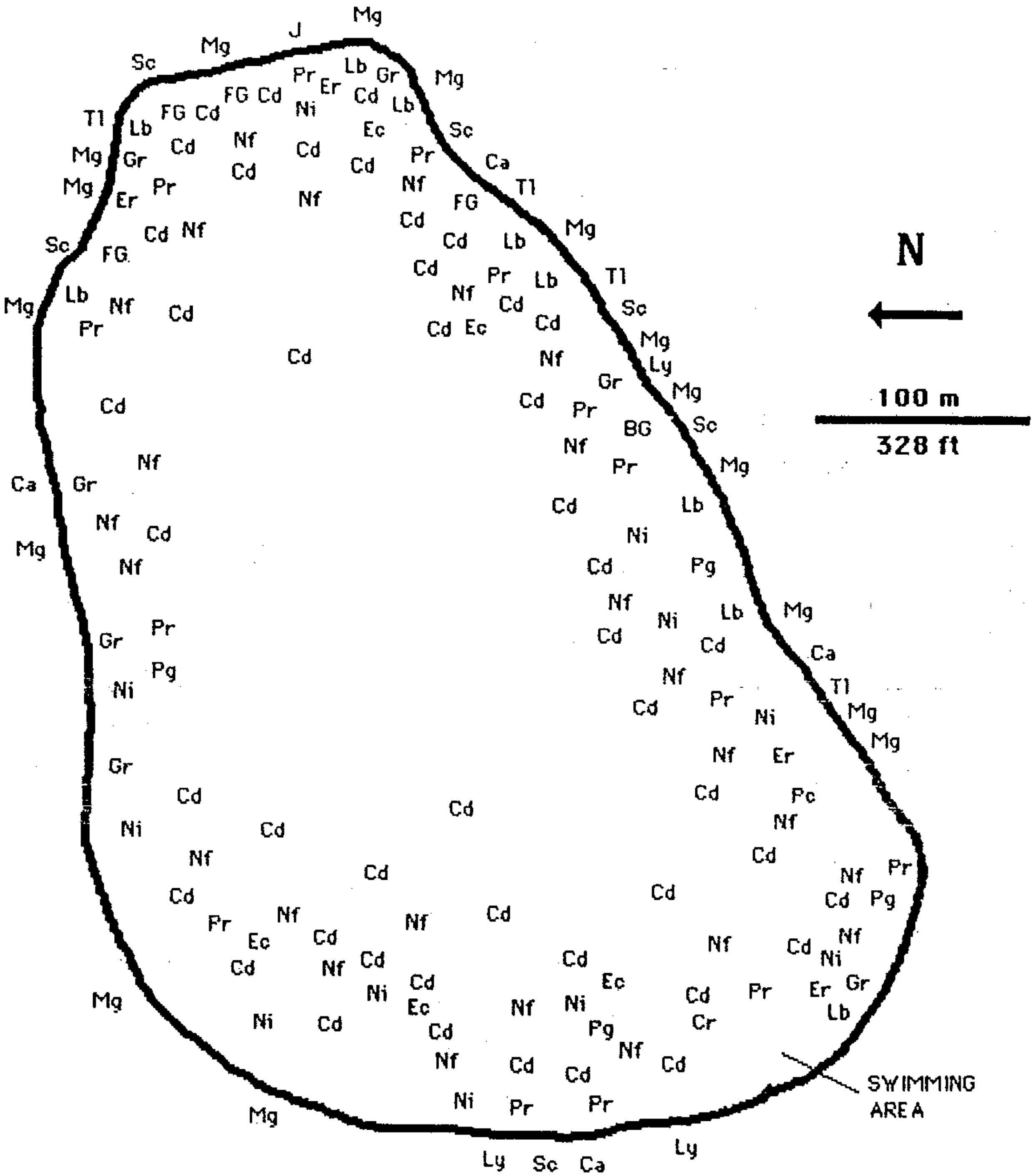
The biomass of macrophytes was measured by setting a large ring (0.88 sq. m) on the bottom of the sediments and harvesting (by diver) all the plants thus enclosed. Depending on the amount of coverage, the macrophyte biomass in Herring Pond ranged from 0 to 2.6 kg/sq.m. The type of dominant macrophyte influenced the amount of biomass present, even in areas of high coverage (75-100%). If Eleocharis was the dominant plant, a virtual carpet of short stems would prevail, without much biomass. In contrast, areas with high coverage of Ceratophyllum would yield greater biomass. Average biomass was moderate relative to many other lakes studied by BEC.

Zooplankton

Zooplankton are of interest because they represent the linkage between the bottom of the food base and higher trophic levels, namely planktivorous fish. Zooplankton were sampled twice during the year, at periods corresponding to late spring (May) and mid-summer (August). The zooplankton community of Herring Pond was primarily dominated by cladocerans, but included copepods and rotifers as well (Appendix B). The most important zooplankton genera were the cladoceran Daphnia in spring, and the cladoceran Eubosmina in summer. In the spring survey, Daphnia was the major contributor (@ 74%) to the total zooplankton biomass, but was virtually absent during the summer survey.

FIGURE 12

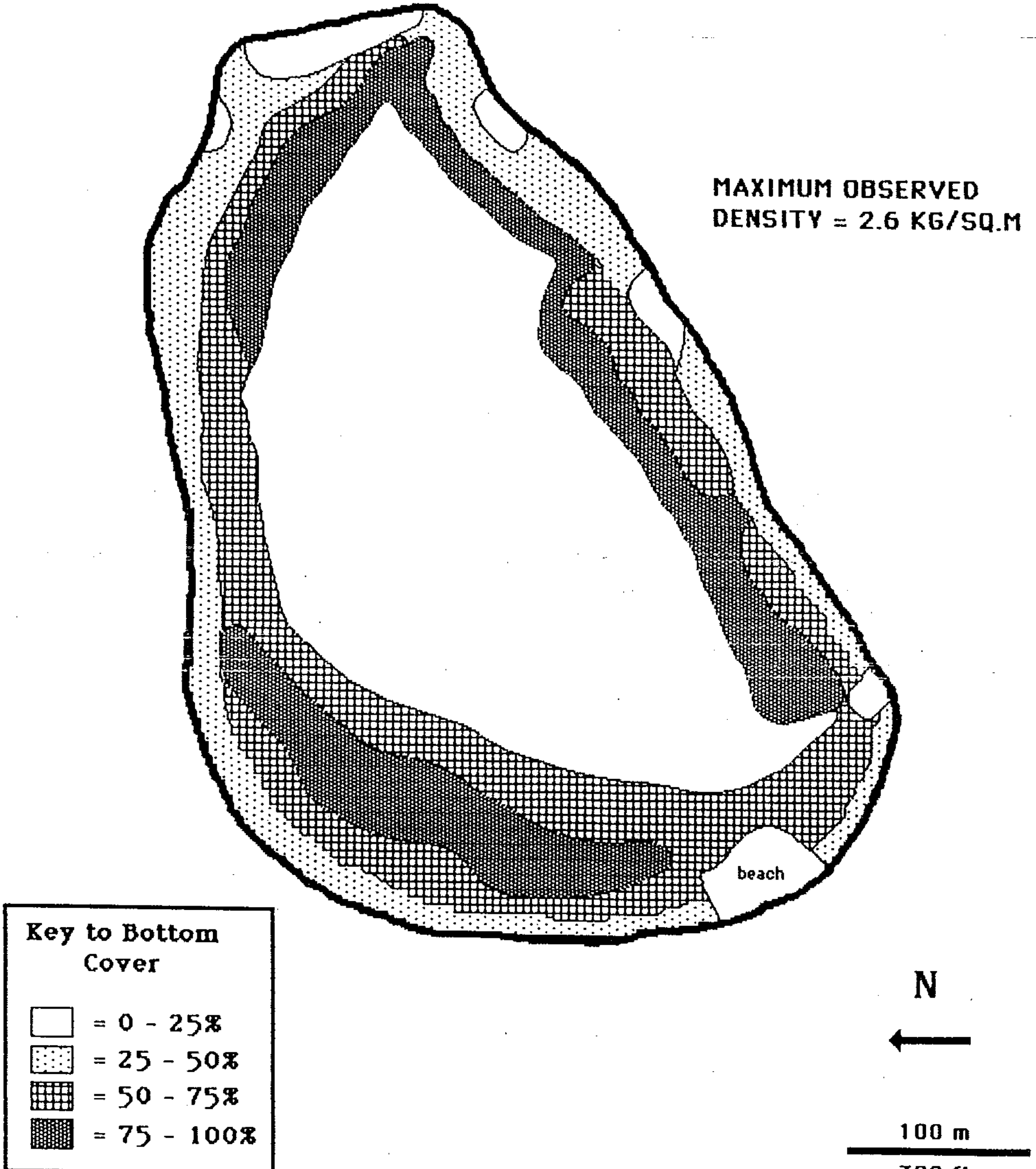
Distribution of Aquatic Macrophyte Taxa in Herring Pond, Eastham, MA



Species List

- BG = Brasenia schreberi
- Ca = Clethra alnifolia
- Cd = Ceratophyllum demersum
- Ch = Chara sp.
- Ec = Elodea canadensis
- Er = Eleocharis robbinsii
- FG = Filamentous green algae
- Gr = Gratiola lutea
- J = Juncus sp.
- Lb = Lobelia dortmanna
- Ly = Lythrum salicaria
- Mg = Myrica gale
- Nf = Najas flexilis
- Ni = Nitella sp.
- Pg = Potamogeton sp.
- Pr = Potamogeton richardsonii
- Sc = Scirpus sp.
- Tl = Typha latifolia

FIGURE 13
Density of Bottom Coverage by Aquatic Macrophytes in Herring Pond, Eastham, MA



Zooplankton communities differed markedly between the two surveys. Numerically, zooplankton were nearly 3.5 times more abundant in spring than in summer, whereas spring zooplankton biomass was nearly 11 times greater than in summer. There was a shift in the mean size from 0.59 mm in spring to 0.30 mm in summer. The overall impression is that of a relatively unstable zooplankton community, and one that is possibly impacted heavily by fish predation with respect to individual size and composition. The observed shift in mean size of zooplankton may be reflective of a seasonally changing algal assemblage and size selective grazing behavior of the different cladoceran genera. Alternatively, the changing size structure of the zooplankton community may be controlled by the predatory activities of abundant planktivorous fish, particularly alewife. If so, this would lead to the conclusion that the size of the zooplankton community is experiencing both bottom up (food availability) and top down (fish predation) control. However, the low summer biomass and near absence of zooplankters larger than the minimum size consumable by alewife strongly suggests fish predation as the controlling influence in this system. Departure of young alewife in fall and rejuvenation by resting eggs are important factors in the apparent spring recovery of Daphnia.

Macroinvertebrates

The invertebrates of Herring Pond were qualitatively sampled by dip net and visual observation. A limited variety of taxa were present in Herring Pond, and no single taxa was observed to be especially abundant. Molluscan invertebrates in Herring Pond were represented by fresh water clams (Unionidae). Other frequently observed invertebrate inhabitants included pillow mites (Hydracarina) and crayfish (Cambaridae).

Fish

Of the 262 fish caught during the Herring Pond fishery survey conducted by BEC, seven species were represented (Table 7a). Included among these were yellow perch (Perca flavescens), pumpkinseed (Lepomis gibbosus), golden shiner (Notemigonus crysoleucas), killifish (Fundulus diaphanus), american eel (Anguilla rostrata), alewife (Alosa pseudoharengus), and a solitary chain pickerel (Esox niger).

The survey conducted by the Massachusetts Division of Fisheries and Wildlife (MDFW) in June, 1988, found many of the same fishes as the BEC survey with a few exceptions. Most notably, The MDFW observed both rainbow trout (Onchorynchus mykiss) and brown trout (Salmo trutta) in Herring Pond, whereas these species were not captured during the BEC survey; these species were observed by divers and caught by fishermen while BEC personnel were present, however. Alewife were not observed in the pond by the MDFW, but a few were observed in the herring run. The results of the MDFW survey are presented in Table 7b.

TABLE 7a

HERRING POND FISH SURVEY. (8/8/88) (BEC)

FISH SPECIES	COMMON NAME	No. CAUGHT	WT.(kg) CAUGHT	% OF TOTAL No.	% OF TOTAL WT.	MEAN LENGTH(mm)	MEAN WT. (g)	GROWTH RATE
Alosa pseudoherengus	Alewife	6		2.2		86		
Anguilla rostrata	American eel	11		4.2		381		
Esox niger	Chain Pickerel	1		.3		233		
Fundulus diaphanus	Killifish	37		14.0				
Lepomis gibbosus	Pumpkin Seed	96		37.0		121		
Notemigonus crysoleucas	Golden Shiner	89		34.0		163		
Perca flavescens	Yellow Perch	22		8.3		148		
	Total	262		100%				

TABLE 7b

HERRING POND FISH SURVEY. (6/13/88) (MDFW)

FISH SPECIES	COMMON NAME	No. CAUGHT	WT.(kg) CAUGHT	% OF TOTAL No.	% OF TOTAL WT.	MEAN LENGTH(mm)	MEAN WT. (g)	GROWTH RATE
Esox niger	Chain Pickerel	21	3.8	6.4		296	181	
Fundulus diaphanus	Killifish	7		2.2				
Lepomis gibbosus	Pumpkin Seed	188	10.7	57.5		124	57	
Notemigonus crysoleucas	Golden Shiner	21		6.4				
Perca flavescens	Yellow Perch	65	4.9	19.9		174	75	
Morone americana	White Perch	15		4.6				
Salmo trutta	Brown Trout	3		.9				
Onchorynchus mykiss	Rainbow Trout	6		1.8				
Ictaluras nebulosus	Brown Bullhead	1		.3				
	Total	327		100%				

The rather dense growths of coontail (Ceratophyllum demersum) in the offshore waters provide ample cover for fish. These growths do not present a nuisance to boaters or bathers, and a healthy fishery requires some measure of macrophyte cover. These densely covered littoral areas are ideal for species such as pumpkinseed and golden shiners, whereas the deeper, more offshore pelagic zones are better suited for yellow perch and alewife. Killifish are most often associated with the shallow shoreline areas.

Critical to the evaluation of the Herring Pond fishery is the assessment of the magnitude of the alewife spawning run and the impact of this species on the pond's zooplankton community. The spring spawning run was monitored and logged by Natural Resource Department personnel of the Town of Eastham in April and May of 1988 and 1989. Only four alewife were observed in the channel in 1988, and low water levels prevented access to the pond. The 1989 run was much more successful.

The Natural Resource Department also collected nineteen adult alewife and provided these along with the herring log to BEC personnel for examination. This allowed for the estimate of the number of alewife entering Herring Pond, and an estimate of the reproductive potential of the population. The latter was facilitated by examining the ovaries of adult female alewife to estimate the number of eggs entering the pond during the run (Table 8).

Spawning female alewife were carrying an average of about 89,000 eggs. Sea-run females typically produce 60,000 to 100,000 eggs (Scott and Crossman, 1979). Eggs are broadcast at random, and hatching takes place in about 6 days at 15.6^{o} C. It is estimated that 240 to about 720 alewife entered Herring Pond during the spawning runs. A male:female ratio of about 1:1 suggests that between 10 million and 32 million alewife eggs were spawned in Herring Pond during the 1989 spawning run. Assuming a survival rate of between 0.1 percent and 1.0 percent, an average of 105,000 likely survive to juvenile stages (range = 10,000 to 320,000).

Sediment Analysis

The depth of the soft sediment in Herring Pond was mapped in August 1987. The sediment layer was measured by a diver pushing a metal rod into the bottom to the depth of first refusal. Notes were made about the nature of the underlying substratum. The depth of the sediments is shown in Figure 14, and the volume is shown in Table 9. A typical transect of the pond sediments would reveal sandy nearshore zones with minimal soft sediment cover giving way to deeper zones characterized by increasing soft sediment depths. From a relative standpoint, the soft sediment volume in Herring Pond is minimal.

TABLE 8

HERRING POND HERRING RUN STATISTICS

Number of fish taken = 17

Female/Male ratio = 1.13

Range of weights = 140 - 232 g

Average weight of adults = 191 g

Range of lengths = 229 - 305 mm

Average length of adults = 267 mm

Average weight of eggs/female = 36 g

Average percent of female body weight represented by eggs = 17% (range 14.4 - 20.3%)

Number of eggs/g of eggs = 2,480

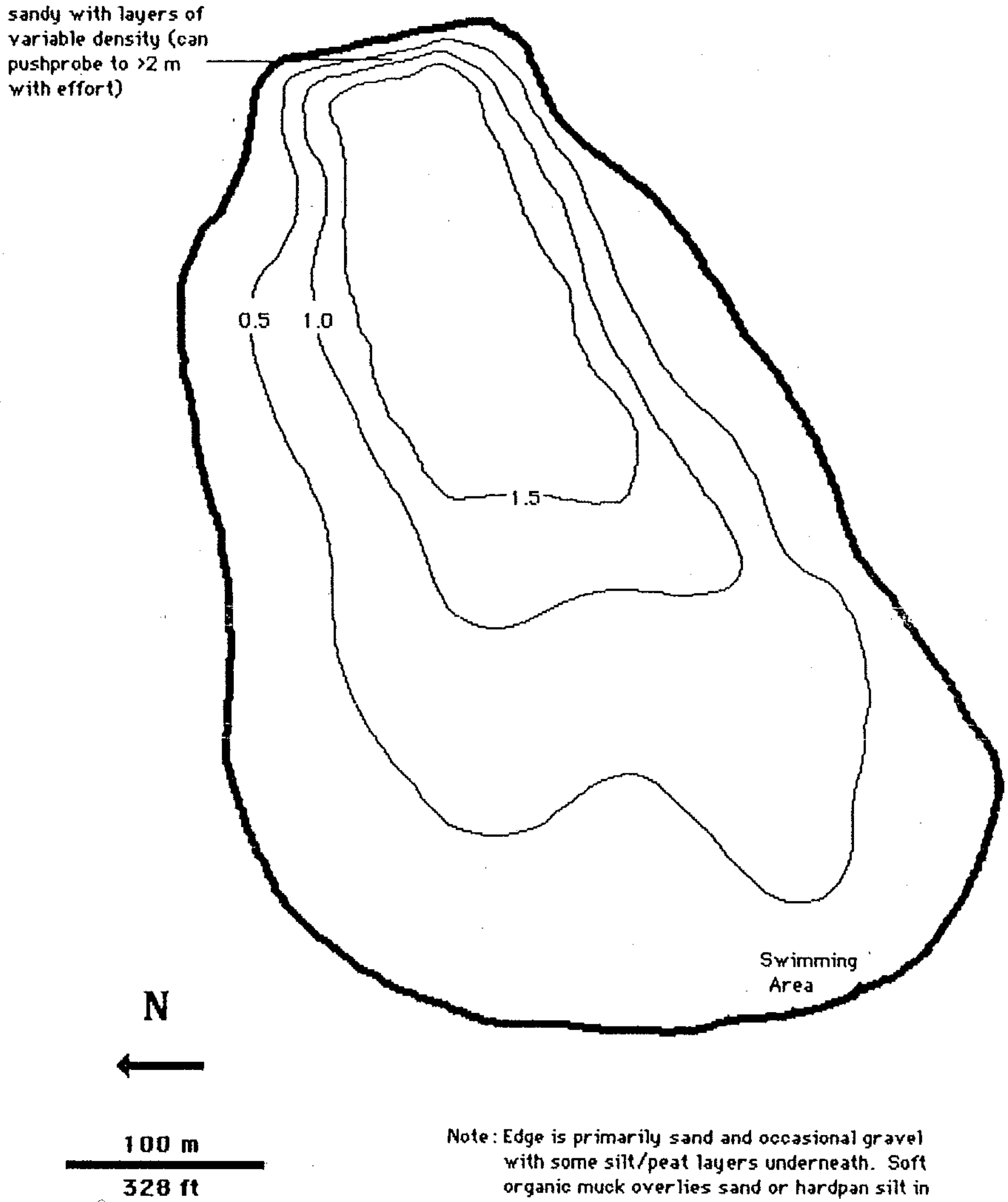
Average eggs/female = 89,280

Range of eggs/female = 71,920 - 119,040

FIGURE 14

Soft Sediment Depth in Herring Pond, Eastham, MA

(All contours given in meters)



Note: Edge is primarily sand and occasional gravel with some silt/peat layers underneath. Soft organic muck overlies sand or hardpan silt in the central portion of the pond, with a rapid transition between the edge and central portions of the pond

TABLE 9

SOFT SEDIMENT VOLUME IN HERRING POND

Soft Sediment Depth Range (M)	Volume Contained Within Range (CU.M)
0.0 - 0.5	19659
0.5 - 1.0	39537
1.0 - 1.5	24352
>1.5	38743
Total	>122291

Sediment samples were taken from the pond at the in-lake sampling station (HP-2; position indicated on Figure 1) via coring device operated manually by a diver. The chemical characteristics of the samples are shown in Table 10. The heavy metal contents were compared to the USGS (1977) flag limits for sediment contaminants and to the MDWPC (1979) criteria for sediments. USGS flag limits were not exceeded by any of the selected parameters. Values for cadmium (5.1 mg/kg) fall into Category II (5-10 mg/kg) under Massachusetts state criteria, whereas arsenic values were somewhat high at 51.0 mg/kg, placing it in Category III (>20 mg/kg). Although there are no existing flag limits for total iron, the observed values were moderately high. Total volatile solid content (% organic matter) places the sediments into the Type C material category. Other values indicated no serious pollution of the sediments, placing the sediments in the MDWPC Category I. The reason for the abundance of arsenic in the sediments is not known.

Comparison with other studies

The earliest documented survey of Herring Pond was conducted by the Massachusetts Division of Fisheries and Wildlife (MDFW) in July of 1911. This survey was very general as most information gathered was of a qualitative nature. Records of this survey report that the pond possesses an abundant cover of pond weed (*Potamogeton perfoliatum*) and milfoil (*Myriophyllum* sp.). The fish community was represented by pickerel, eel, red perch, and catfish. The report refers to past reports of herring inhabiting the pond, but states that at the time the herring run channel was too clogged. Turbidity, probably referring to secchi disk transparency, was noted at 19 ft (6.4 m) . The surrounding shoreline area was characterized as mostly pasture land, except for woods along the southern shore of the pond, and mostly pebbly. The maximum depth observed was 33 ft (10.1 m) and the average depth was 21 ft (6.4 m).

In a later survey (August 1948), MDFW noted a maximum depth of 35 ft (10.7 m), but a mean depth of only 14 ft (4.3 m). Transparency was noted as 18 ft (5.5 m). Plankton biomass was estimated at 0.773 cc. per cubic meter, and probably refers to total plankton (phyto- + zoo-). This translates to an rather high 773 ug/l assuming plankton specific density approximates unity (i.e., @ 1g/ml). At this time, the shoreline area surrounding Herring Pond was primarily open fields with few residences. A public right-of-way was established to allow easy access from a dirt road (Crosby Rd.) connecting Bridge Road to Herring Brook Road. Seining operations and gill netting revealed an abundance of banded killifish and alewife. Emergent, floating and submerged aquatic vegetation was common. The study concluded that Herring Pond was not suitable to support smallmouth bass, which had previously been stocked (1920), and not adapted for the growth and reproduction of yellow perch and chain pickerel. Recommendations, however, called for the management of Herring Pond for the latter two species.

TABLE 10

CHEMICAL CHARACTERISTICS OF HERRING POND SEDIMENTS

Parameter	Value at stations sampled in August of 1988
	HP-2
Total Volatile Solids (%)	11.0
Nitrate Nitrogen (mg/kg)	87
Total Kjeldahl-Nitrogen (mg/l)	4,680
Total Phosphate (mg/kg)	21.5
Oil & Grease (mg/kg)	63
Total Metals:	
Arsenic	51.0
Cadmium	5.1
Chromium	30
Copper	25
Iron	8,327
Manganese	164
Nickel	1
Lead	45
Vanadium	18
Zinc	53
Mercury	<0.04

Herring Pond was reclaimed by MDFW in October 1958, and standing crop was estimated at 40 pounds per acre. In November 1958, 3,000 fingerling smallmouth bass were stocked in Herring Pond. It was suggested that the alewife which spawn in the pond in abundance would provide an ample food supply for the smallmouth bass. In the years 1961-63, attempts were made to establish a trout fishery in Herring Pond as brown trout was stocked in the pond during these years. MDFW has frequently stocked Herring Pond with various trout species since 1980. The number of fish stocked varied, but was generally between 1,000 and 1,500 fish per year.

Herring Pond was surveyed again by the Massachusetts Division of Water Pollution Control (MDWPC, 1979) in July of 1979, to establish baseline water quality conditions and to obtain necessary information related to priority ranking of lakes and ponds for which Phase I (Diagnostic/Feasibility) study funds had been requested. Sampling stations were established in the central portion of the pond and at the outlet (comparable to HP-2 and HP-1 in the BEC study, respectively). An in-lake temperature profile indicated that the pond was stratified with a maximum temperature of 25.5^{o} C and a minimum of 11.1^{o}C. The thermocline was detected at a depth of about 6.5 m. Dissolved oxygen concentrations ranged from 0.0 to 9.4 mg/l. Specific conductance was between 680 and 740 umhos/cm, and the pH ranged from 6.6 to 8.8 std. units.

Nutrient values were slightly greater than observed during the BEC study. Nitrate-nitrogen was undetectable, but ammonia-nitrogen ranged from 0.00 mg/l in surface samples to 0.79 mg/l in bottom samples. Total kjeldahl nitrogen was also greatest in bottom samples and ranged from 0.78 mg/l to 2.4 mg/l. Total phosphorus ranged from 90 to 160 ug/l.

Other chemical parameters were measured throughout the system; chloride was found at about 175 mg/l, hardness from 66 to 117 mg/l; and total alkalinity from 15 to 28 mg/l. Comparison of these values with the present study does not indicate any appreciable changes in these parameters. Fecal coliform was found at low levels (<5/100 ml to 20/100 ml).

The macrophyte survey conducted by the MDWPC identified 10 aquatic and wetland species (MDWPC, 1979). The more important aquatic genera were _Lobelia_, _Najas_ and _Gratiola_. The pattern of density shows greatest coverage found around the southeast shore, with a less dense patch along the north and west shores.

Comparing these results with the BEC study conducted in August 1988, a greater density of macrophytes was found around the southern shore of the pond by BEC. Differences may be due to varying methodology or natural shifts in plant density. A total of 18 species were identified in the BEC study, with general but not complete agreement with the previous survey. Important plant genera found in the BEC study included _Ceratophyllum_ and _Nitella_ in addition to those included by the MDWPC.

Questionnaire Survey

A watershed resident questionnaire was distributed throughout the Herring Pond watershed in August, 1988. Responses to this questionnaire are helpful in evaluating the preferences and practices of potential pond users. Approximately 49 questionnaires were distributed and 13 responses were completed for a 27% return rate. Interest in responding appeared to be a function of distance from the pond. Eight of the thirteen respondents live within one hundred feet of the pond. Thus, the survey has a high representation of the abutting residences, which are likely to have the greatest influence on the pond.

Thirty-eight percent of the responding households are permanent year-round residences (Table 11). The usage rate of Herring Pond is 100%, with frequency of use divided between daily (62%), weekly (23%) and monthly (15%). The average occupancy rate is 2.6 persons per household. The range of occupants is from 1 to 4 persons per dwelling.

The preferred recreational activity is swimming (100%), followed by fishing (46%) and sailing (31%). Other recreational activities identified include windsurfing (15%) and canoeing (8%).

Drinking water needs are met by well water (92%), as are washing water needs, and by bottled water (8%). These wells tend to be somewhat shallow, with a mean depth of 42 ft, and most are within 250 ft of the lake.

All of the respondents rely on on-site wastewater disposal systems, a slim majority of which are a tank and leachfield system (58%). Nearly as common (42%), cesspools are used for disposal of wastes. The mean age of these systems is 13.9 years. Most (75%) are within 250 ft of the pond, and more than half of these (58%) are within 100 ft of the pond. The average time span since the systems have been inspected or pumped was more than 4 years with a range of less than one to twenty years.

Fertilization of private lawns was practiced by about 18% of the respondents. Garbage grinders were relatively rare (8%), but a majority of the households did have washing machines (83%). Of those using washing machines on the premises, most (92%) used a phosphate-containing detergent. About 58% of the dishwashing detergents reported were phosphate-containing brands.

Despite the modest rate of return, the results of the questionnaire survey appear to adequately reflect residential conditions in the Herring Pond watershed. Field investigation and discussions with watershed residents by BEC personnel revealed no unusual concerns or features relating to Herring Pond.

TABLE 11

SUMMARY OF QUESTIONNAIRE RESPONSES FOR THE HERRING POND STUDY AREA

# responding	13
% responding	27%
Lake usage rate	
Daily	62%
Weekly	23%
Monthly or less	15%
Preferred activities	
Swimming	100%
Sailing	31%
Windsurfing	15%
Fishing	46%
Canoeing	8%
Persons/household	
Mean	2.6
Range	1-4
Residency (months/yr)	
12	38%
Less than 12	62%
Property distance from lake (ft)	
0′-100′	62%
100′-500′	15%
>500′	8%
No response	15%
Drinking water source	
On-site well	92%
Bottled water	8%
Washing water source	
On-site well	100%
Waste disposal system	
Cesspool	42%
Tank and leachfield	58%

TABLE 11 - CONTINUED

On-site disposal system	
Age (yrs)	
Mean	13.9 yr
Range	2-25 yr
Distance from lake (ft)	
0'-50'	8%
50'-100'	50%
100'-250'	17%
> 250'	25%
Years since last inspection/pumping	
Mean	4.25 yr
Range	1-20 yr
On-site wells	
Depth (ft)	
Mean	42
Range	15-100
Distance from lake (ft)	
0-50	8%
50-100	42%
100-250	25%
250-500	25%
Well location relative to waste disposal system	
Upslope	40%
Downslope	20%
Alongside	40%
Fertilizer used on lawn	18%
Washing machine used	83%
Garbage disposal used	8%
Phosphate detergent used	
Clothes	92%
Dishes	58%

HYDROLOGIC BUDGET

The hydrology of Herring Pond is determined by direct precipitation onto the pond surface, contributions from groundwater seepage, and to a lesser extent runoff from the watershed. Losses from the pond occur through surface outflow and evaporation. A schematic depiction of possible hydrologic pathways is presented in Figure 15, but not all are employed at Herring Pond.

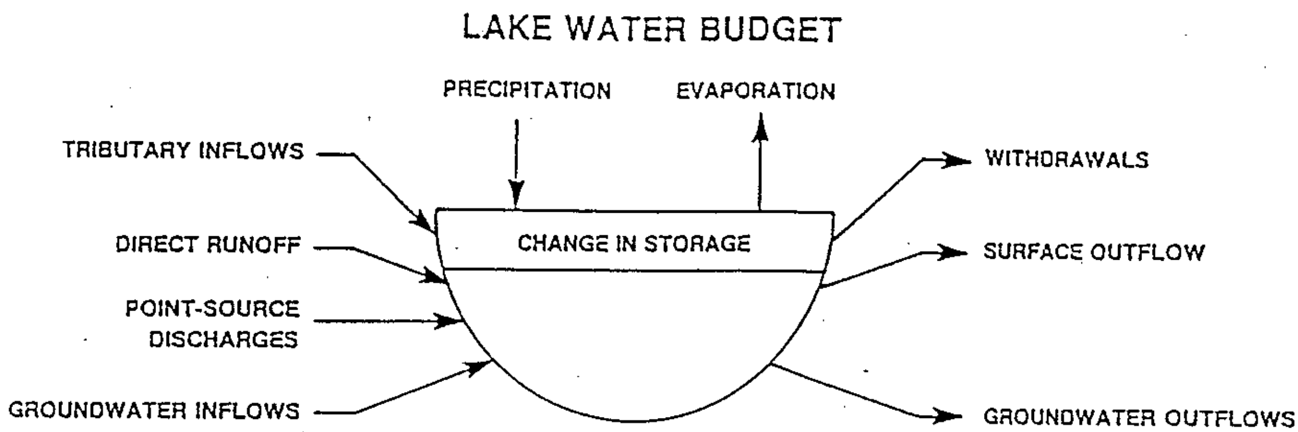
Several different methods were used to estimate flow through the Herring Pond system. Calculations for the different methods are presented in Appendix C. One estimate of mean flow was determined by using the area of the watershed and applying yield coefficients, factors which relate the amount of flow to watershed features. Given the watershed area of 53.0 ha (131 ac), and a yield coefficient of 0.7 to 1.0 cu.m/min per square kilometer (1.0 to 1.5 cfs per square mile) of drainage area (Sopper and Lull 1970, for similar watersheds), an average flow of 0.35 to 0.52 cu.m/min (around 0.30 cfs) would be expected to pass through Herring Pond.

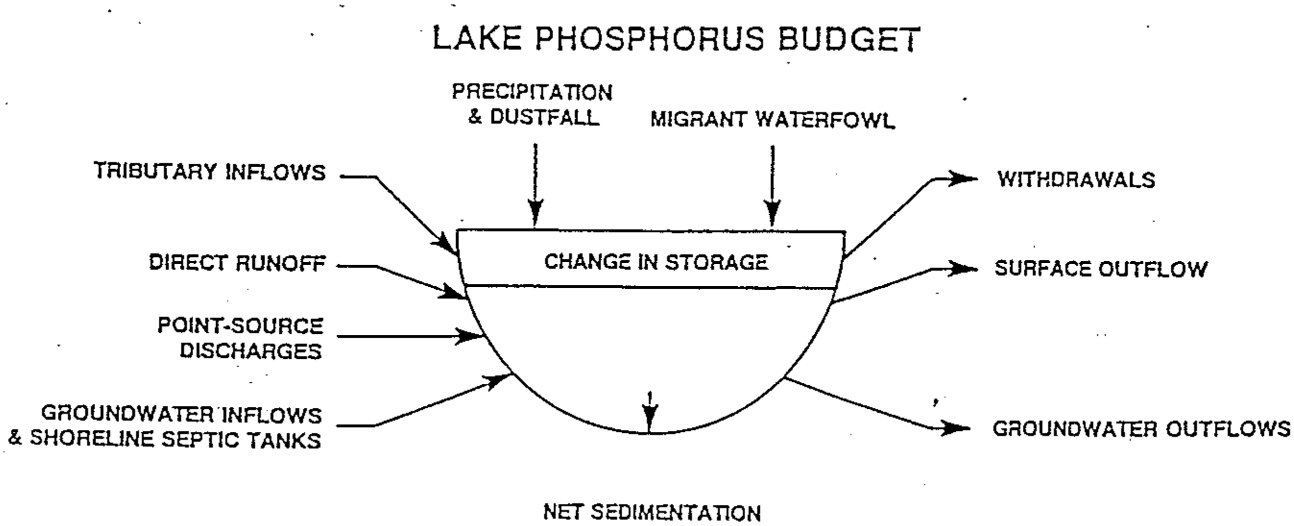
Runoff production in New England averages between 51-61 cm/yr, or 20-24 in/yr (Higgins and Colonell, 1971). If contributions from direct precipitation onto the pond and evaporative losses from same are included, then flows of 0.62 to 0.72 cu.m/min would be expected. When dealing with watersheds as small as the Herring Pond watershed, estimates of flow based on model equations are likely to be subject to substantial error. However, when comparing these estimates to calculations based upon empirical data, distinguishing features (e.g., topography, land use, and soils) of the particular watershed may be elucidated.

Actual measurements of water inputs to Herring Pond included determination of direct precipitation inputs and estimation of groundwater seepage. Precipitation is likely to be a major determinant of groundwater inseepage and consequently influences the hydrologic budget to a great extent. Data available from the National Oceanographic and Atmospheric Administration (NOAA) allows evaluation of long-term trends in the Eastham area. The long-term (30-year) monthly precipitation pattern (Figure 16) indicates that precipitation is distributed relatively evenly throughout the year. Because Chatham, MA, the nearest weather station to Eastham, lacks long-term precipitation records, long-term precipitation was composited from other regional stations. The mean annual precipitation level is 114.3 cm, with a composited maximum of 163.5 cm and a minimum of 68.3 cm.

FIGURE 15

SCHEMATIC WATER AND PHOSPHORUS BUDGET

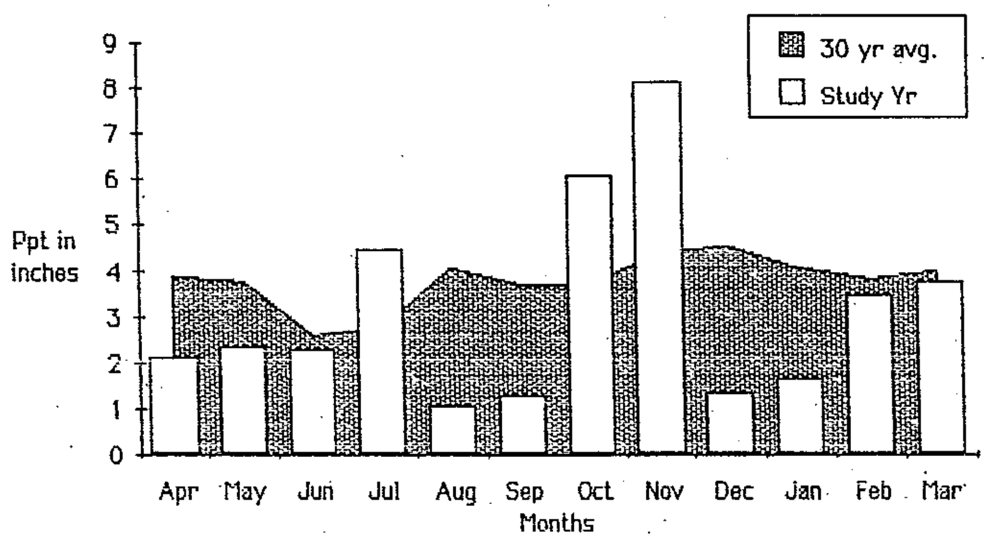




Taken from : United States Environmental Protection Agency (1988) The Lake and Reservoir Restoration Guidance Manual. Washington, D.C.

FIGURE 16

PRECIPITATION CHARACTERISTICS OF THE EASTHAM, MA, AREA



Long-term mean = 114.3 cm

Long-term max. = 163.5 cm

Long-term min. = 68.3 cm

Study Year total = 96.3 cm

Long-term trends frequently bear little resemblance to annual patterns, however. The total precipitation during the study year (1988-1989 for routine monitoring purposes) was 96.3 cm, substantially below the long-term average. Three months exhibited distinctly above average precipitation and four months displayed precipitation far below average. A degree of temporal variability resulted from the scattered nature of months exhibiting above and below average precipitation.

Direct measurement of groundwater seepage was conducted in both spring (Table 12) and in mid-summer (Table 13) using seepage meters. Seepage meter locations are shown in Figure 17. Ideally, this will provide a reasonable range of seepage values for both wet and dry periods as it is assumed that groundwater seepage is directly related to the precipitation regime. Examination of monthly precipitation data for the study year, however, revealed that July was a rather wet month, although the resulting early-August seepage values were substantially less than during the spring survey. The resulting estimates of daily seepage required no adjustments and were assumed to be acceptably accurate.

Partitioning the total inflow to and outflow from Herring Pond is made difficult by the low magnitude of the total throughflow and the absence of a regular water source of substantial nature. Calculations used to derive the various components are presented in Appendix C. The partitioned input values are summarized in Table 14 and Figure 18. Groundwater seepage appears to be the major source of water (56.5%) to Herring Pond. Direct precipitation is also very important, accounting for the remaining 43.5% of the annual hydrologic income. The outlet structure, HP-1, serves as a potential source of water to Herring Pond, but this only occurs during a rare storm tide and was not observed by BEC during this study.

The calculated total inflow is 0.736 cu.m/min, although there is unquestionably substantial variability associated with this estimate. A range of perhaps 0.5 to 1.3 cu.m/min is appropriate for general discussion, but the variability inherent in the precipitation and groundwater components suggests an even greater possible range. In an absolute sense, flow into Herring Pond is apparently quite low.

Sources of outflow include evaporation across the pond surface and direct flow through the outlet structure. Groundwater recharge is an additional source of outflow from Herring Pond, and was observed to be greatest during the summer seepage survey. The mostly sandy bottom of the pond allows groundwater inflow and outflow. The pond edge has a hydraulic gradient suited more for inflow during spring months and outflow during summer. The greatest variability was observed along the eastern periphery of the pond where the groundwater elevation would be expected to

TABLE 12

HERRING POND SEEPAGE (#1)

Date	Meter #	Dist. from shore (M)	Seepage time (HR)	Volume change (L)	Seepage (L/SQ.M/D)
05/21/88	1	1.5	3.80	.64	16.17
	2	8.8	3.80	.67	16.93
	3	1.8	3.80	2.50	63.16
	4	7.3	3.80	.64	16.17
	5	3.0	3.80	.41	10.36
	6	12.5	3.80	.05	1.26
	7	1.8	3.80	-.48	-12.13
	8	13.7	3.80	-.35	-8.84
	9	.9	3.90	.97	23.88
	10	10.7	3.90	.42	10.34
	11	2.7	3.80	.14	3.54
	12	11.0	3.80	.11	2.78
05/22/88	13	1.5	3.40	.25	7.06
	14	11.0	3.40	-.07	-1.98
	15	2.7	3.40	.85	24.00
	16	10.1	3.40	.31	8.75
	17	1.8	3.70	.46	11.94
	18	7.3	3.70	.85	22.05
	19	1.2	3.70	0.00	0.00
	20	11.0	3.80	1.18	29.81
	21	1.8	3.80	.71	17.94
	22	11.9	3.80	.93	23.49
	23	1.2	3.80	1.26	31.83
	24	10.1	3.80	.98	24.76

HERRING SEEPAGE CALCULATIONS

TRANSECT (METER #'S)	SEEPAGE L/SQ.M/D	LENGTH ALONG SHORELINE (M)	DISTANCE FROM SHORE (M)	AREAL SEEPAGE (L/D)		
1-2	16.5	132	35	76449		
3-4	39.7	132	50	261777		
5-6	5.8	132	70	53689		
7-8	-10.5	132	90	-124552		
9-10	17.1	132	100	225822		
11-12	3.2	132	65	27095		
13-14	2.5	132	30	10063		
15-16	16.4	132	35	75659		
17-18	17.0	132	40	89731		
19-20	14.9	132	12	23610		
21-22	20.7	132	10	27345		
23-24	28.3	132	15	56024		
			INFLOW	927263	=	.644 CU.M/MIN
			OUTFLOW	-124552	=	-.086 CU.M/MIN

TABLE 13

HERRING POND SEEPAGE (#2)

Date	Meter #	Dist. from shore (M)	Seepage time (HR)	Volume change (L)	Seepage (L/SQ.M/D)
08/08/88	1	2.1	2.70	.12	4.27
	2	7.6	2.70	.12	4.27
	3	1.8	2.80	.44	15.09
	4	7.6	2.80	.22	7.54
	5	1.5	2.90	.24	7.94
	6	7.0	2.90	.39	12.91
	7	2.7	2.90	-.20	-6.62
	8	10.1	2.90	.28	9.27
	9	2.7	2.90	-.06	-1.99
	10	7.6	2.90	-.22	-7.28
	11	2.1	2.90	.76	25.16
	12	8.8	2.90	.80	26.48
	13	2.1	3.80	.03	.76
	14	10.7	3.70	-.04	-1.04
	15	1.8	3.60	.49	13.07
	16	7.0	3.60	.14	3.73
	17	1.8	3.80	-.38	-9.60
	18	7.6	3.80	.17	4.29
	19	3.4	3.90	-.49	-12.06
	20	11.3	3.80	-.11	-2.78
	21	3.4	3.80	-.22	-5.56
	22	9.8	3.90	-.04	-.98
	23	4.0	3.90	.36	8.86
	24	11.0	3.90	.48	11.82

HERRING SEEPAGE CALCULATIONS

TRANSECT (METER #'S)	SEEPAGE L/SQ.M/D	LENGTH ALONG SHORELINE (M)	DISTANCE FROM SHORE (M)	AREAL SEEPAGE (L/D)		
1-2	4.3	132	35	19712		
3-4	11.3	132	50	74674		
5-6	10.4	132	70	96351		
7-8	1.3	132	90	15731		
9-10	-4.6	132	100	-61175		
11-12	25.8	132	65	221542		
13-14	-.1	132	30	-554		
15-16	8.4	132	35	38808		
17-18	-2.7	132	40	-14006		
19-20	-7.4	132	12	-11754		
21-22	-3.3	132	10	-4318		
23-24	10.3	132	15	20470		
			INFLOW	487288	=	.338 CU.M/MIN
			OUTFLOW	-91807	=	-.064 CU.M/MIN

FIGURE 17

LOCATION OF SEEPAGE METERS
IN HERRING POND
ON MAY 21-22 & AUGUST 8,1988

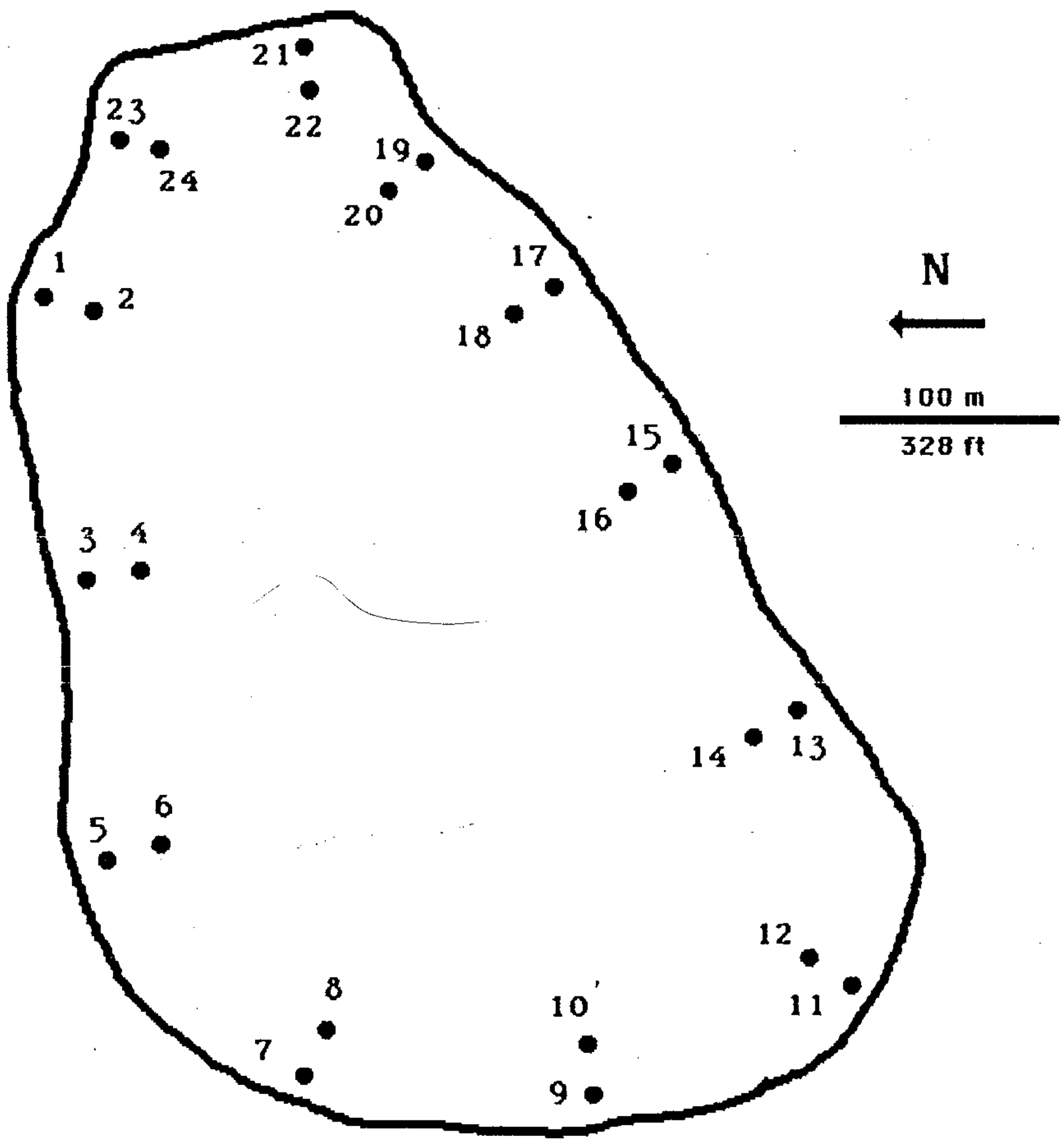
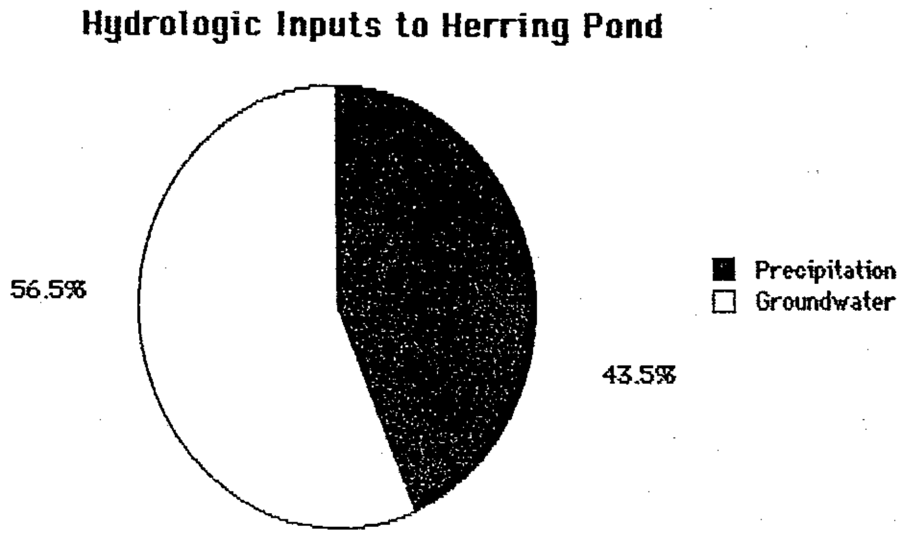


TABLE 14

HYDROLOGIC BUDGET FOR HERRING POND

Inputs	cu.m/min	% of Total
Precipitation (Direct Input)	0.32	43.5
Groundwater (Direct Input)	0.42	56.5
Total	0.74	100
Outputs		
Evaporation	0.22	29.7
Groundwater (outseepage)	0.46	62.2
Outflow (through HP-1)	0.06	8.1
Total	0.74	100
Detention Time	**Years**	**Days**
Mean	2.81	1,024
Annual Range	1.6 - 4.2	584 - 1,533
Response Time	1.05 - 1.75	383 - 639
Flushing Rate	**Per Year**	
Mean	0.36	
Annual Range	0.24 - 0.63	

FIGURE 18


Hydrologic Inputs to Herring Pond
56.5%
43.5%
Precipitation
Groundwater

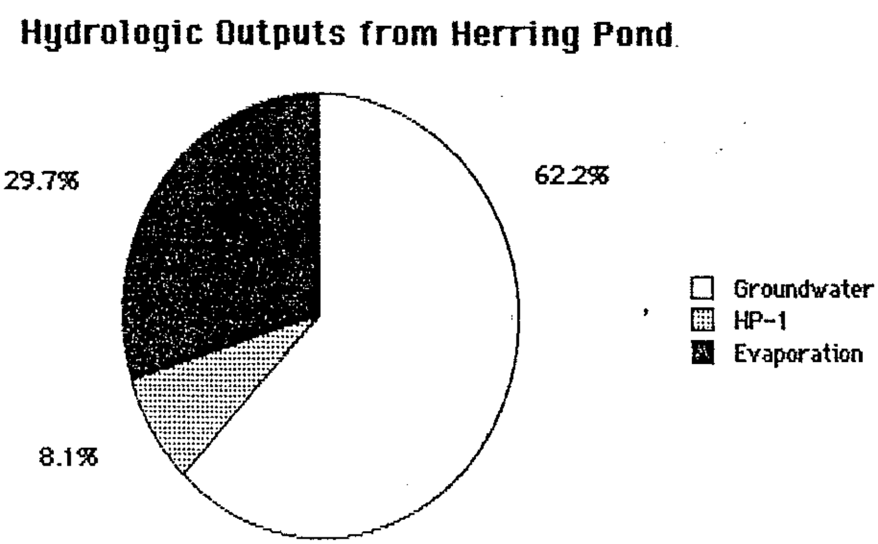

Hydrologic Outputs from Herring Pond
29.7%
62.2%
8.1%
Groundwater
HP-1
Evaporation

exhibit the greatest fluctuations. Examination of groundwater elevation in the permanent monitoring wells (Table 6, Figure 10) during the spring of 1989 revealed higher elevations along the eastern portion of the watershed. This would suggest that the direction of groundwater flow in the watershed would be from northeast to southwest. Direct measurement of seepage confirmed that seepage along the eastern periphery of the pond was greatest during spring months, but also revealed relatively constant inseepage along the southwestern periphery. As noted in the groundwater assessment section of this report, seepage measurements combined with interstitial porewater chloride concentration reveal that Herring Pond is subject to saltwater intrusions along the southwestern periphery of the pond. Therefore, seasonal variability in groundwater inseepage appears to be greatest around the eastern periphery of Herring Pond.

Evaporation accounts for 29.7% of the observed normal outflow, while flow through the outlet structure accounts for only 8.1% of the calculated outflow. During the seepage surveys, measured groundwater recharge (outseepage) was not as significant as expected, but by subtraction accounts for 62.2% of outflow from Herring Pond. In Herring Pond, zones of outseepage are probably limited to shoreline edges of the pond. In this way, outseepage may have been overlooked during the BEC seepage surveys, as seepage meters were usually placed a minimum of 1 to 2 meters from the shoreline. When outflow (evaporative losses and outseepage) greatly exceeds the normal inflow, the water level in the pond declines, and water ceases to flow through the outlet. Outflow from the pond through the outlet was observed on about half of the sampling dates. Outlet flow was generally observed during spring and late fall and winter months.

Dividing the volume of the pond by the mean inflow, a mean detention time of 2.81 years, or 1,026 days, is obtained. This equates to a flushing rate of 0.36 times per year. Long-term precipitation suggest a range of flushing rates of 0.24 to 0.63 flushings per year. This suggests that pollutants entering Herring Pond remain there for an extended period of time, interacting with the other components of the system to produce the observed conditions.

The response time, calculated according to Dillon and Rigler (1975), is between 1.05 and 1.75 years for Herring Pond (Table 14, Appendix C). The response time is an estimate of the detention time necessary for input pollutants to fully express their potential impact on the system. In the case of Herring Pond, the necessary response time is exceeded at all times. This means that nutrients entering the pond remain there long enough to be completely used in primary production, unless other factors (e.g., reduced bioavailability or non-nutrient limitation of primary production) intervene. Given that groundwater seepage accounts for such a large percentage of the input to Herring

Pond, it follows that any impairment of groundwater quality as a result of human activities within the watershed will likely be expressed in the pond.

Response time also aids prediction of the time frame over which post-implementation improvements become noticeable. Unless in-lake action is taken, reducing external nutrient loading will not lead to rapid improvement in the water quality of Herring Pond. Even then, it may be close to a year after restoration efforts are concluded before chemical equilibria are reached and the pond exhibits altered conditions. In the case of Herring Pond, maintenance rather than restoration should be stressed. Most management techniques which are applicable in Herring Pond will most likely not produce readily obvious changes in pond conditions, but will protect the pond from future degradation.

NUTRIENT BUDGETS

Phosphorus

Export coefficients for phosphorus can be used in conjunction with land use data to estimate the load generated in the Herring Pond watershed. The best of a wealth of literature values for areal phosphorus export have been summarized by Reckhow et al. (1980). Selections can be made from a presented range of values 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, 1987), who summarized another pertinent body of literature.

Chosen export coefficients and corresponding justification are presented in Table 15. The coefficients, corresponding land areas, and resultant nutrient loads are given in Table 16. Based on this analysis, 136 kg of phosphorus are generated in the watershed each year. Only a portion of this phosphorus can be expected to reach Herring Pond, however, given the lack of a stormwater drainage system or other channelized surface water connection to the pond.

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 pond. These equations depend upon certain assumptions, however, which may not be precisely met at Herring Pond. Derivation of certain necessary parameter values is subject to considerable uncertainty, but these models do provide estimates based on logic and empirical data. These estimates are often useful reference points when evaluating loading through limited data for a variety of contributing sources. The potential pathways for nutrient gains and losses are shown in Figure 15 although not all of these pathways exist in the Herring Pond system.

Applying the model equations given in Table 17, and using the values presented in Table 18, the loading range given in Table 18 is obtained. Herring Pond functions as though it is receiving a phosphorus load of between 7 and 35 kg/yr, depending upon which model best represents processes in Herring Pond. The Kirchner-Dillon, Chapra, and Vollenweider models are least reliable here, as they depend upon variables for which the least precise estimates can be obtained from the available data. The Vollenweider model predicted 15.1 kg/yr, which was nearly identical to the Jones-Bachman and Larsen-Mercier models, while the Kirchner-Dillon model predicted a phosphorus load of about 35 kg/yr. However, the Vollenweider and Kirchner-Dillon models depend upon an estimate of influent phosphorus concentration which was substituted for by incorporating mean in-lake concentrations into the model. The Chapra model on the other hand, relies upon knowledge of flow-weighted average phosphorus

TABLE 15

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

NUTRIENT SOURCE	EXPORT COEFFICIENT (KG/HA/YR) NITROGEN	PHOSPHORUS	SELECTION CRITERIA
LAND USE:			
Residential	4.00	.65	Low density, low usage
Recreation/Park	1.50	.20	Seasonal usage
Cemetery	5.19	.80	lower range for pasture
Open	5.19	.80	As above
Forest	2.50	.24	Mixed, low density
OTHER SOURCES:			
Atmospheric Deposition	6.50	.20	Residential, no agriculture
Groundwater(baseline)	.90	.60	Mid-range values selected
Aquatic Birds	1.00	.14	A few migratory waterfowl
Internal Loading	4.16	2.25	Stratified, low sediment [P]
Septic Systems	4.60	1.50	Major, particularly N.E. region

TABLE 16

NUTRIENT LOAD GENERATION BY SOURCES IN THE WATERSHED OF HERRING POND

NUTRIENT SOURCE	ASSOCIATED AREA (HECTARES)	EXPORT COEFFICIENT (KG/HA/YR) NITROGEN	PHOSPHORUS	LOAD GENERATED (KG/YR) NITROGEN	PHOSPHORUS
LAND USE:					
Residential	23.5	4.00	.65	94	15
Recreation/Park	.7	1.50	.20	1	0
Cemetery	.65	5.19	.80	3	1
Open	2.71	5.19	.80	14	2
Forest	7.8	2.50	.24	19	2
OTHER SOURCES:					
Atmospheric Deposition	17.7	6.50	.20	115	4
Groundwater(baseline)	7.3	.90	.60	7	4
Aquatic Birds	18.0 bird-yr	1.00	.14	18	3
Internal Loading	17.7 ha-yr	4.16	2.25	74	40
Septic System Inflow	43.7 cap-yr	4.60	1.50,	201	66
TOTAL				546	136

TABLE 17

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

Kirchner & Dillon, 1975 (K-D)
TP=L * (1-Rp)/(Z * F)
L=(TP * Z * F)/(1-Rp)

Vollenweider, 1975 (V)
TP=L/(Z * (S+F))
L=TP * (Z * (S+F))

Chapra, 1975 (C)
TP=L * (1-R)/(Z * F)
L=(TP * Z * F)/(1-R)

Larsen & Mercier, 1975 (L-M)
TP=L * $(1-R_{LM})$/(Z * F)
L=(TP * Z * F)/$(1-R_{LM})$

Jones & Bachmann, 1976 (J-B)
TP=(0.84 * L)/(Z * (0.65+F)
L=(TP * Z * (0.65+F)/0.84

TP=Total P as ug/l in spring

L=P load as mg $P/m^2/yr$

Z=mean depth as m

F=flushing/yr

Pin=Flow weighted average input concentration of phosphorus

Pout=Flow weighted average output concentration of phosphorus

S=effluent TP/influent TP

qs=Areal water load=Z(F) m/yr

Vs=Settling velocity=Z(S) m

R=Retention coefficient (phosphorus)
=(P in - P out)/P in

Rp=Retention coefficient (water load)
=Vs/(Vs+qs) (Vs=13.2)

$R_{LM}=1/(1+(F^{.5}))$

TABLE 18

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

Variable	Parameter Value
TP [ug/l]	12.7
Z [m]	6.2
F $[yr^{-1}]$	0.36
Pin	29
Pout	21
S=P out/P in	0.72
qs=Z(F) [m/yr]	2.23
Vs=Z(S) [m]	4.49
R=(P in - P out)/P in	0.276
Rp=13.2/(13.2+qs)	0.856
$R_{LM}=1/(1+F^{.5})$	0.625
Predicted Load $(g/m^2/yr)$ By Each Model	
K-D	0.20
V	0.09
C	0.04
L-M	0.08
J-B	0.09
Predicted Load (kg/yr) By Each Model	
K-D	34.7
V	15.1
C	6.9
L-M	13.4
J-B	16.8
Vollenweider Criteria	
Critical Load	
$g/m^2/yr$	0.30
kg/yr	52.4
Permissible Load	
$g/m^2/yr$	0.15
kg/yr	26.2

concentrations in inputs and outputs. Lacking a true tributary system, this model is inappropriate at Herring Pond. Eliminating these from consideration, the Jones-Bachmann and Larsen-Mercier models predict phosphorus loads of 16.8 and 13.4 kg/yr, respectively.

Vollenweider (1968) established loading criteria based on system morphology and hydrology; a phosphorus load of less than 26.2 kg/yr would be considered permissible under this scheme, while a load in excess of 52.4 kg/yr would be deemed critical (in a detrimental sense). The apparent phosphorus load to Herring Pond does not exceed these limits, suggesting that Herring Pond is not in a state of accelerated eutrophication, but exists in a more or less stable mesotrophic state. This is a reasonable appraisal of conditions in Herring Pond, based on visual observations and monitoring data.

The most reliable approach to load assessment 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. Calculations essential to this approach are presented in Appendix C. Based on the assumption that the phosphorus load to the pond should be equivalent to the average concentration times the volume times the annual flushing rate, a total load of 8.2 to 19.7 kg/yr is obtained.

Potential sources of phosphorus for Herring Pond include birds (mainly waterfowl), internal loading, groundwater inflow, and atmospheric deposition. Direct drainage may provide some measure of the phosphorus load, but the highly permeable soils and lack of storm drainage system combine to all but eliminate this as a source. The sum of the loads obtained for each of these sources individually provides another estimate of the total phosphorus load. The load attributable to birds is best estimated by the export coefficient approach (Tables 15 and 16), which suggests an input of about 3 kg/yr.

In Herring Pond, total phosphorus content on a mass balance basis increased more than two-fold following the onset of stratification. During periods of mixis (i.e., unstratified), the average total phosphorus concentration in Herring Pond is 18 ug/l. During periods of stratification, however, total phosphorus concentrations increase to about 43 ug/l. The latter value was volume-weighted to account for differences in volume of individual strata. On a whole-lake basis these data translate into an increase in total phosphorus from 19 kgP during mixis to 47 kgP during stratification. This increase was immediately apparent following the onset of stratification on 6/20/88 and persisted throughout the summer months. Such a dramatic increase in total phosphorus clearly represents an internally supplied, or recycled component of the annual phosphorus budget.

The internal load, or recycled component, is a composite of loads contributed by sediment release of phosphorus under anoxic conditions, pumping of phosphorus from the sediments by macrophytes, and sediment resuspension and associated remineralization. The recycled component, or that which is recycled by biochemical activity under anoxic conditions, actually represents accumulated contributions from past nutrient loading. Collectively, anoxic release, macrophyte pumping, and sediment resuspension are estimated to contribute approximately 40 kg/yr. Calculations and assumptions used to derive the internal load to Herring Pond are contained in Appendix C.

Given the high iron content of the water in the pond and well oxygenated conditions for the greater portion of the year, only a portion of this load is likely to actually become available for uptake by plants. Hypolimnetic oxygen values fall to below 1 mg/l only at the very bottom of the pond and only for a period of about 3 months. Additionally, on an areal basis only about one-half of the pond sediment was actually subject to anoxic conditions as thermocline depth was generally at 6 to 7 meters during periods of stratification. Determination of the anoxic internal load to Herring Pond was arrived at using a model developed by Nurnberg (1987), which accounted for duration and areal extent of anoxia at the sediment-water interface. Estimated macrophyte pumping rates were arrived at using data for Eurasian Milfoil (Myriophyllum spicatum), a highly productive plant with unusually high shoot turnover (Smith and Adams, 1986) (for calculations see Appendix C). Assuming that between 25 and 50% of the internal load actually becomes available in the water column, approximately 10 to 20 kgP/yr are available from internal loading in Herring Pond.

Thermocline instability has been shown to facilitate the vertical transport of nutrients from the hypolimnia of lakes (Kortmann et al. 1982). This commonly occurs in response to meteorological disturbances or during fall cooling when density gradients are reduced, allowing mixing across the thermocline. Therefore, a substantial portion of the phosphorus mobilized from the sediments through anaerobic processes may become incorporated into the epilimnion of Herring Pond despite thermal stratification.

The contribution of groundwater to the phosphorus load is estimated as the volume of inflow times the average interstitial porewater phosphorus concentration (for calculations see Appendix C). The groundwater load actually constitutes an additional component of internal loading, as the quality of incoming groundwater is a function of its interaction with the pond sediments. However, for this discussion it will be considered seperately. Oxidation of iron should quantitatively immobilize phosphorus in an oxidized surface layer when the atomic ratio in the interstitial porewater is greater than about 1.8 (Stauffer, 1981). Atomic Fe/P ratios in Herring Pond porewater samples greatly exceed this value, and at first glance would be expected to allow negligible phosphorus release under oxic conditions. Upon inseepage into the open waters of the pond, this source of phosphorus may remain unavailable unless incorporated into deeper anoxic zones of the pond. Being colder than typical epilimnetic water in temperate zone lakes, inseeping groundwater would tend to follow density gradients to deeper, anoxic zones where the associated iron-phosphate complex may dissociate. Other factors for which information specific to Herring Pond is lacking, exert considerable influence on this scenario. Interstitial water-soluble sulfide, pH, and temperature are involved in regulating equilibrium concentrations of both iron and phosphorus in sediment interstitial waters (Holdren and Armstrong, 1986). Incomplete knowledge of the ionic composition and temperature regime of Herring Pond interstitial porewater produces uncertainty as to the actual phosphorus load from groundwater. Based on calculations relating interstitial porewater phosphorus concentration to groundwater inseepage, a mean loading of 0.13 kgP/D is obtained, or about 48 kgP/yr (see Appendix C). Assuming that interactions at the sediment-water interface keep this load at the low end of its range, a load of between 12 and 24 kg/yr is postulated.

The groundwater phosphorus load to Herring Pond is a product of both baseline groundwater nutrient concentrations and influence from on-site wastewater disposal systems. Contributions from on-site wastewater systems are estimated as the difference between total groundwater loading and baseline groundwater loading (Appendix C). Baseline groundwater quality in Herring pond is a function of a combination of saltwater intrusion and precipitation-recharged sources. In Herring Pond, approximately 77% of the phosphorus input via groundwater is attributable to on-site wastewater disposal systems.

The load of phosphorus added by precipitation is determined by both actual rainfall and wind-transported material, or dryfall. Based on nutrient export coefficients for similar watersheds (Reckow et al 1980), atmospheric inputs of phosphorus to Herring Pond are estimated to be approximately 3.5 kg/yr.

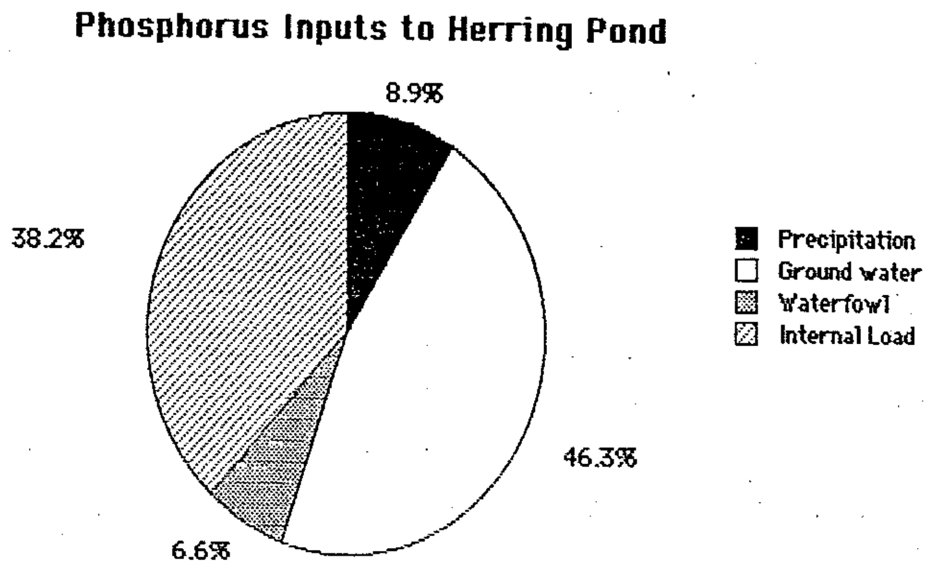
A summary of itemized loading estimates is presented in Table 19, while the partitioning of the estimated total load among contributing sources is given in both Table 19 and Figure 19. The resulting total phosphorus load is 28 to 50 kg/yr. This not totally consistent with load estimates obtained by other means. While the range of the estimate is large in relation to the values obtained (nearly a twofold difference between upper and lower limits), the actual quantity of phosphorus represented by the range is quite low. Variability is likely to be high when dealing with such numbers. These numbers span the range of values provided by the Vollenweider Criteria for critical and

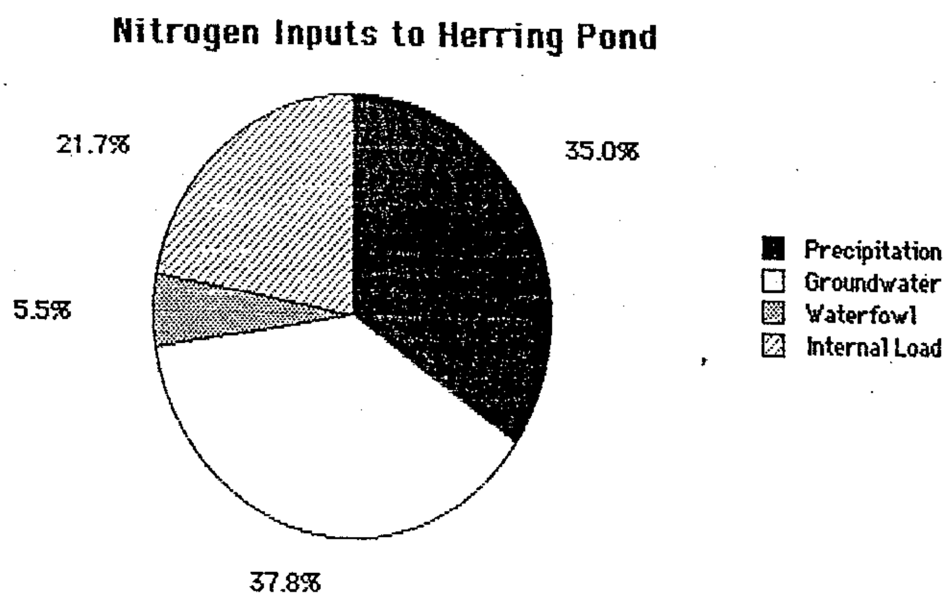
TABLE 19

NUTRIENT LOADS TO HERRING 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
Precipitation (Direct Input)	3.5	6.9-12.4	115.1	32.1-37.9
Groundwater (Direct Input)	12.1-24.2	42.9-48.1	121.4-127.8	35.6-40.0
Bird Inputs (Direct Input)	2.6	5.2-9.2	18.0	5.0-5.9
Internal Load (Anoxic release, Macrophyte pumping, Sediment resuspension)	10-20	35.5-39.8	49-98	16.1-27.3
Total	28.2-50.3	100	303.5-358.9	100

FIGURE 19


Phosphorus Inputs to Herring Pond
8.9%
38.2%
46.3%
6.6%
Precipitation
Ground water
Waterfowl
Internal Load


Nitrogen Inputs to Herring Pond
21.7%
35.0%
5.5%
37.8%
Precipitation
Groundwater
Waterfowl
Internal Load

permissable loading (Table 18). The actual load to Herring Pond is likely to reside midway within the range, suggesting moderate fertilization of Herring Pond. A substantial portion of this load represents internally supplied phosphorus available for only a brief period of the year. As a result, on a year-wide basis Herring Pond behaves as if the annual phosphorus load was closer to that calculated using models or other means {(i.e, concentration x flushing rate x volume) (see Appendix C)}.

It is doubtful that the actual externally supplied component of the annual phosphorus budget exceeds the Vollenweider Criteria for critical loading to Herring Pond. If this component is maintained at or near the present rate, Herring Pond is unlikely to exhibit further noticeable deterioration.

The approximate partitioning of the annual phosphorus load among potential sources suggests that groundwater and internal loading are the two largest contributing sources of phosphorus for Herring Pond, at a combined total of about 84%. Considering the relative contribution of groundwater to the hydrology of Herring Pond and the associated phosphorus levels, as well as the multiple mechanisms by which phosphorus can be transported within the pond, this is not especially surprising. Reducing the phosphorus load from groundwater inputs to Herring Pond is likely to be a feasible goal, and one which will aid in protecting the aesthetics of the pond for future generations.

Nitrogen

Derivation of a nitrogen budget was approached in the same manner as was the phosphorus budget. Export coefficients and resulting loads are given in Tables 15 and 16. No model equations were applied to estimate the nitrogen load, as suitable equations have not been derived. A breakdown of the total nitrogen load by individual source is presented in Table 19 and shown in Figure 19. Calculation of individual loading components is presented in Appendix C.

Nitrogen export coefficients suggest that 546 kg of nitrogen are generated within the Herring Pond watershed each year. Assuming the same delivery scenario as postulated for phosphorus, about 331 kg of nitrogen would enter the pond each year. Based on the average in-lake concentration times the water load, a load of between 161 and 387 kg/yr is derived. Based on the summation of individually calculated loads from specific sources, a total nitrogen load of 303 to 359 kg/yr is obtained. Groundwater and atmospheric depositon are the largest contributors, with slightly smaller contributions attributed to internal loading.

There is considerable interconversion of nitrogen forms in Herring Pond on a nearly continual basis. A substantial fraction of the nitrogen entering the pond from inseeping groundwater is available as ammonia. Much of the nitrogen supply in the bottom muck may remain unavailable in organic form, but there is an actively cycling pool of nitrogen which is released from organic matter through aerobic or anaerobic decay, most often as ammonia nitrogen. Ammonia is rapidly converted to nitrate in the presence of oxygen in this system, with zones of anoxia limited primarily to the hypolimnion during summer months. Nitrate is in turn converted back into organic matter; some of the ammonia may be converted directly back into organic matter as well.

A Note on Uncertainty

In a system such as Herring Pond, precise levels of nutrient loading are difficult to quantify at the level of resolution afforded by such a study as this. The sporadic nature of many inputs and recycling within the pond introduce considerable potential for error, and one must be careful not to rely too heavily on any one number or equation. An error of just a few kilograms in a phosphorus budget as small as that of Herring Pond is substantial, necessitating the use of ranges which seem rather wide. A sincere effort has been made in this report to temper evaluations with knowledge gained from other studies and with intuition gained from experience. The different approaches employed in constructing the hydrologic and nutrient budgets have produced results which are in general agreement, and the partitioning of loads among sources is logical, albeit somewhat speculative.

Herring Pond does not appear to be undergoing severely progressive macrophyte proliferation. Elevated in-lake total phosphorus concentrations during summer months does suggest that there exists the potential for a macrophyte community to increase beyond its present status. The observed increase in undesirable blue-green algal populations during the summer months appeared to result from increased phosphorus concentrations. It appears that the nutrient sources to this pond are internal reserves and transport of pollutants to the pond via groundwater. Groundwater is a relatively major contributor of phosphorus and nitrogen to Herring Pond, and represents a load which can be reduced by improved watershed management practices. The resulting change in water quality may not be discernible within the context of the observed variability, however.

DIAGNOSTIC SUMMARY

Herring Pond is a kettlehole lake of moderate area and depth which lies in a sandy Cape Cod watershed that has experienced considerable residential developement over the last half-century. The largest source of water for the pond is groundwater inseepage, which is a product of both precipitation-recharged groundwater and saltwater intrusion. Precipitation is the second largest water source; Groundwater and precipitation together supply virtually all inflow to Herring Pond. Groundwater brings a moderate nutrient load to Herring Pond, which has a hydraulic detention time of 1.6 to 4.2 years. Therefore, the pond exists as a sink for nutrient inputs. Phosphorus is in relatively shorter supply than is nitrogen, and much of the phosphorus in the water column is bound in organic complexes. Internal loading and groundwater appear to provide the majority of the phosphorus in Herring Pond. It appears that the greater portion of the groundwater phosphorus load is attributable to on-site wastewater disposal systems.

During summer months when the pond is thermally stratified, anoxic release of phosphorus from the sediments results in a major increase in phosphorus in the water column. Much of this is unavailable for uptake in surface waters, however, as most forms iron-phosphate complexes upon oxygenation. While this condition is generally regarded as an indicator of deteriorating environmental quality, it is not of primary concern at this time. If the impact of anoxia on Herring Pond water quality increases over time, however, remedial actions may become necessary.

Herring Pond possesses great aesthetic appeal as well as being very popular as a facility for water-based recreation. From a fishery standpoint, Herring Pond provides spawning habitat for sea-run alewife (Alosa pseudoharengus). Biological nuisances rarely occur, and have not as yet, substantially impaired the recreational utility of the pond. Use restrictions intended to manage and protect the pond for maximum benefit to summer users and the environment affect recreation more than do natural factors. Encroachment of macrophytes, particularly in private swimming areas, is perceived as a potential problem. Rooted aquatic plants create few problems at this time, especially at the public beach, and provide necessary cover for the fish community in Herring Pond.

MANAGEMENT RECOMMENDATIONS

To maintain Herring Pond in a condition appropriate to its desired uses and status as a recreational and aesthetic focal point of the watershed in specific and the Town of Eastham in general, it is desirable to reduce unnecessary loadings of all pollutants, especially phosphorus and nitrogen. As direct precipitation and birds are largely uncontrollable sources of these pollutants, reductions should center on groundwater inputs and possibly internal recycling of phosphorus from the pond sediments. It should be kept in mind, however, that biological production (ultimately fish) requires some degree of overall fertility, such that elimination of nutrient sources could decrease fish production. Prevention of increased pollutant loading is the key to successful long-term management of Herring Pond.

All of the residences in the Herring Pond watershed are serviced by on-site wastewater treatment systems, many of which are antiquated cesspool systems, and if not properly maintained or upgraded, pose a threat to groundwater quality entering the pond. Based on the assessment of the volume and quality of groundwater entering Herring Pond, it is apparent that some impairment of pond water quality is attributable to malfunctioning or mismanaged septic systems. Through improved "housekeeping" practices, the influence of on-site wastewater systems on groundwater quality can be reduced. This would represent a desirable check against future deterioration of pond water quality, and has positive side benefits for drinking water supply in Eastham.

Internal recycling would appear to be a logical target for the control of phosphorus entering Herring Pond. Management techniques to control this source of phosphorus, such as nutrient precipitation and inactivation, do exist, but ocassionally produce undesirable side effects. Prohibiton of large motorized craft (not a problem in Herring Pond) limits the amount of nutrient-rich sediment resuspension. Large-scale reduction of rooted aquatic plants could also reduce internal recycling, but would also reduce fish cover and sediment stabilization capacity.

Continued management of the Herring Run to provide access to Herring Pond is recommended. This is necessary to assure the future success of the pond as a spawning ground for sea-run adult alewife and a nursery for young alewife.

A long-term, comprehensive monitoring program will be necessary to determine the effectiveness of the recommended management plan. The program should include assessment of water quality (in-lake and groundwater) and macrophytes, as well as access to Herring Pond via the Herring Run during alewife spawning runs.

PART 2

FEASIBILITY ASSESSMENT

EVALUATION OF MANAGEMENT OPTIONS

Management Objectives

The establishment of management objectives is critical to the evaluation of management options and necessary to the development of priorities for restoration activities. Through meetings with residents of the Herring Pond area, and through questionnaire responses, it was determined that swimming, non-motorized boating and fishing are the most desired uses of the pond. Others, particularly those living close to the pond itself, stress the aesthetic value provided by the pond as well. A common concern of the majority is the increasing density of aquatic plants in nearshore areas as well as the future status of Herring Pond as a resource.

Available Techniques

The number of actual techniques available for lake and watershed management is not overwhelming (Table 20). 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 potential problems of Herring Pond and its watershed allows elimination of certain alternatives from further consideration. Dredging is generally unwarranted in Herring Pond as the majority of soft sediment exists in the deeper portions of the pond. Macrophyte harvesting could be applicable in some shoreline zones, but is not necessary in public swimming areas and should be discouraged on any large scale. A degree of cover is desired to provide fish cover, sediment stability, and to act as a bio-filter for groundwater. Water level control cannot be practiced at Herring Pond without the use of a pumping system to help drain the pond. Little benefit would be provided by this action as the majority of macrophytes in Herring Pond occur in deeper zones, thus requiring the removal of a large volume of water from the pond. Lacking a true inlet, refilling the pond to normal levels would be very slow, not to mention the possible damage inflicted upon the pond's alewife fishery. Additionally, not all potential nuisance species in the pond are susceptible to winter drawdown, while others may actually increase following rewatering (Cooke et al., 1986). A drawdown is therefore not recommended.

Application of herbicides has been shown to be somewhat successful in eliminating and controlling macrophyte growths. Major drawbacks of biocidal application exist, however. This method of control does not attack the source of the problem or remove decomposing plant and organic matter. Additionally, it requires follow-up treatment which escalates the cost over a period of years. Possibilities of long-term damage as a result of negative side-effects are also of major concern. Following

TABLE 20

LAKE RESTORATION AND MANAGEMENT OPTIONS

Technique	Descriptive Notes
A. In-Lake Level	Actions performed within a water body.
1. Aeration And/Or Destratification	Mechanical maintenance of oxygen levels and prevention of stagnation.
2. Biocidal Chemical Treatment	Addition of inhibitory substances intended to eliminate target species.
3. Biomanipulation/Habitat Management	Facilitation of biological interactions to alter ecosystem processes.
4. Bottom Sealing	Physical obstruction of rooted plant growths and/or sediment-water interaction.
5. Chemical Sediment Treatment	Addition of compounds which alter sediment features to limit plant growths or control chemical exchange reactions.
6. Dilution And Flushing	Increased flow to minimize retention of undesirable materials.
7. Dredging	Removal of sediments under wet or dry conditions.
8. Dye Addition	Introduction of suspended pigments to create light inhibition of plant growths.
9. Hydroraking and Rotovation	Disturbance of sediments, often with removal of plants, to disrupt growth.
10. Hypolimnetic Withdrawal	Removal of oxygen-poor, nutrient-rich bottom waters.
11. Macrophyte Harvesting	Removal of plants by mechanical means.
12. Nutrient Inactivation	Chemical complexing and precipitation of undesirable dissolved substances.
13. Water Level Control	Flooding or drying of target areas to aid or eliminate target species.

TABLE 20 - CONTINUED

B. Watershed Level	Approaches applied to the drainage area of a water body.
1. Agricultural Best Management Practices	Application of techniques in forestry, animal, and crop science intended to minimize adverse impacts.
2. Bank And Slope Stabilization	Erosion control to reduce inputs of sediment and related substances.
3. 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. Limit Lawn Fertilization	Reduce potential for nutrient loading to a water body.
d. Limit 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.
4. Detention Basin Use And Maintenance	Lengthening of time of travel for pollutant flows and facilitation of natural purification processes.
5. Increased Street Sweeping	Frequent removal of potential runoff pollutants from roads.
6. Maintenance And Upgrade Of On-Site Disposal Systems	Proper operation of localized systems and maximal treatment of wastewater to remove pollutants.
7. Provision Of Sanitary Sewers	Community level collection and treatment of wastewater to remove pollutants.
8. Stormwater/Wastewater Diversion	Routing of pollutant flows away from a target water body.
9. Zoning/Land Use Planning	Management of land to minimize deleterious impacts on water.

treatment with a specific compound, target species are often replaced by an algal bloom or other potentially resistant species. Chara and Potamogeton often invade a treated area, the latter being present in Herring Pond. This may require other chemicals to be used, making herbicide treatment even more expensive. Impacts of herbicides on humans are poorly understood, and there is almost no information on the long-term ecological consequences of their use. The initial benefit-cost ratio can be desirably high, but over the long-term this ratio is likely to be very low (USEPA, 1988). Certain products, however, have been shown to provide effective relief from nuisance growths with little or no proven ill effects (e.g., SONAR). Chemical treatment is a sensitive issue, however, and should be examined very closely before being recommended as a management option in any situation. Considering the limited extent and distribution of macrophytes in Herring Pond, herbicide application is rejected as a management action.

Biomanipulation usually involves the removal or introduction of species, and no such action is desired at Herring 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. Biomanipulation would be inconsistent with the management objectives set for Herring Pond by Town concensus. However, if an alewife spawning run is to be promoted, continued maintenance of the herring run (channel between the pond outlet and bay) is necessary. Deepening and weir maintenance will be needed periodically.

At the watershed level, there is very little overland flow to impound, treat, or reroute. The use of detention basins, diversion of stormwater, and frequent sweeping of streets are not applicable techniques in the Herring Pond watershed. The provision of sanitary sewers or diversion of domestic wastewater from the watershed has some merit, but the potential drawbacks appear to outweigh any benefits provided by these actions. Water supply problems may occur as a result of reduced recharge from on-site disposal systems, and the cost of providing wastewater treatment would be very high and potentially unbearable. Modification of the existing disposal approach appears preferable.

With the motion by the Town to purchase the Horton property in 1989, the Town moved to control development in the watershed of Herring Pond. The Horton property is an approximately 25 acre tract of land along the northern shore of Herring Pond. In the absence of a sanitary sewer system, this motion would act to prevent an increase in pollutant build-up in the watershed by preventing an increase in the number of potential on-site wastewater disposal systems.

There is no agricultural activity in the watershed to which best management practices could be applied, and only a few localized portions of the Herring Pond shoreline 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 minimal, and is restricted to small engines. Applicable management techniques for Herring Pond appear to be limited, none of which alone can provide the desired level of improvement or maintenance. It will require a combination of techniques, each of which will effectively reduce a portion of the nutrient load from one or more sources.

Not all of the applicable management techniques are appropriate for Herring Pond, either. While hypolimnetic withdrawal could be brought about by using pumping techniques, the normal flow of water into Herring Pond is insufficient to allow an effective withdrawal without artificial replacement of withdrawn water. The associated benefit-cost ratio would be too small to justify such an operation. Aeration or destratification might prove beneficial, but initial capital investment would be great and anticipated annual maintenance and operation costs could prove prohibitive. Mechanical harvesting could be executed in select shoreline areas where dense macrophyte growths do occur, but large-scale removal tends to be inefficient and would provide little or no added benefit which could not be attained by other measures (e.g., bottom barriers). Along private shorefronts where benthic barrier installation is either difficult or undesirable, small scale removal of macrophytes can be practiced. There is a variety of relatively inexpensive products on the market which are designed to remove weeds, but slight modifications of simple garden rakes will usually suffice.

The techniques which will be most appropriate for the long-term management of the Herring Pond system are those which deal directly with groundwater and the high internal phosphorus load attributable to anoxic release from the sediments. Some in-lake control of rooted plants may also be necessary on a small scale if macrophyte density and distribution continue to increase. Management techniques remaining for consideration therefore include:

- Benthic Barriers
- Limited low-tech harvesting
- Maintenance and Upgrade of On-Site Disposal System
- Behavioral modifications for the reduction of pollutant accumulation in the watershed
- Management of Herring Run
- Nutrient Inactivation/Precipitation

Evaluation of Viable Alternatives

The techniques considered at this stage (listed above) are ones that are appropriate for improving or maintaining conditions in Herring Pond, but may be rejected for not being as effective as other alternatives or for being prohibitive in cost for the final results. Whenever possible, it is preferable to invest dollars in those techniques which remove or reduce the factors leading to lake degradation rather than in treatment of the expressed symptoms.

Installation of benthic barriers along selected problem shoreline areas would prevent macrophyte proliferation in these zones. Due to the relatively high cost of materials and application, and the depths at which most macrophytes occur in Herring Pond, installation will be limited to small areas. The ideal product should be effective, permeable (to allow gas release), have low application difficulty, and be affordable. The most appropriate benthic barriers that meet these standards are polypropylene (Typar) and fiberglass-PVC (Aquascreen). Typar is less expensive than Aquascreen, but has a specific gravity less than one (0.90), while Aquascreen is much heavier (specific gravity = 2.54). Not only would the heavier material be easier to install, it would be more likely to maintain its position once installed. There is, however, a substantial cost differential between the two products. Excluding costs associated with installation, Aquascreen costs about 2 to 3 times that for Typar (Cooke and Kennedy, 1988). Adjoining residents could cut the costs essentially in half by applying the benthic barrier in a paired-beach arrangement, providing for a greater swimming area as well.

Along shoreline areas where macrophytes are not perceived as a major nuisance, small-scale mechanical removal may be the selected option. This is likely to be less expensive than benthic barrier installation, but will require more frequent attention. Because macrophyte growths are not overly dense in Herring Pond, removal by small hand-held implements should provide adequate relief in most shoreline areas.

In Herring Pond there are areas of extensive coverage of the bottom by macrophytes (Figure 13), although the density of plants (as biomass) is not great. Reduction of plant biomass would contribute slightly to nutrient reduction in Herring Pond. Control of these macrophytes will maintain the aesthetic appeal of the pond as well as the recreational utility of the pond, particularly swimming. Macrophyte cover, to some extent, is desirable in Herring Pond. Complete elimination of macrophytes is not recommended, as they provide refuge and cover for various members of the pond fish community and food for waterfowl. In addition to plant control in key recreational areas, selected management techniques should be aimed at maintaining a level of cover near the existing situation (ca. 30%).

The importance of groundwater in the Herring Pond system dictates that any additional nutrient loading to this hydrologic input be strictly regulated. The most important nutrient source entering the groundwater is the effluent from septic systems in the watershed. One way in which this source of nutrients can be reduced is through more conscientious "housekeeping". This involves such measures as discontinued use of detergents containing phosphorus and improved disposal system maintenance. If these practices are implemented by watershed residents, a substantial reduction in the nutrient load to Herring Pond will be realized. Such a reduction may be necessary to offset possible loading increases from future development.

An educational program designed to explain the relationship between septic systems and the pond is advisable. The importance of upgrading and maintaining septic systems in a regular fashion should be included. Similarly, environmentally-wise practices, (e.g., using phosphorus-free detergents, reducing lawn fertilization) should be popularized, since these also help reduce non-point sources of pollution.

Maintenance of Herring Brook is necessary to provide conditions suitable for alewife (Alosa pseudoharengus) to complete a critical stage in their life history, the spawning run. Adequate conditions are provided in the ocean for adult alewife, but if spawning runs are obstructed or polluted, then the species fails because conditions necessary during a critical stage in the life history of the species are not met. Herring Pond is capable of providing ideal spawning habitat for alewife, providing the herring run is kept unobstructed and water levels are maintained, particularly during the spring spawning period, to allow easy access through the fishway. This will require the assistance of the Eastham Natural Resources Department to monitor the fishway regularly and remove obstructions (logs, sand, or gravel) which might hinder the migration of spawning alewives. If properly maintained, Herring Pond will continue to function as a "nursery" for young alewife.

Nutrient precipitation and inactivation are techniques aimed at eliminating phosphorus from the water column or preventing its release from the sediments during periods of anoxia. Iron, calcium, and aluminum have salts which can combine (sorb) with phosphorus and effectively removing it from the water column. Of these, aluminum is most frequently used, as phosphorus binds very tightly to aluminum salts and is effective at low to zero dissolved oxygen levels. Whereas phosphorus precipitation removes phosphorus from the water column, inactivation is the long-term control of phosphorus release from the sediments by adding as much aluminum sulfate (Alum) to the lake as possible without exceeding limits dictated by environmental safety. In water having a pH between 6 and 8, aluminum hydroxide ($Al(OH)_3$) is readily formed and produces a floc which adsorbs phosphorus-containing particulate matter from the water. Below a pH of 6, however, $Al(OH)_2$ and elemental aluminum (Al^{+3}) become the dominant forms. Both of these can be toxic to lake species (USEPA, 1988).

Herring Pond would appear to be an ideal candidate for alum treatment. The treatment tends to be more effective and long-lasting in deep, stratified lakes exhibiting long detention times. Conversely, in ponds which are shallow, unstratified, or that have short detention times, effectiveness of alum treatments tends to be brief. In some cases, high flows wash out the floc or quickly cover it with a layer of nutrient-rich silt. To realize maximum benefit from this type of treatment it is necessary to divert or reduce further phosphorus loading from other sources.

Thus, after reviewing viable techniques and in light of the characteristics of the system, the recommended in-lake management techniques are benthic barrier installation and small-scale macrophyte harvesting in localized, select areas, and maintenance of the herring run, particularly during alewife spawning season. At the watershed level the preferred options include maintenance/upgrade of septic systems and behavior modifications by watershed residents. If water quality declines or algal densities increase to nuisance levels, then techniques aimed at nutrient precipitation/inactivation should be given consideration.

RECOMMENDED MANAGEMENT APPROACH

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

1. Install benthic barriers in selected littoral areas to prevent recolonization of removed macrophytes. This technique could be used by private shoreline residents or by the Town, as deemed necessary.

2. Employ limited low-tech harvesting of macrophytes in localized areas where plant densities attain nuisance levels. This technique is most applicable to shoreline residents who perceive an increase in rooted plant coverage.

3. Prepare an educational brochure informing watershed residents of their role in determining the water quality of Herring Pond and describing ways in which residents can minimize pollutant loading. This brochure would be useful throughout the Town, as groundwater contamination is a widespread concern.

4. Maintain an unobstructed fishway to provide easy access to the pond by spawning alewife. The Natural Resource Department should continue its maintenance program.

5. Treat the pond with Alum (if deemed necessary) to precipitate and/or inactivate phosphorus in the water column and sediments, if conditions appear to worsen over the next decade.

6. Monitor groundwater and pond condition to assess improvements and facilitate informed future management decisions. A long-term monitoring program, consisting of seasonal chemical assessments with summer plant assemblage evaluation, is desirable.

IMPACT OF RECOMMENDED MANAGEMENT ACTIONS

The recommended management program would result in measurable changes in the quality of water entering Herring Pond (Table 21). Without employing in-lake restoration techniques, the quality of water in the pond may not change detectably, but the improved quality of incoming water will act as an insurance policy against potential future degradation. Phosphorus loading could decline by nearly 20%. Nitrogen loading would likely decrease as well, but only as a function of septic system upgrade in the watershed. The variability in these estimates of change are a function of uncertainty associated with multiple and possibly overlapping pollutant removal processes. The result of these changes should be insurance against future degradation, and maintenance of the pond's recreational status by preventing densities of plants from attaining nuisance levels.

Elimination of the use of phosphate-detergents alone could reduce the loading of phosphorus to Herring Pond via groundwater by nearly 2.3 kgP/yr, or by about 13%. This is a substantial reduction and would aid in reducing the total phosphorus budget, particularly the externally generated fraction. This would enhance the effect of in-lake management actions.

The anticipated changes in water quality should keep Herring Pond acceptable for its designated uses, and could maintain the visual appeal of the pond to area residents. Herring Pond has the potential to be an even more outstanding water resource than it is, providing greater benefits to area residents. The costs are not prohibitively high, and the tangible and intangible benefits are large and attainable.

TABLE 21

ANTICIPATED CHANGES IN HERRING POND
TO RESULT FROM THE PROPOSED MANAGEMENT PROGRAM

	% Change in Selected Parameters			
Management Plan Element	TP-Load	TN-Load	Water Load	Macrophyte Density
Benthic Barriers	0 to -1	0 to -1	0	-1 to -5 *
Manual Harvesting	0 to -1	0 to -1	0	-1 to -5
Alum Treatment **	-25 to -50	0 to -1	0	?
Education	-5 to -20	-5 to -10	0	0
Total	-30 to -72	-5 to -13	0	-2 to -10

Notes: * Reduction would be in areas of heaviest recreational use.

** Alum Treatment is only recommended if all other actions fail to provide the desired results. Macrophyte density may not decline following alum application; benefits will include reduced algal blooms and increased water transparency.

EDUCATION PROGRAM

Environmental education is critical to the improvement and safeguarding of natural resources, as the potential impacts arising out of human demand can exceed the technological and economic capacity to repair the damage once it is done. By informing watershed residents of their role in determining the quality of water resources, it is hoped that many impacts can be avoided or reduced in magnitude, making technological fixes unnecessary or at least affordable. In the case of Herring Pond, the opportunity exists to adjust domestic practices within the watershed before permanent damage has been done. An appropriate educational program, therefore, should be directed at preserving the improvements which technology can provide, and at avoiding additional hazards not currently threatening the pond.

The distribution of a brochure to watershed residents is the recommended mode of education. This brochure should provide a summary of important relationships and make specific recommendations regarding residential practices which affect water quality. Although the brochure may be prepared by a consultant, it should be distributed under the auspices of the Board of Selectmen.

One primary target of the brochure should be groundwater and its role as a link between residents and the Herring Pond system. It is important that residents recognize that the inputs to septic systems can reach the pond, sometimes with minimal treatment. The potential impact of the use of garbage grinders, phosphorus-containing detergents, and irresponsible waste disposal practices should be made clear. Residential practices which minimize inputs to the pond via other routes (e.g., reduced lawn fertilization, bagging leaves or grass clippings) should be stressed.

A total of $12,000 has been allocated for an educational program. An informational brochure can be developed for this price, and several thousand brochures produced as well. The choice of distributional mode is left to Town officials, but an approach which involves as many local citizens as possible in the actual transfer of information is desirable. An introductory meeting, including the press, would maximize exposure and program success. Two or three informational articles, based on the prepared brochure, should also be made available to local papers and civic groups for use in promoting sound environmental management. A workshop, overseen by the Eastham Department of Natural Resources, could also be put on to enhance the effectiveness of the educational brochure by providing assistance and guidance.

Maintenance and Upgrade of Existing Wastewater Disposal Systems

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 variables related to the performance of these systems are the depth to groundwater and the type of soil below the system (Veneman, 1986). The greatest possible vertical distance to groundwater and an intermediate percolation rate are desirable. While dilution by groundwater may be substantial, conversion of pollutants to harmless or immobile forms is often minimal once a substance has entered the zone of saturation. Slow movement of effluent through a large aerated zone of soil with high adsorptive capacity is the optimal situation for treatment, but these are rarely realized in practice, as actual design must blend treatment needs with disposal volume demand.

Other operational considerations of importance 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 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).

Since less than half of the watershed population is comprised of permanent residents (38% in Table 11, although a few non-reporting seasonal homes are known), the delivery of wastes to disposal systems will be rather discontinuous. This jeopardizes the sustenance of the microbial community in the settling tank and biofilm, a biological slime layer consisting of bacteria, protozoans, and fungi inhabiting the surface of crushed stone in leach fields. However, it maximizes the regeneration of the soil adsorptive capacity. A trade-off exists between these two characteristics. Although well developed microbial communities are effective in reducing pollutant loading to the groundwater, the adsorptive capacity of the soil may become exhausted from continuous use. This is an important point for shoreline residents; with proper system maintenance, system alteration or replacement might not become necessary.

The BEC survey of watershed residents (Table 11) indicated that only 58% of the on-site disposal systems were conventional tank and leachfield units and that 42% were cesspools. The mean age of these systems was 14 years, and the average time since inspection/pumping was greater than 4 years. DiLibero (1986) has recommended an inspection interval of six months to two years, with cleaning and maintenance as warranted by inspection. As only 27% of distributed questionnaires were returned, these numbers may not accurately reflect the status of these systems. In particular, unreported seasonal residences are likely to have rudimentary disposal systems. As a result, there exist uncertainties regarding the maintenance of these systems in terms of inspection and pumping schedules.

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 the septage must be transported for ultimate disposal. It is difficult to be against the protection of a water resource such as Herring Pond as well as the groundwater from which drinking water is obtained at a per home cost of $50 to $150/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 (1984). Information from this and other useful publications is included in Appendix D.

The proposed Education Program would elaborate on these points, and outline the various measures that each residence can take to reduce the influence of septic systems on Herring Pond. Of the $12,000 proposed for this program, approximately $10,000 will be required for research, organization, and production of the brochure, and $2,000 for dissemination of the brochure.

As regards system upgrades, 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 present health hazards at concentrations above the established 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 groundwater 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.

There are several actions that the Town of Eastham could take to provide incentives to improve septic system management. For instance, the Town might consider imposing septic system taxes or awarding tax rebates based on frequency of system servicing. Septic system inspection notifications issued to watershed residences by the Town might also be considered, and could provide helpful reminders.

IN-LAKE MANAGEMENT ACTIONS

Benthic Barriers

The recommended approach to macrophyte control in swimming areas involves the application of bottom covers. While alternative cover materials could be considered in the design process of a Phase II program, the preferred material at this time is Aquascreen. This is the same material which is being used with success in a neighboring Eastham pond, Great Pond. 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 4.2 m (14 ft) width, and is amenable to anchoring with stakes or weights. It is durable, manageable, and reusable (Cooke et al., 1986). The price per square foot is about $0.40.

Funding for the Aquascreen by the Clean Lakes Program would only apply to application at the public beach area. A survey of shoreline residents could be conducted to determine the amount of this product necessary to treat private shoreline areas. It is suggested that the Town of Eastham make a bulk purchase of the product based on this survey and make it available to shoreline residents at cost. Based on the macrophyte survey conducted during this study, it is unlikely that the cost of the material required to treat "trouble" areas will exceed $9,000. Use of alternative controls (e.g., low-tech harvesting) could reduce this figure appreciably. Neighboring shoreline residences may find it beneficial as well as economical to install the aquascreen in a "paired-beach" arrangement, i.e, installing the screens overlapping the property borders to provide increased swimming area. The projected costs for materials and installation are shown in Table 22.

Application of the screen can be complicated, and the slope of the sediment in Herring Pond suggests that some difficulty can be expected if attempts are made to install the aquascreen in areas which are steeply sloped. Most of the shoreline areas in Herring Pond facilitate easy installation of the Aquascreen.

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 or sand-filled bags could also be used as inexpensive, durable weights. Alternative methods of securing the cover are presented in Figure 20. The cover can be rolled onto the bottom by divers, snorkelers, or from a boat. In either case it is advisable to have a diver or snorkeler anchor the cover and check for proper positioning.

The bottom cover should be removed just prior to the swimming season, or it may be left in place indefinitely. It should be noted that if left in position for long periods the bottom cover

TABLE 22

COSTS ASSOCIATED WITH MACROPHYTE CONTROL BY A BOTTOM COVER

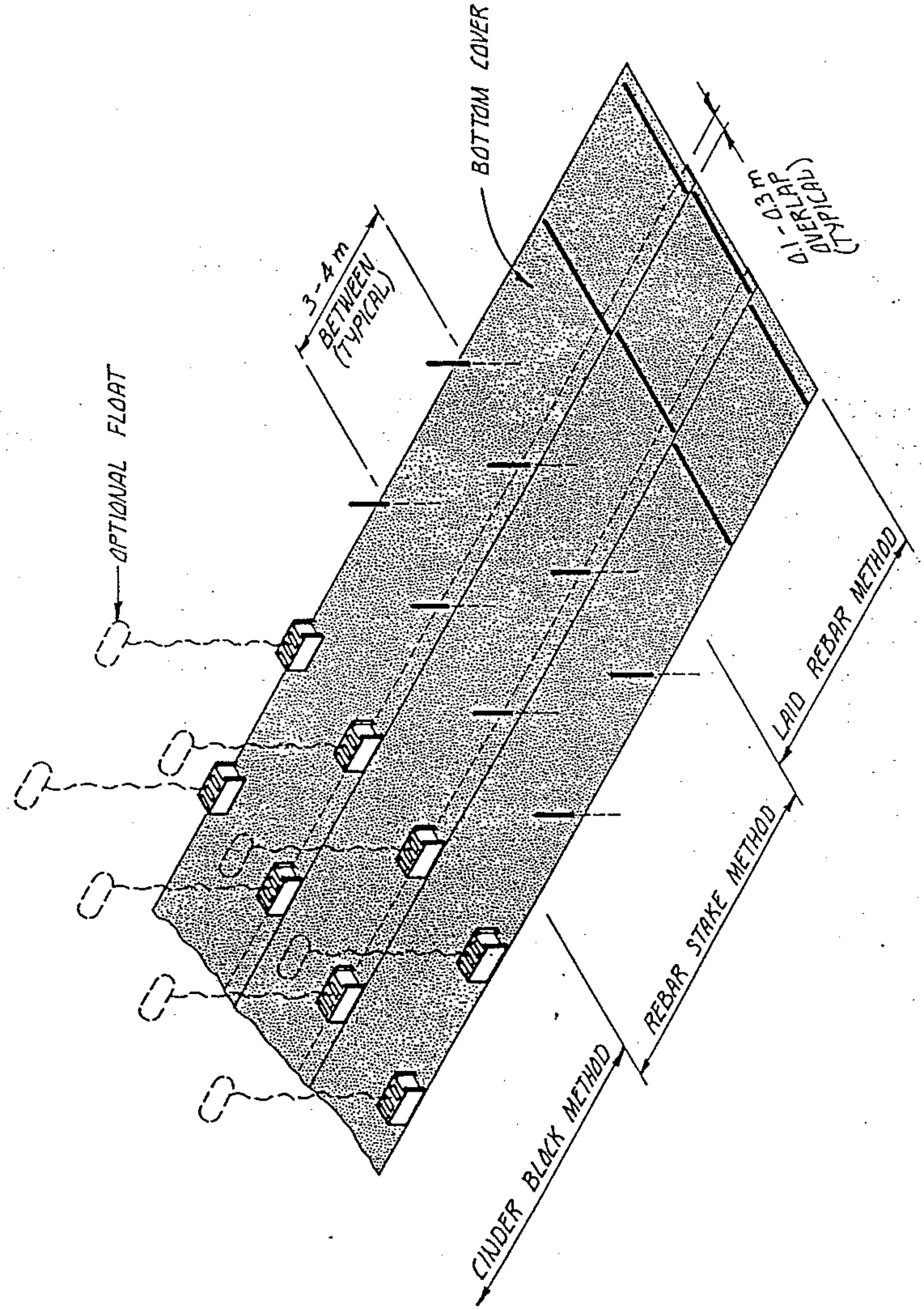
Item or Task	Estimated Cost ($)	Maximum Amount ($) Reimbursable Under Clean Lakes Program*	Local Share ($)
21,000 sq.ft. of Aquascreen @ $0.40/sq.ft.	8,400	0	8,400
300 stakes or weights @ $2/	600	0	600
Installation and Removal (2-man crew @ $500/day for 1.5 days/man)	1,500/yr	0	1,500/yr
Additional Support (brushes for cleaning, useful hardware)	200/yr	0	200/yr
Total Capital Outlay	9,000	0	9,000
Annual Expenses	1,700	0	1,700

* Massachusetts Clean Lakes Program

Note: Costs associated with Aquascreen installation at public beach areas has traditionally been 75% refundable by CLP.

FIGURE 20

APPLICATION OF BENTHIC BARRIER



may accumulate silts and other materials which may allow recolonization of nuisance plants. Additionally, the roots of many plants can extend through the mesh cover, should propagules settle on the cover (e.g., plant fragments dislodged by storms or harvesting). 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 (Cooke et al., 1986). In some cases it has not been necessary to apply the cover again for two years.

Limited Macrophyte Harvesting

In addition to bottom barrier installation, limited removal of macrophytes from nearshore zones can provide immediate relief in nuisance areas. There are a variety of lake rakes on the market, but simply modifying basic silage forks has proven to work very well. The modification involves adding a longer handle and bending the tines of the fork to act more as a rake. There are also ways in which a simple garden cultivator can be modified to act as a chisel plow.

In Herring Pond, coontail (Ceratophyllum sp.) is a major potential nuisance species in nearshore zones. This species is weakly attached to the sediment and can be easily removed by raking. Coontail is a perennial species, capable of over-wintering and beginning growth at ice-out or earlier. Therefore, removal of the whole plant is recommended. If the roots are removed, then these simple tools can provide long-term control of aquatic macrophytes. These simple implements are relatively inexpensive, with costs generally being a function of size and complexity. These tools as well as the labor associated with their implementation will be the responsibilities of the private shoreline property owners. Disposal of the removed vegetation should not be difficult, as the amount of plant biomass removed from each individual property should be quite minimal. Once removed, this plant matter can be used as a high quality mulch for private gardens.

Maintenance of Herring Run

Maintenance of the herring run to Herring Pond will act to assure the success of the alewife fishery in the pond and the role of the pond as nursery for young alewives. This action will continue to fall under the auspices of the Town of Eastham, and should be overseen by the Eastham Natural Resource Department. This management action will require efforts to monitor the passage through the fishway by spawning alewife during the spawning season, and maintenance of an unobstructed fishway. Fishway maintenance will involve the removal of sand, gravel, logs, and other debris which might deny access to the pond by migrating alewife. Maintenance of existing weirs and possibly installation of new ones should be undertaken.

Nutrient Inactivation/Precipitation

Nutrient diversion alone will not guarantee that visible improvements in Herring Pond water quality will be realized as much of the annual phosphorus budget is attributable to recycling from nutrient-rich sediments. Phosphorus inactivation/precipitation is a technique designed to control the release of phosphorus from the sediments as well as the removal of phosphorus from the water column through application of aluminum salts (i.e., aluminum sulfate (alum) and sodium aluminate). Herring Pond possesses many of the characteristics necessary to qualify it as an ideal candidate for an Alum treatment. It is deep with a long residence time and a large fraction of its annual phosphorus is attributable to internal recycling/loading from the sediments.

Nutrient precipitation/inactivation is particularly effective in reducing blooms of nuisance algae, particularly blue-green algae and filamentous algae. A potential limitation of this technique is its questionable ability to control rooted aquatic vegetation. Coontail (Ceratophyllum sp.), the most prominent macrophyte genus in Herring Pond, is a weakly rooted plant which may be subject to control by this technique.

This technique requires knowledge of the pond's chemistry, particularly pH and alkalinity. These characteristics dictate the dose of aluminum salt(s) to be added to the pond to effectively and safely remove phosphorus (P) from the water column and retard P removal from the sediments. Aluminum sulfate (alum) and/or sodium aluminate are added to the water column to form a precipitate of aluminum phosphate or colloidal aluminum hydroxide, to which certian P fractions are bound (Cooke et al. 1986). To guarantee inactivation of sediment phosphorus, hypolimnetic injection of the aluminum salts is recommended. It is important to maintain a pH value of 6.0 or greater during application. Below this pH there is a sharp increase in potentially toxic dissolved aluminum (Al(III)) as well as a decrease in the formation of aluminum hydroxide floc necessary to precipitate P from the water column or hinder its release from the sediments. Regulation of pH above 6.0 is accomplished by adjustment of the composition of the applied aluminum salt mixture. In most cases the ratio of alum to sodium aluminate is approximately 2:1.

Dissolved organic phosphorus is less efficiently precipitated than are inorganic and particular forms. The timing of application therefore becomes critical as under P-limiting conditions some blue-greens adaptively form enzymes (e.g., alkaline phosphatase) enabling them to utilize organically bound phosphorus (Heath and Cooke, 1975).

Costs accociated with this technique are highly variable with surface treatments generally less costly than hypolimnetic applications. Costs associated with chemicals and labor requirements for several of the hypolimnetic treatments undertaken in New England since 1986 have been in the $340 to

$900/acre range, although the majority fell in the range of $400 to $600/acre (Smith and Palmstrom, 1988). Herring Pond displays elevated phosphorus levels in surface water samples as well as in hypolimnetic samples. Therefore, treatment of the pond will likely require both phosphorus precipitation and inactivation. To precipitate and inactivate phosphorus in Herring Pond will require about 40,000 gallons of alum and 20,000 gallons of sodium aluminate. The aluminum concentration of this dosage is recommended to be about 20 mg Al/liter. Total cost of treating Herring Pond can be expected to range between $65,000 and $75,000 (1990 dollars). Variability associated with this estimate is attributed primarily to labor and mobilization costs.

MONITORING PROGRAM

A monitoring program will be necessary to assess the success of management actions and aid in the formulation of appropriate management policies and supplementary management programs. Of primary interest are changes in the concentrations of total phosphorus, ortho-phosphorus, and the control of macrophyte populations. Monitoring of macrophyte populations should include species identification, distribution, and density (biomass and areal percent cover). Other selected parameters to be assessed include flow, dissolved oxygen, pH, specific conductance and chlorophyll a. The assessment of these parameters will allow evaluation of the effectiveness of the recommended management actions. The measurement of in-lake chlorophyll a values will aid in alerting lake managers of a possible shift from a macrophyte to an algal problem. The other parameters are critical in assessing phosphorus loading, and potential phosphorus availability.

Recommended parameters, frequency of measurement, and associated costs are provided in Table 23. A three-year program is shown, as most funding agencies do not address longer term needs. Monitoring should continue indefinitely, although the level of effort could be reduced as warranted. The cost of the entire three-year monitoring program is estimated at close to $23,000. Monitoring costs, on a per unit basis, will rise annually or biennially in accordance with inflation, and are reflected in cost increases as shown in Table 23.

Assessment of the quality of the groundwater following institution of the groundwater management protection educational program requires the sampling of permanent monitoring wells (Figure 10) and local domestic wells. The parameters to be sampled include nutrient fractions (NH_3, NO_3 and total filterable phosphorus) and chloride. The wells to be sampled should correspond with those wells sampled during this study which have exhibited potential impact from on-site waste-water disposal systems (e.g., wells B,D,E,F, and K; Figure 9). These wells would provide standard locations at which the groundwater quality could be assessed seasonally. These are private wells and will require permission from home owners to be included in the monitoring program.

Monitoring should begin prior to implementation of recommended activities, and be carried out over a three-year period. Long-term monitoring at a less intensive level (e.g., seasonally for TFP and NO_3) should be instituted at the conclusion of the three-year project-oriented monitoring program.

This monitoring program will allow assessment of the success of the proposed management alternatives. Specific comparison of pre-project and post-project phosphorus concentration and macrophyte density is desirable. The proposed project is designed to prevent the increase in macrophyte densities to unacceptable levels and to prevent Herring Pond phosphorus concentrations from reaching critical levels.

TABLE 23

COSTS OF THREE YEAR MONITORING PROGRAM
ASSOCIATED WITH MANAGEMENT OPTIONS

Item or Task	Estimated Cost ($)	Max. Amount ($) Reimbusable Under C.L.P. **	Local Share ($)
First Year			
1.) Macrophyte Monitoring Field Evaluation of plant density; May and August @ $750/inspection.	1,500	1,125	375
2.) Groundwater Assessment Sampling of 10 wells @ 4 times/ year. Analysis for NO_3,NH_3,TFP, and Cl; @ $60/sample.	2,400	1,800	600
3.) In-lake water quality monitoring Sampling at 1 site @ 4 times/year. Analysis for OP, TP, DO, pH, conductivity, and chlorophyll *a*; @ $90/sample.	360	270	90
4.) Labor costs for sampling 4 man-days, @ $600/man-day.	2,400	1,800	600
First year total	6,660	4,995	1,665
Second Year			
1.) Macrophyte Monitoring 1 inspection @ $750.	750	563	187
2.) Groundwater Assessment Sampling of 10 wells @ 4 times/yr Analysis as above	2,400	1,800	600
3.) In-lake WQ monitoring Sampling at 1 site @ 4 times/yr. Analysis as above	360	270	90
4.) Labor costs for sampling As above	2,400	1,800	600
Second year sub-total	5,910		
10% contingency	591		
Second year total	6,501	4,876	1,625

TABLE 23 - CONTINUED

Third Year

1-4) Same as second year

Third year sub- total	6,501		
10% contingency	650		
Third year total	7,151	5,363	1,788
Reports, meetings, PALIS	2,000	1,500	500
Total Costs	$22,312	16,734	5,578

* Massachusetts Clean Lakes Program
** Assumes 75% funding level under C.L.P.

FUNDING ALTERNATIVES

Several sources of funding for management activities in Herring Pond and its watershed exist (Table 24), but funds are very limited at this time. The Clean Lakes Program, which sponsored this study, has been the usual key source of support. However, the MA Clean Lakes Program, while still staffed, has no new funds allocated to new projects. Unless there is a change in current funding policy, this program will be a source of technical advice only.

The matching of funds from different agencies of the Commonwealth is discouraged by the Massachusetts Clean Lakes Program, although most other agencies listed in Table 24 have no statutory objection. The Clean Lakes Program seeks to gain local committment through monetary involvement with projects, usually at the 25% level. This is often not a problem with small projects or large and wealthy communities, but does present financial difficulties for large projects or smaller communities. The proposed Herring Pond Management Program and the Town of Eastham fit somewhere midway between these two extremes. In-kind services are not currently recognized by the Massachusetts Clean Lakes Program as monetary contributions to a project, further reducing viable options for funding the portion of the project not covered by the Clean Lakes Program.

On the Federal Level, both the Clean Lakes Program and Non-Point Source Pollution Abatement Program are becoming more active. Most funds for both programs are already allocated to projects for 1990, but pursuit of funding for 1991 is encouraged. Application deadlines are usually in January, with decisions rendered in March. The Non-Point Source Pollution Abatement Program in particular is expanding rapidly in Massachusetts, and might offer funds for a study of the impact of education programs on septic system management and related groundwater impacts.

Several creative programs have recently been proposed in the Massachusetts legislature, but the current budgetary crisis leaves little hope of enactment in the near future. If the Town desires immediate action to implement the management program, it will likely require that most, if not all, of the necessary funding is provided by Eastham residents. If the Town elects to "go it alone" in the absence of near-future assistance from the Clean Lakes Program, they may wish to select from the list of recommended actions to maximize the benefit:cost ratio for their investment. Purchase of hand-held weed rakes and the recommended quantity of Aquascreen by shoreline residents, combined with an eductional brochure outlining sound, responsible domestic practices, should provide a level of protection commensurate with the necessary capital outlay. Costs could be kept to a minimum if the Town of Eastham accepts the responsibility of researching and producing the brochure.

TABLE 24

POTENTIAL FUNDING SOURCES FOR THE PROPOSED
RESTORATION OF HERRING POND

Source	Funding Level	Notes
Massachusetts Clean Lakes Program (Ch. 628 of the Acts of 1981, DEP)	75%	Financially deficient; Unlikely source of funding in the near future.
Federal Clean Lakes Program (Sec. 314 of PL 92-500, USEPA)	50%	Financially deficient. Future funding possible.
Small Watershed Protection Program (PL 83-56, SCS)	50%	Requires high cost:benefit ratio.
Rivers and Harbors Program (Division of Waterways, DEM)	50%	Jan. 15 deadline; can be applied to recreational enhancement. Under current fiscal restriction.
Federal Land and Water Conservation Fund; Division of Conservation Services, EOEA (Federal Pass Through)	50%	Acquisition of lands for outdoor recreation. Need to have up-to-date open space plans. Funds available.
Mass. Self Help Program M.G.L. Chap. 132A, Sec. 11 (DCS/EOEA)	(up to) 80%	Grants to Conservation Commissions for Land Acquisition; need approved open space plan. Funds available.
USEPA Non-Point Source Pollution Abatement Program Clean Water Act Sec. 319 (USEPA, admin. by MDEP)	60%	Grants to Watershed Associations, Towns, or Regional Organizations for implementation of non-point source pollution abatement techniques. Funds are currently available.

ENVIRONMENTAL EVALUATION

Appendix E 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.

The major environmental issues surrounding the proposed project relate to the application of aluminum salts to precipitate and inactivate phosphorus in Herring Pond, if in the future this action is desired. If an alum treatment is deemed necessary to provide the level of phosphorus reduction desired, discretion should be used concerning area treated and dosage. It is recommended that the extent of plant removal, either by limited mechanical removal or benthic barrier installation, be limited to 1,000 square feet per shorefront residence. This should allow for the maintenance of suitable habitat for the pond's fish community, and also provide for improved recreational utility of the pond. As the management actions are for the betterment of the pond environment, no serious opposition to the project is anticipated. An Environmental Impact Report may be required, however, to address any issues which the MEPA unit feels are in need of further elucidation.

Copies of this report or relevant excerpts have been sent to the Massachusetts Division of Water Pollution Control, Division of Fisheries and Wildlife, Historical Commission, and Natural Heritage Program for review and comment. Review by the Conservation Commission and the Board of Selectmen have also been requested. Copies of all comments received can be found in Appendix E.

NECESSARY PERMITS

Under the current regulatory climate, the proposed project could require passage through 12 different approval processes involving 11 federal or state agencies (Table 25). Most of these processes are simple, however; three are initiated by this report, and five are part of the Massachusetts Clean Lakes Program Phase II application procedure. This leaves only MEPA review (ENF filing), the Wetlands Protection Act and Water Quality Certificate (Notice of Intent filing), and the ACOE Section 404 Permit to be handled independently. Not all aspects of the project require all permit processes; only the alum treatment would involve an extensive process overall.

To receive state funds for implementation, Eastham must comply with laws relating to discrimination, wage rates and housing, provide proof of title to the project site, and sign the appropriate intergovernmental (substate) agreement. Review processes by the Division of Fisheries and Wildlife, the Massachusetts Historical Commission, and the Natural Heritage Program have been initiated with the filing of this report. The review by the EOEA (MEPA unit) will be initiated by the filing of the attached ENF (Appendix E); Eastham officials should file this document at their earliest convenience. The Eastham Conservation Commission will be reviewing this report, but a formal Notice of Intent should be filed by Town officials to initiate the approval process associated with the Wetlands Protection Act. If state level funding is not acquired, many of these approvals are unnecessary.

The disposal of the removed plant material may require approval by the Division of Hazardous Waste. The local field office of the DEP should be consulted by Town officials for determination of applicability with regard to any intended harvesting program.

If alum treatment is chosen as a management action, an application must be filed by Town officials with the DWPC for a Water Quality Certificate as well as with the U.S. Army Corps. of Engineers for a Section 404 Permit. All of the other approval processes noted above are also required, necessitating a faoirly long (up to one year) lead time prior to implementation. As this technique is not recommended for immediate application, no action is necessary at this time.

TABLE 25

PERMITS AND OTHER APPROVAL PROCESSES ASSOCIATED WITH THE PROPOSED MANAGEMENT ACTIONS

PERMIT/CERTIFICATE/LICENSE/APPROVAL WHICH MUST BE OBTAINED	CONTACT AGENCY AND ADDRESS	REVIEW TIME (DAYS)	APPLICABILITY TO MANAGEMENT ACTIONS		
			Bottom Covers	Harvesting	Alum Treatment
Title to Project Site	Lakes Section, DWPC, DEP Lyman School, Westview Bldg. Westborough, MA 01581 508-366-9181	None, submit w/appl.	X	X	X
Fair Housing (EO 215)	Exec. Office Communities/Devel. 100 Cambridge St., Rm 1404 Boston, MA 02202 617-727-7824	None, Contact OECD for determination	y	y	X
Commission Against Discrimmination	MA Comm. Against Discrimmination 1 Ashburton Place Boston, MA 02108 617-727-7309	120	y	y	X
Wage Rate Compliance	Dept. Labor and Industries 100 Cambridge St., 11th Floor Boston, MA 02202 617-727-3454	None, submit within 15 days after work done.	y	y	X
MA Env. Policy Act (ENF Review)	Exec. Off. Env. Affairs (MEPA) 100 Cambridge St., 20th Floor Boston, MA 02202 617-727-5830	30 *	y	y	
Natural Heritage Program	MA Natural Heritage Prog., DFW 100 Cambridge St. Boston, MA 02202 617-727-9194	Approx. 30 ** Submit letter of finding w/appl.	X	X	X
Historical Commission	MA Historical Commission 80 Boylston St. Boston, MA 02116 617-727-8570	Approx. 30 ** Submit letter of finding w/appl.	X	X	X
Div. Fisheries and Wildlife	Div. Fisheries and Wildlife Field Headquarters Westborough, MA 01581 508-366-4470	15 **	X	X	

TABLE 25 - CONTINUED

PERMITS AND OTHER APPROVAL PROCESSES ASSOCIATED WITH THE PROPOSED MANAGEMENT ACTIONS

PERMIT/CERTIFICATE/LICENSE/APPROVAL WHICH MUST BE OBTAINED	CONTACT AGENCY AND ADDRESS	REVIEW TIME (DAYS)	APPLICABILITY TO MANAGEMENT ACTIONS: Bottom Covers	Harvesting	Alum Treatment
Wetlands Protection Act	Eastham Conservation Commission 2500 State Highway Eastham, MA 02642 508-255-0333	42	X	X	X
Div. Solid and Hazardous Waste	Div. Solid Waste, DEQE 75 Grove Street Worcester, MA 01605 508-792-7653	***		?	
Army Corps of Engineers Section 404 Permit	Regulatory Branch U.S. Army Corps of Engineers 424 Trapelo Road Waltham, MA 02254 617-647-8332	120			X
Water Quality Certificate **	Permits Section, DWPC One Winter Street Boston, MA 02108 617-292-5673	90			X

y Necessary only if supported by state funds.

* If EIR required, final approval will not be given until EIR is reviewed.

** Review of project by appropriate agency initiated by this report.

*** No statutory limit, longest when EIR is required.

PHASE II TASK RESPONSIBILITIES

Grant arrangements and other administrative tasks which must be performed prior to the hiring of a Phase II consultant must be handled by Town officials. Permit application filings and much of the related documentation are also the responsibility of the Town, although a qualified consultant can greatly ease the burden this process imposes. The Clean Lakes Program has in the past shared the cost of impact statement preparation if one is required.

All tasks associated with monitoring and education program development are the responsibility of the Phase II consultant, although Town involvement with the educational program is strongly encouraged, particularly with respect to distribution and publicity. It is recommended that the Town accept responsibility for the initial bulk purchase of benthic barriers, but final purchase, installation, and maintenance be the responsibility of private shorefront property owners.

Should the Clean Lakes Program funding not be obtained, either through fiscal restriction of the Commonwealth budget or ineligibility of management actions (e.g., benthic barriers in front of private residences), the Town of Eastham would have to shoulder the costs of the maintenance program or seek alternative sources of funding. The Board of Selectmen could act as its own representative to file the Environmental Notification Form and Notice of Intent, select a consultant to prepare a brochure and conduct monitoring, and generally administer the program. The magnitude of expenses is not so great as to preclude local action in the absence of Clean Lakes Program funding, and many actions can be scaled down to meet the resources of the Town of Eastham.

PUBLIC PARTICIPATION

In addition to review by the agencies mentioned in the Environmental Evaluation section of this report, the public at large was involved with the development of management alternatives. To date, one public meeting and numerous informal discussions have been conducted by BEC in the Town of Eastham.

Participants at the meeting were encouraged to express their views and make recommendations. Local support for the project has been high, as it is perceived as one of the major elements of a desired pond revitalization program. A summary of the issues discussed at the public meeting and any written comments received are included in Appendix F.

RELATION TO EXISTING PLANS AND PROGRAMS

The proposed lake restoration and management plan is entirely consistent with all stated objectives and community-sponsored activities in the watershed. Participation by concerned citizens in the proposed management activities could reduce costs and may result in a more effective management of Herring Pond and its watershed.

The purchase by the Town of the Horton Property, a 25-acre tract on the northern shore of Herring Pond, will act to reduce future potential cultural impacts. Implementation of an education program will inform watershed residents how changes in domestic practices will reduce the current pollutant loading to groundwater sources and the relationship of groundwater to pond water quality.

The proposed in-lake actions will improve conditions without impairment to downstream flows or water quality. The result will be an enhancement of recreational value and visual appeal.

FEASIBILITY SUMMARY

An evaluation of possible management options was conducted, and those alternatives which were not appropriate or feasible were eliminated from further consideration. Remaining options included: limited macrophyte harvesting; lake bottom covering; herring run management; using non-phosphate detergents; and maintaining and upgrading on-site wastewater disposal systems. Nutrient precipitation/inactivation is also a feasible alternative and would be recommended if pond conditions were to deteriorate.

Control of macrophytes in select nearshore zones using reusable mesh covers has been recommended as well as the limited removal of macrophytes by low-tech harvesting techniques. It is also recommended that the herring run to the pond be maintained as an unobstructed fishway. No other in-lake techniques are recommended at this time, although future control of phosphorus through aluminum salt application warrants consideration.

Watershed management centers around the improvement and protection of groundwater quality entering Herring Pond. The input of unnecessary pollutant loads (e.g., from detergents or fertilizers) should be eliminated, with an initial attempt through education. Likewise, maintenance and upgrade of on-site wastewater disposal systems must be encouraged.

A tentative implementation schedule and associated costs are presented in Table 26. A monitoring program and the production and dissemination of an educational brochure are included. The total anticipated cost of the management program is about $43,300. Monitoring costs over a three-year period account for $22,300 of this total. If in the future nutrient precipitation/inactivation becomes necessary, the total cost could escalate to as much as $118,000. Potential funding sources have been discussed, with the Massachusetts Clean Lakes Program usually targeted as the likely primary source. Because of the current fiscal budgetary crisis, however, funding from this source is very unlikely. Therefore, other funding sources should be investigated. The federal Non-Point Source Pollution Abatement Program represents the most viable option at this time.

The projected cost for the management program for Herring Pond is by no means negligible. It is, however, inexpensive in comparison to other lake restoration projects requiring a greater level of engineering and design work, such as lakes requiring major volumes of sediment to be removed, or the rerouting of major storm drain systems. Herring Pond is less in need of such major actions than of protection and maintenance; the outlined program should retain and improve the desirable features of Herring Pond without excessive expense.

TABLE 26

SUMMARY OF MANAGEMENT ACTIONS, IMPLEMENTATION SCHEDULE, AND ASSOCIATED COSTS

Item/Task	Spring 1991- Fall 1991	Winter 1992	Spring 1992	Summer 1992	Fall 1992	Winter 1993	Spring 1993	Summer 1993	Fall 1993	Winter 1994	Spring 1994- Winter 1995	Total Costs Est. ($)
Grant Arrangements w/DEP, Line up Potential Additional Funding Sources	X											
Groundwater Education Program		$4,000	$4,000	$4,000								$12,000
Benthic Barrier Purchase		$9,000										$9,000
Permits		$2,250										$2,250
Monitoring			$2,040	$2,040	$1,290	$1,290	$1,419	$2,240	$1,419	$1,419	$9,155	$22,312
Total Cost	X	$15,250	$6,040	$6,040	$1,290	$1,290	$1,419	$2,240	$1,419	$1,419	$9,155	$45,562

Note: Estimated total costs do not include additional costs for hand-held weed rake purchases or for nutrient precipitation/inactivation treatment, if necessary.

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APPENDIX A

MATERIALS AND METHODS:

EQUIPMENT, INSTRUMENTATION, TECHNIQUES, AND SPECIFIC HANDLING REQUIREMENTS

FIELD/LABORATORY ANALYSES AND EQUIPMENT

PARAMETER	COLLECTION/TEST TYPE	EQUIPMENT NEEDS
Ammonia nitrogen	Colorimetric	417A-Distillation step- Ammonia-free water, distillation apparatus, borate buffer solution, sodium hydroxide, dechlorinating agent, phenylarsine oxide, sodium arsenite, sodium sulfite, sodium thiosulfate, neutralization agent, sodium hydroxide, sulfuric acid, boric acid 417B-Nesslerization- Spectrophotometer w/1 to 5 cm path, Nessler tubes, pH meter, zinc sulfate solution, EDTA, Nessler reagent, stock ammonium solution, potassium chloroplatinate solution, cobaltous chloride solution, membrane filters, suction filter apparatus 417D-Electrode method- pH meter, ammonia electrode, magnetic stirrer apparatus, ammonia-free water, sodium hydroxide, stock ammonia solution
Total kjeldahl nitrogen	Colorimetric	420B-Semi-micro-Kjeldahl method- Digestion apparatus, distillation apparatus, pH meter, digestion reagent (potassium sulfate, mercuric oxide, sulfuric acid), phenolphthalein indicator, sodium hydroxide-sodium thiosulfate reagent, borate buffer and sodium hydroxide 417B or 417E- See ammonia above
Total alkalinity	Titration	403-Std. Method- sodium carbonate solution, sulfuric or hydrochloric acid, mixed bromocresol green-methyl red indicator, methyl orange solution, phenophthalein indicator, sodium thiosulfate
Chloride	Titration	407A-Argentometric method- Potassium chromate indicator, silver nitrate solution, standard sodium chloride, titration apparatus
Total solids	Gravimetric (dried)	209A-Std. Method- Evaporating dish, muffle furnace, steam bath, drying oven, dessicator, balance
Total volatile solids	Gravimetric (ignited)	209E-Std. Method- No additions to 209A 209A- See Total Solids above
Total suspended solids	Gravimetric (filtered/dried)	209D-Std. Method- glass fiber filters, suction filter apparatus, crucibles or planchets, in addition to 209A 209A- See Total Solids above
Arsenic	Atomic absorption	Atomic absorption unit and related supplies, argon-hydrogen or nitrogen-hydrogen gas
Cadmium	Atomic absorption	Atomic absorption unit and related supplies, air-acetylene gas
Chromium	Atomic absorption	Atomic absorption unit and related supplies, air-acetylene gas

FIELD/LABORATORY ANALYSES AND EQUIPMENT

PARAMETER	COLLECTION/TEST TYPE	EQUIPMENT NEEDS
Copper	Atomic absorption	Atomic absorption unit and related supplies, air-acetylene gas
Iron	Atomic absorption Colorimetric	Atomic absorption unit and related supplies, air-acetylene gas 315B-Phenanthroline method- Spectrophotometer w/1 to 5 cm path, Nessler tubes, acid-washed glassware, separatory funnels, membrane filters, suction filtration apparatus, hydrochloric acid, hydroxylamine solution, ammonium acetate buffer solution, sodium acetate solution, phenanthroline solution, stock iron solution
Lead	Atomic absorption	Atomic absorption unit and related supplies, air-acetylene gas
Manganese	Atomic absorption	Atomic absorption unit and related supplies, air-acetylene gas
Mercury	Atomic absorption	Atomic absorption unit and related supplies, cold vapor method supplies
Nickel	Atomic absorption	Atomic absorption unit and related supplies, air-acetylene gas
Vanadium	Atomic absorption	Atomic absorption unit and related supplies, nitrous oxide-acetylene gas
Zinc	Atomic absorption	Atomic absorption unit and related supplies, air-acetylene gas
Oil and grease	Extraction/gravimetric	503A-Partition/gravimetric method- Separatory funnel, distillation apparatus, water bath, filter paper, gravity filtration apparatus, hydrochloric acid, trichlorotrifluoroethane, sodium sulfate
Polychlorinated biphenyls	Gas chromatographic	Gas chromatograph and related supplies
Pesticides (general scan)	Gas chromatographic	Gas chromatograph and related supplies
Organic content	Gravimetric (dried/ignited)	209E- See Total Volatile Solids above

FIELD/LABORATORY ANALYSES AND EQUIPMENT

PARAMETER	COLLECTION/TEST TYPE	EQUIPMENT NEEDS
Fecal coliform	Incubated filter plate count	909C-Membrane filter procedure- M-FC medium, culture dishes, incubator, pipettes, sterile filter apparatus, membrane filters, absorbent pads, forceps, fluorescent lamp with magnifying lens (10 to 15X), suction filter apparatus
Fecal streptococci	Incubated filter plate count	910B-Membrane filter procedure- KF Streptococcus agar, culture dish incubator, pipettes, sterile filter apparatus, membrane filters, absorbent pads, forceps, fluorescent lamp with magnifying lens (10 to 15X), suction filter apparatus
Grain size distribution	Gravimetric (sieved)	ASTM seive series, hydrometer, collection pans, balance
Sediment settling features	Volumetric	Large and small settling columns (clear tubes, pref. graduated, with sampling/outlet ports at intervals), watch
Chlorophyll a	Extraction/absorption	0.45 um filter paper, Millipore suction filter apparatus or equivalent, 90% acetone solution, tissue grinder, graduated test tubes, spectrophotometer w/2 nm band width, conc. H_2SO_4
Phytoplankton abundance	Microscopic cell count	Graduated settling tubes, Sedgewick-Rafter and Palmer-Maloney counting slides, microscope with capability of 100 to 400X, tally sheets, computer (w/tabulation/biomass conversion prog.), identification manuals, ocular measuring device
Zooplankton abundance/ size distribution	Microscopic count	Graduated settling tubes, Sedgewick-Rafter counting slide, microscope with capability of 40 to 100X (overhead proj. scope), tally sheets, computer (w/tabulation/biomass conversion prog.), identification manuals, ocular measuring device
Macrophyte abundance/ distribution	Visual	Hand lens, ident. manuals
Macroinvertebrate abundance	Visual or microscopic examination	Petri dishes, stereoscope with capability of 4 to 40X, dissection kit, ident. manuals, hand lens
Fish abundance/growth rate	Visual and microscopic scale examination	Ident. manuals, microscope with capability of 40 to 100X (overhead projector scope), flat microscope slides or acetate scale impressions, forceps, ocular measuring device

FIELD/LABORATORY ANALYSES AND EQUIPMENT

PARAMETER	COLLECTION/TEST TYPE	EQUIPMENT NEEDS
FIELD WORK: Water Sample Collection - General field needs		Vehicle, first aid kit, flashlight, tools/repair supplies Boat, trailer, oars, motor, fuel tank/line, rope, life jackets, seat cushions, fire extinguisher, light/whistle safety assembly and anchors Ice auger, toboggan/sled, ice ladle Boots/waders, rubber gloves, rain gear Coolers, carrying crates, labels/tape, marking pens, pencils, paper/clipboards, field notebooks, waterproof notebook, lab/field sheets, maps Assorted sample containers, preservatives (specific needs below)
Surface water	Grab	1 to 4 L jug or jar, Scott bottle, funnel, extension poles/tape
Stormwater runoff	Grab or composite	1 to 4 L jug and jar
Groundwater Wells	Grab	1 to 4 L jug or jar, well logger, well bailer or pump
Porewater	Grab or composite	1 to 4 L jug or jar, LIP sampler w/hand pump and trap
Seepage	Volumetric	Seepage meters w/bags and spouts, grad. cyl., tape measure, float-markers, watch
Biological Collections - Bacteria	Grab	Sterile plastic bags or glass bottles
Phytoplankton	Grab or tube composite	100 to 250 ml bottles w/Lugol's solution, 10 m flexible tube (1 to 2 cm dia.), 1 L dark bottle (for chl)
Zooplankton	150 um mesh net tow	250 to 500 ml bottles w/formalin, 150 um mesh tow net, calibrated rope
Macrophytes	Ekman or manual	Ekman dredge, areal grid sampler, plastic bags, SCUBA gear, ident. manuals
Macroinvertebrates	D-net or Ekman dredge	Ekman dredge, D-net, sorting pan, forceps, 500 ml jars, alcohol or formalin, std. seives
Fish	Gill net, trap net or seine	Gill net, trap net, seine, net pickers, live well, measuring board, weighing scale, needle nose pliers, scale envelopes, dip net

FIELD/LABORATORY ANALYSES AND EQUIPMENT

PARAMETER	COLLECTION/TEST TYPE	EQUIPMENT NEEDS
Sediment Sampling and Physical Measurements –		
Sediment collection	Core or Ekman grab	Ekman dredge, lucite core tubes, mixing bucket, glass and plastic widemouth containers, SCUBA gear
Soft sediment depth	Probe to refusal	Graduated rods with screw connections, SCUBA gear
Water discharge (flow)	Volumetric	Floats, Gurley meter, stopwatch, tape measure/graduated rod
Lake bathymetry	Sonic fathometer or line soundings	Electronic fathometer assembly, graduated plumbline, operated from a boat
Morphometric lake features	Physical/calculation	Maps, ruler, planimeter, measuring wheel, calculator/computer (typically done in office after field reconnaisance)
Field Analyses –		
Secchi disk transparency	Visual	20 cm Secchi disk on graduated rope
Temperature	Thermistor	Thermistor (incl. w/DO and Cond. meters) on 30 m cable
Dissolved oxygen	Membrane electrode or Winkler titration	YSI Model 57 or modified Model 51A or equivalent DO meter w/30 m cable, probe repair kit Winkler chemicals, pipettes, titration apparatus, stoppered bottle for sample
Percent oxygen saturation	Calculation from T/DO	Calculator/computer; can be done in field or in office/lab later
pH	Potentiometric	Orion SA250 pH meter or equivalent, pH 4, 7 &10 buffers, distilled water. Hach colorimetric kits can be used for field approximation; pH meter can also be used in lab.
Specific conductance	Platinized electrode	YSI Model 33 S-C-T meter or equivalent, conductivity standard, platinizing solution, distilled water; can also be used in lab
Turbidity	Nephelometric	Hach Model 1860 turbidimeter or equivalent, power source, paper towels, distilled water; can also be used in lab

FIELD/LABORATORY ANALYSES AND EQUIPMENT

PARAMETER	COLLECTION/TEST TYPE	EQUIPMENT NEEDS
LABORATORY ANALYSES: General laboratory needs		Refrigerator/freezer, cabinets/benchtops, hood/overall ventillation system, electronic balance, drying oven, muffle furnace, autoclave, dessicator, incubator, titration apparatus, distillation apparatus, magnetic stirrer assembly, 2 nm band width spectrophotometer, acid wash assembly, rubber gloves, cleaning supplies (incl. acids and non-P detergent), goggles, chemical handling supplies (scoops, paper, etc.), alarm timer, distilled water source, shower/eye wash, assorted glassware Some items are repeated below where used
Total phosphorus	Colorimetric	424C-Persulfate digestion- hot plate or autoclave, autoclavable, acid-washed glassware, phenophthalein indicator, sulfuric acid, ammonium persulfate, sodium hydroxide 424F-Ascorbic acid method- See SRP below
Total filterable phosphorus	Colorimetric	424A-Filtration step- 0.45 um membrane filters, suction filtration apparatus, acid washed collection vessel 424C- Persulfate digestion- See TP above 424F-Ascorbic acid method- See SRP below
Soluble reactive phosphorus	Colorimetric	424F-Ascorbic acid method- Acid-washed glassware, spectrophotometer w/5-10 cm path, sulfuric acid, potassium antimonyl tartrate solution, ammonium molybdate solution, ascorbic acid solution, stock P solution
Nitrate nitrogen	Colorimetric	418B-Electrode method- pH meter, nitrate electrode, magnetic stir apparatus, stock nitrate solution 418C-Cadmium reduction method- Reduction column, spectrophotometer w/1 to 5 cm path, copper-cadmium granules, sulfanilamide reagent, N(1-naphthyl)-ethylenediamine dihydrochlorids solution, ammonium chloride-EDTA solution, hdrochloric acid, copper sulfate solution, stock nitrate solution, membrane filters, suction filter apparatus 418D-Chromotropic acid method- Spectrophotometer w/1 to 5 cm path, stock nitrate solution, sulfite urea solution, antimony reagent, chromotopic acid reagent, sulfuric acid

SAMPLE COLLECTION AND PROCESSING METHODOLOGY FOR BEC SURVEYS

PARAMETER	COLLECTION/TEST TYPE	STD. METH	EPA METHOD	OTHER METHOD	RECOMMENDED SAMPLE SIZE (ml)	SAMPLE PRESERV.	RECOMMENDED HOLDING TIME (hr or as noted)
Water sample collection General surface water	Grab	105 2.a		DEQE			
Stormwater runoff	Grab or composite	105 2.a&b		DEQE			
Groundwater Wells	Grab	105 2.a		SMDCF			
Porewater	Grab or composite	105 2.a&b		WLB MWMB			
Seepage	Volumetric			MWA LEE			
Sediment sample collection	Core or Ekman grab			H&L CH.12 H&B			
Water discharge	Volumetric			H&L CH.5 SCS			
Total phosphorus	Colorimetric	424 C,F	365.1-4	H&L CH.7	100	Refrigerate/freeze	48
Total filterable phosphorus	Colorimetric	424 A,C,F	365.1-4	H&L CH.7	100	Filter, refrigerate/freeze	48
Soluble reactive phosphorus	Colorimetric	424 A,F	365.1-3	H&L CH.7	100	Filter, refrigerate/freeze	48
Nitrate nitrogen	Colorimetric	418 D	353.3	H&L CH.7	100	H2SO4 to pH<2	48
Ammonia nitrogen	Colorimetric	417 A,B	350.2	H&L CH.7	500	H2SO4 to pH<2	168
Total kjeldahl nitrogen	Colorimetric	420 B	351.3	H&L CH.7	500	H2SO4 to pH<2	168
Temperature	Thermistor	212	170.1	H&L CH.2			Immediate
Dissolved oxygen	Membrane electrode or Winkler titration	421 A,B,C,F	360.1&2	H&L CH.6			Immediate (electrode) to 8 (Winkler)

SAMPLE COLLECTION AND PROCESSING METHODOLOGY FOR BEC SURVEYS

PARAMETER	COLLECTION/TEST TYPE	STD. METH	EPA METHOD	OTHER METHOD	RECOMMENDED SAMPLE SIZE (ml)	SAMPLE PRESERV.	RECOMMENDED HOLDING TIME (hr or as noted)
Percent oxygen saturation	Calculation from T/DO			H&L CH.6			
pH	Potentiometric	423	150.1	H&L CH.8			2
Total alkalinity	Titration	403	310.1	H&L CH.8	200	Refrigerate	24
Chloride	Titration	407 A,B,C	325.3	H&L CH.7	100	Refrigerate	672
Specific conductance	Platinized electrode	205	120.1	H&L CH.7		Refrigerate	672
Secchi disk transparency	Visual			H&L CH.2 P			Immediate
Turbidity	Nephelometric	214 A	180.1		50	Darkness	24
Total solids	Gravimetric (dried)	209 A	160.3	H&L CH.7	500	Refrigerate	168
Total volatile solids	Gravimetric (ignited)	209 E	160.4	H&L CH.7	500	Refrigerate	168
Total suspended solids	Gravimetric (filtered/dried)	209 B	160.1	H&L CH.7	500	Refrigerate	168
Arsenic	Atomic absorption	303 E	206.1&2		50	HNO3 to pH<2	6 months
Cadmium	Atomic absorption	303 A	213.1&2		50	HNO3 to pH<2	6 months
Chromium	Atomic absorption	303 A	218.1&2		50	HNO3 to pH<2	6 months
Copper	Atomic absorption	303 A	220.1&2		50	HNO3 to pH<2	6 months

SAMPLE COLLECTION AND PROCESSING METHODOLOGY FOR BEC SURVEYS

PARAMETER	COLLECTION/TEST TYPE	STD. METH	EPA METHOD	OTHER METHOD	RECOMMENDED SAMPLE SIZE (ml)	SAMPLE PRESERV.	RECOMMENDED HOLDING TIME (hr or as noted)
Iron	Atomic absorption Colorimetric	303 A 315 B	236.1&2		50	HNO3 to pH<2	6 months
Lead	Atomic absorption	303 A	239.1&2		50	HNO3 to pH<2	6 months
Manganese	Atomic absorption	303 A	243.1&2		50	HNO3 to pH<2	6 months
Mercury	Atomic absorption	303 F	245.1&2 245.5		500	HNO3 to pH<2	6 months
Nickel	Atomic absorption	303 A	249.1&2		50	HNO3 to pH<2	6 months
Vanadium	Atomic absorption	303 C	286.1&2		50	HNO3 to pH<2	6 months
Zinc	Atomic absorption	303 A	289.1&2		50	HNO3 to pH<2	6 months
Oil and grease	Extraction/gravimetric	503 A,C	413.1		1000	H2SO4 to pH<2	672
Polychlorinated biphenyls	Gas chromatographic			FR			
Pesticides (general scan)	Gas chromatographic			FR			
Organic content	Gravimetric (dried/ignited)	209 E	160.4				
Grain size distribution	Gravimetric (sieved)			H&L CH.5 H&B			
Sediment settling features	Volumetric			H&B			
Fecal coliform	Incubated filter plate count	909 C		B&H III.C.2	125	Refrigerate	6
Fecal streptococci	Incubated filter plate count	910 B		B&H III.D.2	125	Refrigerate	6

SAMPLE COLLECTION AND PROCESSING METHODOLOGY FOR BEC SURVEYS

PARAMETER	COLLECTION/TEST TYPE	STD. METH	EPA METHOD	OTHER METHOD	RECOMMENDED SAMPLE SIZE (ml)	SAMPLE PRESERV.	RECOMMENDED HOLDING TIME (hr or as noted)
Chlorophyll a	Extraction/absorption	1003 G.3	W CH.2.5.2.1&3	H&L CH.10	1000	Refrigerate in dark	8
Biological collections							
Phytoplankton	Grab or tube composite	1002 B.2&3	W CH.2.2&3	H&L CH.10		Lugol's	6 months
Zooplankton	150 um mesh net tow	1002 B.2&4	W CH.2.2&3	H&L CH.11		Formalin	6 months
Macrophytes	Ekman or manual	1004 D.1 1004 D.2a&b	W CH.3	H&L CH.20		Formalin	48
Macroinvertebrates	D-net or Ekman dredge	1005 B.3.a.6 1005 B.4	W CH.4.3.2&3 W CH.4.4.1&2	H&L CH.12		Alcohol or formalin	6 months
Fish	Gill net, trap net or seine	1006 A.1.abd	W CH.5.2.2.1 W CH.5.2.3	NJL CH.6,7,18&19		Alcohol or formalin	6 months
Phytoplankton abundance	Microscopic cell count	1002 C.1 1002 E.1&4 1002 F.1&2 1002 H.2	W CH.2.4&5.3	H&L CH.10			
Zooplankton abundance/ size distribution	Microscopic count	1002 C.1 1002 E.1&4 1002 F.7 1002 H.2	W CH.2.4&5.3	H&L CH.11			
Macrophyte abundance/ distribution	Visual	1004 B 1004 C.1,2&4 1004 D.3&4	W CH.3	H&L CH.20			
Macroinvertebrate abundance	Visual or microscopic examination	1005 C	W CH.4.4.5	H&L CH.12			
Fish abundance/growth rate	Visual and microscopic scale examination	1006 B	W CH.5.4	NJL CH.15&16			
Soft sediment depth	Probe to refusal			DEQE			
Lake bathymetry	Sonic fathometer			H&L CH.1 DEQE			
Morphometric lake features	Physical/calculation			H&L CH.1			

REFERENCES FOR METHODOLOGY:

Unless otherwise given, Std. Method is from APHA-AWWA-WPCF 16th edition.
Unless otherwise given, EPA Method is from EPA-600/4-79-020.

Other references:

B&W = Bordner and Winter, 1978. Microbiological Methods for Monitoring the Environment. EPA-600/8-78-017, USEPA, Cincinnati, OH.

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FR = Federal Register, 40 CFR, Part 136, Oct. 26, 1984.

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MWMB = Mitchell, Wagner, Monagle and Beluzo, 1989. The Littoral Interstitial Porewater Sampler: Paying "LIP" service to your lake. Lake Reserv. Manage. 5:(in press).

NJL = Nielsen, Johnson and Lampton, 1983. Fisheries Techniques. AFS, Bethesda, MD.

P = Preisendorfer, 1986. Secchi disk science: Visual optics of natural waters. Limnol. Oceanogr. 31:909-926.

SCS = Soil Conservation Service, 1975. Engineering Field Manual for Conservation Practices. USDA, SCS, Washington, DC.

SMDCF = Scalf, McNabb, Dunlap, Cosby and Fryberger, 1981. Manual of Groundwater Sampling Procedures. NWWA, Worthington, OH.

W = Weber, 1973. Biological Field and Laboratory Methods. EPA-600/4-73-001, USEPA, Cincinnati, OH.

WLB = Winter, LeBaugh and Rosenberry, 1988. The design and use of a hydraulic potentiomanometer for direct measurement of differences in hydraulic head between groundwater and surface water. Limnol. Oceanogr. 33:1209-1214.

W&B = Walsh and Bemben, 1977. Disposal and Utilization of Hydraulically Dredged Lake Sediments in Limited Containment Areas. Publication #92, Water Resour. Res. Center, UMASS, Amherst, MA.

W&L = Wetzel and Likens, 1979. Limnological Analyses. W.B. Saunders, Philadelphia, PA.

APPENDIX B

DATA GENERATED BY THE BEC STUDY

FLOW (CFS) IN THE HERRING POND SYSTEM

STATION DATE	HP-1	HP-3
04/05/88	0.00	
04/20/88	.10	
05/11/88	.10	.10
05/23/88	.02	
06/06/88	.10	
06/20/88	0.00	
07/07/88	0.00	
07/18/87	0.00	
08/09/88	0.00	
08/22/88	0.00	
09/06/88	.05	
09/19/88	0.00	
10/26/88	.05	
12/06/88	.10	
01/09/89	.05	
02/16/89	0.00	
03/15/89	0.00	
MAXIMUM	.10	.10
MINIMUM	0.00	.10
MEAN	.03	.10

FLOW (CU.M/MIN) IN HERRING POND SYSTEM

STATION DATE	HP-1	HP-3
04/05/88	0.00	
04/20/88	.17	
05/11/88	.17	.17
05/23/88	.03	
06/06/88	.17	
06/20/88	0.00	
07/07/88	0.00	
07/18/87	0.00	
08/09/88	0.00	
08/22/88	0.00	
09/06/88	.09	
09/19/88	0.00	
10/26/88	.09	
12/06/88	.17	
01/09/89	.09	
02/16/89	0.00	
03/15/89	0.00	
MAXIMUM	.17	.17
MINIMUM	0.00	.17
MEAN	.06	.17

TEMPERATURE (C) IN THE HERRING POND SYSTEM

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B
04/05/88		9.5		7.5
04/20/88	7.8	8.2		8.3
05/11/88	12.2	12.9		11.1
05/23/88	17.2	16.1		11.9
06/06/88	18.2	17.0		12.5
06/20/88		23.2	19.0	13.0
07/07/88		23.8	20.8	13.8
07/18/88		25.6	17.2	13.0
08/09/88		27.8	23.4	14.2
08/22/88		25.0	24.5	16.5
09/06/88	24.0	23.0	21.5	18.0
09/19/88		20.0		11.7
10/26/88	10.7	11.9		12.1
12/06/88	4.0	5.2		5.5
01/09/89	1.0	1.5		1.1
02/16/89		2.3		2.2
03/15/89		2.0		2.9
MAXIMUM	24.0	27.8	24.5	18.0
MINIMUM	1.0	1.5	17.2	1.1
MEAN	11.9	15.0	21.1	10.3

DISSOLVED OXYGEN (MG/L) IN HERRING POND SYSTEM

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B
04/05/88		11.4		3.8
04/20/88	12.0	11.9		4.6
05/11/88	9.7	10.1		5.5
05/23/88	10.7	10.8		2.7
06/06/88	9.3	9.2		.8
06/20/88		7.6	7.7	.2
07/07/88		9.6	9.6	.8
07/18/88		9.3	8.4	2.4
08/09/88		8.7	6.8	.4
08/22/88		8.7	7.1	.8
09/06/88	8.6	8.1	7.5	1.6
09/19/88		8.1		2.8
10/26/88	8.7	10.0		8.9
12/06/88	11.9	11.2		6.3
01/09/89	12.6	12.7		9.6
02/16/89		13.3		8.0
03/15/89		13.7		2.7
MAXIMUM	12.6	13.7	9.6	9.6
MINIMUM	8.6	7.6	6.8	.2
MEAN	10.4	10.3	7.8	3.6

PERCENT OXYGEN SATURATION IN THE HERRING POND SYSTEM

STATION DATE	HP-2S	HP-2M	HP-2B
04/05/88	100		32
04/20/88	100		39
05/11/88	95		50
05/23/88	109		25
06/06/88	95		7
06/20/88	87	83	2
07/07/88	113	107	8
07/18/88	112	87	23
08/09/88	110	79	4
08/22/88	104	84	8
09/06/88	93	84	17
09/19/88	88		26
10/26/88	93		82
12/06/88	88		50
01/09/89	90		67
02/16/89	96		58
03/15/89	99		20
MAXIMUM	113	107	82
MINIMUM	87	79	2
MEAN	98	87	30

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

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B	HP-3
04/05/88		6.8		6.8	
04/20/88	5.8	5.9		6.0	
05/11/88	5.2	5.4		5.6	4.9
05/23/88	5.5	5.6		5.8	
06/06/88	5.8	6.0		6.1	
06/20/88		6.0	5.9	5.8	
07/07/88		6.2	6.3	6.3	
07/18/88		6.6	6.4	6.4	
08/09/88		6.9	6.9	6.7	
08/22/88		7.1	6.9	6.8	
09/06/88	6.6	6.9	6.8	6.8	
09/19/88		6.7		6.8	
10/26/88	6.1	6.1		6.2	
12/06/88	6.5	6.6		6.6	
01/09/89	6.1	6.2		6.2	
02/16/89		6.5		6.4	
03/15/89		6.4		6.4	
MAXIMUM	6.6	7.1	6.9	6.8	4.9
MINIMUM	5.2	5.4	5.9	5.6	4.9

CONDUCTIVITY (UMHOS/CM) IN THE HERRING POND SYSTEM

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B	HP-3
04/05/88		684		687	
04/20/88	605	585		305	
05/11/88	610	610		600	21
05/23/88	620	362		660	
06/06/88	685	690		695	
06/20/88		690	715	705	
07/07/88		670	700	680	
07/18/88		800	800	800	
08/09/88		790	770	780	
08/22/88		700	710	710	
09/06/88	710	705	700	700	
09/19/88		740		750	
10/26/88	620	610		610	
12/06/88	595	510		505	
01/09/89	501	500		499	
02/16/89		550		550	
03/15/89		482		474	
MAXIMUM	710	800	800	800	21
MINIMUM	501	362	700	305	21
MEAN	618	628	732	630	21

TURBIDITY (N.T.U.) IN THE HERRING POND SYSTEM

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B	HP-3
04/05/88		2.0		2.0	
04/20/88	.6	1.0		.8	
05/11/88	1.0	.4		.3	9.5
05/23/88	2.4	3.8		2.9	
06/06/88	1.5	1.6		2.3	
06/20/88		.8	.9	3.8	
07/07/88		.6	.7	2.1	
07/18/88		.6	1.0	6.6	
08/09/88		2.1	1.4	1.6	
08/22/88		1.5	1.3	2.1	
09/06/88	.3	.2	.6	.6	
09/19/88		.6		.7	
10/26/88	1.3	1.1		1.6	
12/06/88	.6	.8		.6	
01/09/89	.7	.8		.6	
02/16/89		.5		1.5	
03/15/89		.6		1.6	
MAXIMUM	2.4	3.8	1.4	6.6	9.5
MINIMUM	.3	.2	.6	.3	9.5
MEAN	1.1	1.1	1.0	1.9	9.5

SECCHI DISK TRANSPARENCY (M) IN THE HERRING POND SYSTEM

STATION DATE	HP-2S
04/05/88	3.4
04/20/88	3.9
05/11/88	6.6
05/23/88	6.3
06/06/88	4.6
06/20/88	4.4
07/07/88	4.3
07/18/88	4.2
08/09/88	4.5
08/22/88	3.0
09/06/88	3.9
09/19/88	4.0
10/26/88	4.5
12/06/88	5.6
01/09/89	4.5
02/16/89	3.5
03/15/89	4.1
MAXIMUM	6.6
MINIMUM	3.0
MEAN	4.4

CHLOROPHYLL (UG/L) IN THE HERRING POND SYSTEM

STATION DATE	HP-2
04/05/88	1.2
04/20/88	1.4
05/11/88	.7
05/23/88	1.0
06/06/88	1.1
06/20/88	1.9
07/07/88	1.4
07/18/88	1.1
08/09/88	1.7
08/22/88	4.2
09/06/88	3.9
09/19/88	4.6
10/25/88	2.2
12/06/88	1.2
01/09/89	2.9
02/16/89	3.2
03/14/89	2.1
MAXIMUM	4.6
MINIMUM	.7
MEAN	2.1

ORTHOPHOSPHORUS (UG/L) IN THE HERRING POND SYSTEM

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B	HP-3
04/05/88		10		10	
04/22/88	10	10		10	
05/11/88	10	10		10	10
05/23/88	10	10		10	
06/06/88	10	10		10	
06/20/88		10	10	10	
07/07/88		10	10	10	
07/18/88		10	10	20	
08/09/88		10	20	30	
08/22/88		10	10	10	
09/06/88	10	10	10	10	
09/19/88		10		10	
10/26/88	10	10		10	
12/06/88	10	10		10	
01/09/89	10	10		10	
02/16/89		10		10	
03/15/89		10		10	
MAXIMUM	10	10	20	30	10
MINIMUM	10	10	10	10	10
MEAN	10	10	12	12	10

TOTAL PHOSPHORUS (UG/L) IN THE HERRING POND SYSTEM

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B	HP-3
04/05/88		23		24	
04/22/88	10	10		10	
05/11/88	20	10		10	50
05/23/88	10	10		10	
06/06/88	10	10		10	
06/20/88		49	43	58	
07/07/88		40	20	30	
07/18/88		42	34	68	
08/09/88		50	50	70	
08/22/88		10	20	30	
09/06/88	110	60	60	90	
09/19/88		20		40	
10/26/88	23	39		25	
12/06/88	20	20		20	
01/09/89	10	30		10	
02/16/89		19		11	
03/15/89		20		14	
MAXIMUM	110	60	60	90	50
MINIMUM	10	10	20	10	50
MEAN	27	27	38	31	50

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

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B	HP-3
04/05/88		.01		.01	
04/22/88	.02	.01		.02	
05/11/88	.01	.02		.01	.17
05/23/88	.01	.01		.01	
06/06/88	.01	.01		.02	
06/20/88		.01	.01	.01	
07/07/88		.01	.02	.03	
07/18/88		.01	.01	.01	
08/09/88		.03	.02	.01	
08/22/88		.01	.04	.01	
09/06/88	.02	.01	.01	.01	
09/19/88		.09		.52	
10/26/88	.02	.03		.03	
12/06/88	.24	.01		.44	
01/09/89	.01	.02		.01	
02/16/89		.06		.10	
03/15/89		.10		.10	
MAXIMUM	.24	.10	.04	.52	.17
MINIMUM	.01	.01	.01	.01	.17
MEAN	.04	.03	.02	.08	.17

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

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B	HP-3
04/05/88		.02		.02	
04/22/88	.01	.02		.02	
05/11/88	.02	.02		.02	.25
05/23/88	.02	.02		.03	
06/06/88	.02	.02		.02	
06/20/88		.02	.02	.02	
07/07/88		.02	.05	.02	
07/18/88		.02	.02	.02	
08/09/88		.02	.02	.02	
08/22/88		.07	.03	.03	
09/06/88	.01	.01	.01	.01	
09/19/88		.02		.02	
10/26/88	.02	.02		.03	
12/06/88	.31	.02		.01	
01/09/89	.05	.04		.07	
02/16/89		.02		.02	
03/15/89		.02		.02	
MAXIMUM	.31	.07	.05	.07	.25
MINIMUM	.01	.01	.01	.01	.25
MEAN	.06	.02	.03	.02	.25

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

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B	HP-3
04/05/88					
04/22/88	.33	.31		.38	
05/11/88	.44	.43		.51	.46
05/23/88	.35	.38		.36	
06/06/88	.49	.45		.52	
06/20/88		.46	.46	.42	
07/07/88		.49	.59	.62	
07/18/88		.54	.55	.57	
08/09/88		.50	.47	.56	
08/22/88		.58	.58	.53	
09/06/88	.47	.46	.70	.70	
09/19/88		.76		.77	
10/26/88	.42	.47		.44	
12/06/88	.47	.45		.69	
01/09/89	.42	.42		.49	
02/16/89		.80		.78	
03/15/89		.55		.54	
MAXIMUM	.49	.80	.70	.78	.46
MINIMUM	.33	.31	.46	.36	.46
MEAN	.42	.50	.56	.56	.46

NITROGEN:PHOSPHORUS RATIOS (wt:wt) IN THE HERRING POND SYSTEM

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B	HP-3
04/05/88					
04/22/88	34.00	33.00		40.00	
05/11/88	23.00	45.00		53.00	14.20
05/23/88	37.00	40.00		39.00	
06/06/88	51.00	47.00		54.00	
06/20/88		9.80	11.16	7.59	
07/07/88		12.75	32.00	21.33	
07/18/88		13.33	16.76	8.68	
08/09/88		10.40	9.80	8.29	
08/22/88		65.00	30.50	18.67	
09/06/88	4.36	7.83	11.83	7.89	
09/19/88		39.00		19.75	
10/26/88	19.13	12.56		18.80	
12/06/88	39.00	23.50		35.00	
01/09/89	47.00	15.33		56.00	
02/16/89		43.16		72.73	
03/15/89		28.50		40.00	
MAXIMUM	51.00	65.00	32.00	72.73	14.20
MINIMUM	4.36	7.83	9.80	7.59	14.20
MEAN	31.81	27.89	18.68	31.29	14.20

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

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B	HP-3
04/05/88		12.0		12.0	
04/22/88	16.0	15.0		13.0	
05/11/88	14.0	15.0		14.0	1.0
05/23/88	12.1	12.1		12.1	
06/06/88	12.0	13.0		14.0	
06/20/88		14.8	14.8	13.0	
07/07/88		16.0	16.0	17.0	
07/18/88		17.0	17.0	20.0	
08/09/88		16.2	16.0	20.1	
08/22/88		13.3	16.0	20.1	
09/06/88	16.0	16.8	16.6	26.3	
09/19/88		17.0		20.0	
10/26/88	14.0	16.0		19.0	
12/06/88	16.0	14.8		15.8	
01/09/89	17.0	17.0		18.0	
02/16/89		17.0		17.0	
03/15/89		17.0		17.0	
MAXIMUM	17.0	17.0	17.0	26.3	1.0
MINIMUM	12.0	12.0	14.8	12.0	1.0
MEAN	14.6	15.3	16.1	17.0	1.0

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

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B	HP-3
04/05/88		2.8		3.2	
04/22/88	6.0	8.0		15.0	
05/11/88	2.0	.4		.4	10.0
05/23/88	.0	.0		4.0	
06/06/88	6.0	6.0		11.0	
06/20/88		3.5	3.0	3.0	
07/07/88		1.0	1.0	1.0	
07/18/88		1.0	2.0	2.0	
08/09/88		1.0	1.0	1.0	
08/22/88		1.0	1.0	1.0	
09/06/88	2.0	1.0	1.0	5.0	
09/19/88		5.6		5.2	
10/26/88	.4	.4		.4	
12/06/88	1.0	1.0		1.0	
01/09/89	2.0	3.0		3.0	
02/16/89		3.3		3.0	
03/15/89		1.2		.8	
MAXIMUM	6.0	8.0	3.0	15.0	10.0
MINIMUM	.0	.0	1.0	.4	10.0
MEAN	2.4	2.4	1.5	3.5	10.0

CHLORIDE (MG/L) IN HERRRING POND SYSTEM

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B	HP-3
04/05/88		186.0		180.0	
04/22/88	278.0	263.0		267.0	
05/11/88	200.0	198.0		198.0	.5
05/23/88	191.0	187.0		205.0	
06/06/88	202.0	205.0		187.0	
06/20/88		198.2	201.8	205.4	
07/07/88		213.0	213.0	216.0	
07/18/88		207.0	204.0	208.0	
08/09/88		209.1	206.2	205.4	
08/22/88		203.6	201.1	198.9	
09/06/88	209.1	212.7	205.4	209.1	
09/19/88		202.0		206.0	
10/26/88	205.0	200.0		209.0	
12/06/88	172.9	173.3		147.7	
01/09/89	201.8	200.0		205.4	
02/16/89		200.0		204.0	
03/15/89		228.0		240.0	
MAXIMUM	278.0	263.0	213.0	267.0	.5
MINIMUM	172.9	173.3	201.1	147.7	.5
MEAN	207.5	205.1	205.2	205.4	.5

TOTAL IRON (MG/L) IN THE HERRING POND SYSTEM

STATION DATE	HP-1	HP-2S	HP-2M	HP-2B	HP-3
04/05/88		.02		.23	
04/22/88	.02	.02		.02	
05/11/88	.06	.07		.08	.11
05/23/88	.12	.08		.12	
06/06/88	.06	.06		.08	
06/20/88		.09	.07	.35	
07/07/88		.05	.05	.27	
07/18/88		.09	.21	.77	
08/09/88		.18	.16	.21	
08/22/88		.02	.02	.33	
09/06/88	.03	.02	.02	1.49	
09/19/88		.02		.04	
10/26/88	.15	.17		.24	
12/06/88	.20	.14		.14	
01/09/89	.02	.02		.02	
02/16/89		.04		.06	
03/15/89		.10		.07	
MAXIMUM	.20	.18	.21	1.49	.11
MINIMUM	.02	.02	.02	.02	.11
MEAN	.08	.07	.09	.27	.11

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

STATION DATE	HP-1	HP-2S	HP-3
04/05/88		10	
04/22/88	10	10	
05/11/88	10	10	10
05/23/88	20	10	
06/06/88	40	10	
06/20/88		10	
07/07/88		10	
07/19/88		2	
08/09/88		10	
08/22/88		10	
09/06/88	10	10	
09/19/88		10	
10/26/88	20	10	
12/06/88	10	10	
01/09/89	10	10	
02/16/89		0	
03/15/89		0	
MAXIMUM	40	10	10
MINIMUM	10	0	10
ARITH. MEAN	16	8	10
GEOM. MEAN	14	9	10

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

STATION DATE	HP-1	HP-2S	HP-3
04/05/88		2000	
04/22/88	10	10	
05/11/88	10	10	10
05/23/88	10	10	
06/06/88	30	10	
06/20/88		10	
07/07/88		10	
07/19/88		1	
08/09/88		10	
08/22/88		10	
09/06/88	10	10	
09/19/88		10	
10/26/88	10	10	
12/06/88	10	10	
01/09/89	10	10	
02/16/89		0	
03/15/89		0	
MAXIMUM	30	2000	10
MINIMUM	10	0	10
ARITH. MEAN	12	125	10
GEOM. MEAN	11	12	10

HERRING POND PHYTOPLANKTON DATA

HP-2 040588

TAXON	CELLS/ML
BACILLARIOPHYTA	
Synedra	6.6
CHLOROPHYTA	
Staurastrum	3.3
CHRYSOPHYTA	
Dinobryon	62.7
CRYPTOPHYTA	
Cryptomonas	23.1
TOTAL	95.7
BACILLARIOPHYTA	6.6
CHLOROPHYTA	3.3
CHRYSOPHYTA	62.7
CRYPTOPHYTA	23.1

TAXON	UG/L
BACILLARIOPHYTA	
Synedra	52.8
CHLOROPHYTA	
Staurastrum	39.6
CHRYSOPHYTA	
Dinobryon	188.1
CRYPTOPHYTA	
Cryptomonas	12.5
TOTAL	293.0
BACILLARIOPHYTA	52.8
CHLOROPHYTA	39.6
CHRYSOPHYTA	188.1
CRYPTOPHYTA	12.5

HP-2 042088

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	6
Cymbella	3
Fragilaria	27
Navicula	3
Synedra	27
CHLOROPHYTA	
Closterium	6
Oocystis	39
CHRYSOPHYTA	
Dinobryon	39
CRYPTOPHYTA	
Cryptomonas	69
CYANOPHYTA	
Anabaena	51
Chroococcus	24
TOTAL	294
BACILLARIOPHYTA	66
CHLOROPHYTA	45
CHRYSOPHYTA	39
CRYPTOPHYTA	69
CYANOPHYTA	75

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	4.2
Cymbella	4.5
Fragilaria	54
Navicula	3
Synedra	216
CHLOROPHYTA	
Closterium	24
Oocystis	15.6
CHRYSOPHYTA	
Dinobryon	117
CRYPTOPHYTA	
Cryptomonas	33
CYANOPHYTA	
Anabaena	158.1
Chroococcus	9.6
TOTAL	639
BACILLARIOPHYTA	281.7
CHLOROPHYTA	39.6
CHRYSOPHYTA	117
CRYPTOPHYTA	33
CYANOPHYTA	167.7

HP-2 051188

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	3.2
Synedra	9.6
CHLOROPHYTA	
Chlamydomonas	22.4
Coelastrum	102.4
Oocystis	12.8
Scenedesmus	25.6
Other green algae	51.2
CHRYSOPHYTA	
Dinobryon	9.6
CRYPTOPHYTA	
Cryptomonas	19.2
CYANOPHYTA	
Chroococcus	28.8
PYRRHOPHYTA	
Peridinium	3.2
TOTAL	288
BACILLARIOPHYTA	12.8
CHLOROPHYTA	214.4
CHRYSOPHYTA	9.6
CRYPTOPHYTA	19.2
CYANOPHYTA	28.8
PYRRHOPHYTA	3.2

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	.6
Synedra	76.8
CHLOROPHYTA	
Chlamydomonas	2.2
Coelastrum	20.4
Oocystis	5.1
Scenedesmus	2.5
Other green algae	51.2
CHRYSOPHYTA	
Dinobryon	28.8
CRYPTOPHYTA	
Cryptomonas	11.5
CYANOPHYTA	
Chroococcus	11.5
PYRRHOPHYTA	
Peridinium	144
TOTAL	354.8
BACILLARIOPHYTA	77.4
CHLOROPHYTA	81.6
CHRYSOPHYTA	28.8
CRYPTOPHYTA	11.5
CYANOPHYTA	11.5
PYRRHOPHYTA	144

HP-2 052388

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	6
Fragilaria	18
CHLOROPHYTA	
Ankistrodesmus	6
Oocystis	75
Quadrigula	60
Scenedesmus	12
Staurastrum	3
CHRYSOPHYTA	
Mallomonas	3
CRYPTOPHYTA	
Cryptomonas	36
CYANOPHYTA	
Chroococcus	441
TOTAL	660
BACILLARIOPHYTA	24
CHLOROPHYTA	156
CHRYSOPHYTA	3
CRYPTOPHYTA	36
CYANOPHYTA	441

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	4.2
Fragilaria	36
CHLOROPHYTA	
Ankistrodesmus	3
Oocystis	30
Quadrigula	12
Scenedesmus	18
Staurastrum	36
CHRYSOPHYTA	
Mallomonas	1.5
CRYPTOPHYTA	
Cryptomonas	21.6
CYANOPHYTA	
Chroococcus	16.1
TOTAL	178.4
BACILLARIOPHYTA	40.2
CHLOROPHYTA	99
CHRYSOPHYTA	1.5
CRYPTOPHYTA	21.6
CYANOPHYTA	16.1

HP-2 060688

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	396.8
Fragilaria	323.2
CHLOROPHYTA	
Ankistrodesmus	9.6
Oocystis	12.8
Scenedesmus	25.6
Sphaerocystis	51.2
Spirogyra	3.2
Staurastrum	9.6
CRYPTOPHYTA	
Cryptomonas	83.2
CYANOPHYTA	
Chroococcus	6.4
PYRRHOPHYTA	
Ceratium	3.2
TOTAL	924.8
BACILLARIOPHYTA	720
CHLOROPHYTA	112
CRYPTOPHYTA	83.2
CYANOPHYTA	6.4
PYRRHOPHYTA	3.2

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	277.7
Fragilaria	646.4
CHLOROPHYTA	
Ankistrodesmus	4.8
Oocystis	38.4
Scenedesmus	38.4
Sphaerocystis	20.4
Spirogyra	640
Staurastrum	115.2
CRYPTOPHYTA	
Cryptomonas	16.6
CYANOPHYTA	
Chroococcus	.0
PYRRHOPHYTA	
Ceratium	768
TOTAL	2566.1
BACILLARIOPHYTA	924.1
CHLOROPHYTA	857.2
CRYPTOPHYTA	16.6
CYANOPHYTA	.0
PYRRHOPHYTA	768

HP-2 062088

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	28.8
CHLOROPHYTA	
Cosmarium	3.2
Oocystis	12.8
Scenedesmus	12.8
Staurastrum	6.4
CRYPTOPHYTA	
Cryptomonas	64
CYANOPHYTA	
Chroococcus	102.4
PYRRHOPHYTA	
Ceratium	6.4
Peridinium	9.6
TOTAL	246.4
BACILLARIOPHYTA	28.8
CHLOROPHYTA	35.2
CRYPTOPHYTA	64
CYANOPHYTA	102.4
PYRRHOPHYTA	16

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	57.6
CHLOROPHYTA	
Cosmarium	2.5
Oocystis	5.1
Scenedesmus	1.2
Staurastrum	76.8
CRYPTOPHYTA	
Cryptomonas	38.4
CYANOPHYTA	
Chroococcus	1.0
PYRRHOPHYTA	
Ceratium	1536
Peridinium	432
TOTAL	2150.7
BACILLARIOPHYTA	57.6
CHLOROPHYTA	85.7
CRYPTOPHYTA	38.4
CYANOPHYTA	1.0
PYRRHOPHYTA	1968

HP-2 070788

TAXON	CELLS/ML
BACILLARIOPHYTA	
Tabellaria	6.4
CHLOROPHYTA	
Ankistrodesmus	3.2
Staurastrum	3.2
Tetraedron	3.2
CHRYSOPHYTA	
Mallomonas	6.4
CRYPTOPHYTA	
Cryptomonas	22.4
CYANOPHYTA	
Chroococcus	566.4
EUGLENOPHYTA	
Trachelomonas	6.4
TOTAL	617.6
BACILLARIOPHYTA	6.4
CHLOROPHYTA	9.6
CHRYSOPHYTA	6.4
CRYPTOPHYTA	22.4
CYANOPHYTA	566.4
EUGLENOPHYTA	6.4

TAXON	UG/L
BACILLARIOPHYTA	
Tabellaria	19.2
CHLOROPHYTA	
Ankistrodesmus	1.6
Staurastrum	38.4
Tetraedron	1.9
CHRYSOPHYTA	
Mallomonas	3.2
CRYPTOPHYTA	
Cryptomonas	4.4
CYANOPHYTA	
Chroococcus	5.6
EUGLENOPHYTA	
Trachelomonas	6.4
TOTAL	80.8
BACILLARIOPHYTA	19.2
CHLOROPHYTA	41.9
CHRYSOPHYTA	3.2
CRYPTOPHYTA	4.4
CYANOPHYTA	5.6
EUGLENOPHYTA	6.4

HP-2 071888

TAXON	CELLS/ML
CHLOROPHYTA	
Ankistrodesmus	3.3
Staurastrum	23.1
CRYPTOPHYTA	
Cryptomonas	6.6
CYANOPHYTA	
Chroococcus	207.9
TOTAL	240.9
CHLOROPHYTA	26.4
CRYPTOPHYTA	6.6
CYANOPHYTA	207.9

TAXON	UG/L
CHLOROPHYTA	
Ankistrodesmus	1.6
Staurastrum	277.2
CRYPTOPHYTA	
Cryptomonas	6.6
CYANOPHYTA	
Chroococcus	2.0
TOTAL	287.5
CHLOROPHYTA	278.8
CRYPTOPHYTA	6.6
CYANOPHYTA	2.0

HP-2 080988

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	3.2
Fragilaria	41.6
Melosira	12.8
CHLOROPHYTA	
Ankistrodesmus	9.6
Staurastrum	6.4
CRYPTOPHYTA	
Cryptomonas	195.2
CYANOPHYTA	
Anabaena	416
Oscillatoria	656
TOTAL	1340.8
BACILLARIOPHYTA	57.6
CHLOROPHYTA	16
CRYPTOPHYTA	195.2
CYANOPHYTA	1072

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	.6
Fragilaria	83.2
Melosira	3.8
CHLOROPHYTA	
Ankistrodesmus	4.8
Staurastrum	76.8
CRYPTOPHYTA	
Cryptomonas	39.0
CYANOPHYTA	
Anabaena	166.4
Oscillatoria	6.5
TOTAL	381.2
BACILLARIOPHYTA	87.6
CHLOROPHYTA	81.6
CRYPTOPHYTA	39.0
CYANOPHYTA	172.9

HP-2 082288

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	12.4
Fragilaria	40.3
Synedra	3.1
CHLOROPHYTA	
Oocystis	12.4
Staurastrum	3.1
CYANOPHYTA	
Anabaena	1007.5
Aphanizomenon	71.3
Chroococcus	55.8
PYRRHOPHYTA	
Peridinium	3.1
TOTAL	1209
BACILLARIOPHYTA	55.8
CHLOROPHYTA	15.5
CYANOPHYTA	1134.6
PYRRHOPHYTA	3.1

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	8.6
Fragilaria	80.6
Synedra	24.8
CHLOROPHYTA	
Oocystis	4.9
Staurastrum	37.2
CYANOPHYTA	
Anabaena	403
Aphanizomenon	.7
Chroococcus	.5
PYRRHOPHYTA	
Peridinium	9.3
TOTAL	569.8
BACILLARIOPHYTA	114.0
CHLOROPHYTA	42.1
CYANOPHYTA	404.2
PYRRHOPHYTA	9.3

HP-2 090688

TAXON	CELLS/ML
BACILLARIOPHYTA	
Synedra	34.1
CHLOROPHYTA	
Ankistrodesmus	3.1
Cladophora	6.2
Staurastrum	6.2
CHRYSOPHYTA	
Mallomonas	9.3
CYANOPHYTA	
Anabaena	31
Oscillatoria	5518
TOTAL	5607.9
BACILLARIOPHYTA	34.1
CHLOROPHYTA	15.5
CHRYSOPHYTA	9.3
CYANOPHYTA	5549

TAXON	UG/L
BACILLARIOPHYTA	
Synedra	387.5
CHLOROPHYTA	
Ankistrodesmus	1.5
Cladophora	124
Staurastrum	74.4
CHRYSOPHYTA	
Mallomonas	4.6
CYANOPHYTA	
Anabaena	12.4
Oscillatoria	55.1
TOTAL	659.6
BACILLARIOPHYTA	387.5
CHLOROPHYTA	199.9
CHRYSOPHYTA	4.6
CYANOPHYTA	67.5

HP-2 091988

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	12.8
Synedra	22.4
CHLOROPHYTA	
Ankistrodesmus	6.4
Staurastrum	3.2
CHRYSOPHYTA	
Mallomonas	3.2
CRYPTOPHYTA	
Cryptomonas	28.8
CYANOPHYTA	
Anabaena	608
Aphanizomenon	736
Oscillatoria	12192
TOTAL	13612.8
BACILLARIOPHYTA	35.2
CHLOROPHYTA	9.6
CHRYSOPHYTA	3.2
CRYPTOPHYTA	28.8
CYANOPHYTA	13536

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	8.9
Synedra	17.9
CHLOROPHYTA	
Ankistrodesmus	3.2
Staurastrum	38.4
CHRYSOPHYTA	
Mallomonas	1.6
CRYPTOPHYTA	
Cryptomonas	28.8
CYANOPHYTA	
Anabaena	243.2
Aphanizomenon	7.3
Oscillatoria	121.9
TOTAL	471.3
BACILLARIOPHYTA	26.8
CHLOROPHYTA	41.6
CHRYSOPHYTA	1.6
CRYPTOPHYTA	28.8
CYANOPHYTA	372.4

HP-2 102588

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	75.9
Fragilaria	706.2
Synedra	6.6
CHLOROPHYTA	
Ankistrodesmus	3.3
Staurastrum	9.9
CHRYSOPHYTA	
Chromulina	36.3
CRYPTOPHYTA	
Cryptomonas	118.8
CYANOPHYTA	
Anabaena	105.6
TOTAL	1062.6
BACILLARIOPHYTA	788.7
CHLOROPHYTA	13.2
CHRYSOPHYTA	36.3
CRYPTOPHYTA	118.8
CYANOPHYTA	105.6

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	53.1
Fragilaria	1412.4
Synedra	52.8
CHLOROPHYTA	
Ankistrodesmus	1.6
Staurastrum	118.8
CHRYSOPHYTA	
Chromulina	36.3
CRYPTOPHYTA	
Cryptomonas	76.5
CYANOPHYTA	
Anabaena	42.2
TOTAL	1793.8
BACILLARIOPHYTA	1518.3
CHLOROPHYTA	120.4
CHRYSOPHYTA	36.3
CRYPTOPHYTA	76.5
CYANOPHYTA	42.2

HP-2 120688

TAXON	CELLS/ML
CHLOROPHYTA	
Ankistrodesmus	3.1
Oocystis	65.1
Quadrigula	12.4
Staurastrum	3.1
Other green algae	24.8
CRYPTOPHYTA	
Cryptomonas	15.5
CYANOPHYTA	
Chroococcus	148.8
TOTAL	272.8
CHLOROPHYTA	108.5
CRYPTOPHYTA	15.5
CYANOPHYTA	148.8

TAXON	UG/L
CHLOROPHYTA	
Ankistrodesmus	1.5
Oocystis	26.0
Quadrigula	2.4
Staurastrum	37.2
Other green algae	24.8
CRYPTOPHYTA	
Cryptomonas	15.5
CYANOPHYTA	
Chroococcus	3.9
TOTAL	111.4
CHLOROPHYTA	92.0
CRYPTOPHYTA	15.5
CYANOPHYTA	3.9

HP-2 010989

TAXON	CELLS/ML
BACILLARIOPHYTA	
Cyclotella	3
Tabellaria	3
CHLOROPHYTA	
Elakatothrix	21
Oocystis	9
Quadrigula	12
CRYPTOPHYTA	
Cryptomonas	9
TOTAL	57
BACILLARIOPHYTA	6
CHLOROPHYTA	42
CRYPTOPHYTA	9

TAXON	UG/L
BACILLARIOPHYTA	
Cyclotella	7.5
Tabellaria	9
CHLOROPHYTA	
Elakatothrix	4.2
Oocystis	3.6
Quadrigula	2.4
CRYPTOPHYTA	
Cryptomonas	1.8
TOTAL	28.5
BACILLARIOPHYTA	16.5
CHLOROPHYTA	10.2
CRYPTOPHYTA	1.8

HP-2 021689

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	40.8
Fragilaria	57.8
Synedra	6.8
CHLOROPHYTA	
Elakatothrix	61.2
Oocystis	27.2
CRYPTOPHYTA	
Cryptomonas	34
TOTAL	227.8
BACILLARIOPHYTA	105.4
CHLOROPHYTA	88.4
CRYPTOPHYTA	34

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	8.1
Fragilaria	115.6
Synedra	155.7
CHLOROPHYTA	
Elakatothrix	12.2
Oocystis	10.8
CRYPTOPHYTA	
Cryptomonas	20.4
TOTAL	323
BACILLARIOPHYTA	279.4
CHLOROPHYTA	23.1
CRYPTOPHYTA	20.4

HP-2 031489

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	19.8
Synedra	75.9
Tabellaria	62.7
CHLOROPHYTA	
Elakatothrix	23.1
CRYPTOPHYTA	
Cryptomonas	13.2
TOTAL	194.7
BACILLARIOPHYTA	158.4
CHLOROPHYTA	23.1
CRYPTOPHYTA	13.2

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	13.8
Synedra	60.7
Tabellaria	1128.6
CHLOROPHYTA	
Elakatothrix	2.3
CRYPTOPHYTA	
Cryptomonas	2.6
TOTAL	1208.1
BACILLARIOPHYTA	1203.1
CHLOROPHYTA	2.3
CRYPTOPHYTA	2.6

HERRING POND ZOOPLANKTON DATA

HERRING POND 051188

TAXON	#/L
ROTIFERA	
Brachionus	.8
COPEPODA	
Cyclops	2.7
Nauplii	3.1
CLADOCERA	
Daphnia ambigua	7.4
Daphnia catawba	1.0
Eubosmina	1.6
TOTAL	16.9
ROTIFERA	.8
COPEPODA	5.9
CLADOCERA	10.2

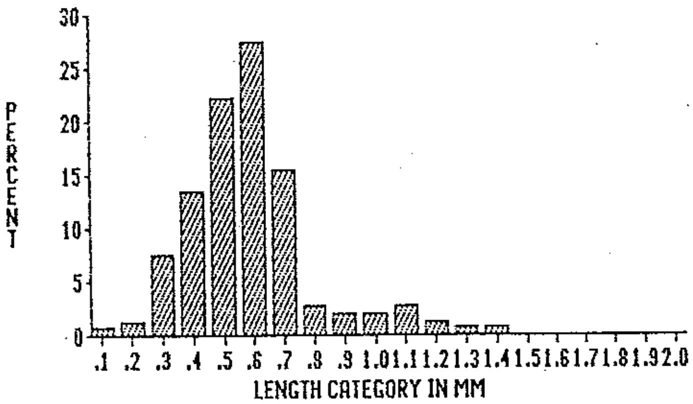
TAXON	UG/L
ROTIFERA	
Brachionus	.1
COPEPODA	
Cyclops	6.8
Nauplii	8.2
CLADOCERA	
Daphnia ambigua	43.3
Daphnia catawba	3.6
Eubosmina	1.5
TOTAL	63.6
ROTIFERA	.1
COPEPODA	15.0
CLADOCERA	48.5

HERRING POND 080988

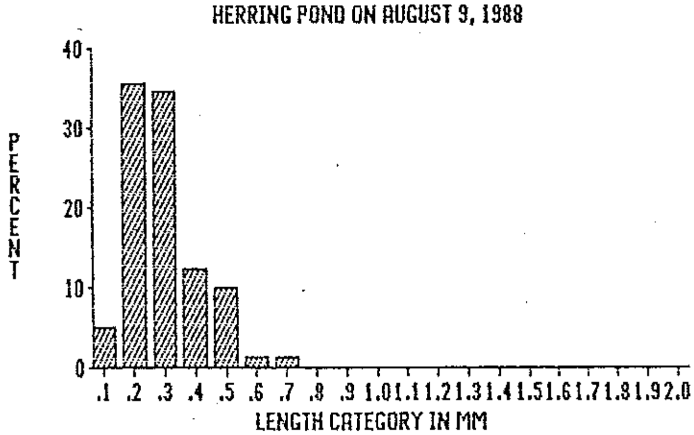
TAXON	#/L
ROTIFERA	
Keratella	.1
COPEPODA	
Cyclops	.1
Diaptomus	.1
Nauplii	.8
CLADOCERA	
Ceriodaphnia	.5
Eubosmina	3.3
TOTAL	5.0
ROTIFERA	.1
COPEPODA	1.0
CLADOCERA	3.9

TAXON	UG/L
ROTIFERA	
Keratella	.2
COPEPODA	
Cyclops	.1
Diaptomus	.1
Nauplii	2.1
CLADOCERA	
Ceriodaphnia	1.4
Eubosmina	3.3
TOTAL	7.2
ROTIFERA	.2
COPEPODA	2.3
CLADOCERA	4.7

ZOOPLANKTON LENGTH DISTRIBUTION IN HERRING POND ON MAY 11, 1988



ZOOPLANKTON LENGTH DISTRIBUTION IN HERRING POND ON AUGUST 9, 1988



ZOOPLANKTON LENGTH DISTRIBUTION FOR SAMPLES COLLECTED FROM HERRING POND IN 1988

LENGTH (MM)	PERCENT OF INDIVIDUALS HERRING POND 051188	HERRING POND 080988
.1	.7	4.9
.2	1.3	35.8
.3	7.4	34.6
.4	13.4	12.3
.5	22.1	9.9
.6	27.5	1.2
.7	15.4	1.2
.8	2.7	0.0
.9	2.0	0.0
1.0	2.0	0.0
1.1	2.7	0.0
1.2	1.3	0.0
1.3	.7	0.0
1.4	.7	0.0
1.5	0.0	0.0
1.6	0.0	0.0
1.7	0.0	0.0
1.8	0.0	0.0
1.9	0.0	0.0
2.0	0.0	0.0
TOTAL	100.0	100.0
MEAN (MM)	.59	.30

APPENDIX C

CONVERSION FACTORS AND CALCULATION SHEETS

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)
Micrograms/Liter (ug/l)	1.0	Parts Per Billion (ppb)
Square Kilometers (sq.km)	0.3861	Square Miles (sq.mi)
Square Meters (sq.m)	0.0001	Hectares (ha)

HYDROLOGIC CALCULATIONS FOR HERRING POND

1.) **Unit Watershed Area Method.**

a.) Watershed Area (ha) : 53.0 (0.204 sq. mi.)

b.) Use yield coefficients (Sopper and Lull, 1970) with watershed area.

Low yield estimate = 1.7 cu. m/min / sq. mi.
High yield estimate = 2.55 cu. m/min / sq. mi.

Low estimate = 1.7 x 0.204 sq. mi. = 0.35 cu. m/min.
High estimate = 2.55 x 0.204 sq. mi. = 0.52 cu. m/min.

Range of flow estimates = 0.35 - 0.52 cu. m/min.

2.) **Runoff Estimate Method.**

a.) Assume that a certain portion of the precipitation (study year ppt = 0.963 m/yr.) is runoff that flows into surface tributaries. Add direct precipitation to pond and subtract evaporative loss. The runoff estimates used are from Higgins and Colonell (1971).

b.) High runoff range = 0.61 m/yr x 53.0 ha = 323,300 cu. m/yr.

Low runoff range = 0.51 m/yr x 53.0 ha = 270,300 cu. m/yr.

c.) Direct precipitation on Herring Pond (4/88-3/89):

0.963 m/yr x 17.7 ha = 170,451 cu. m/yr.

d.) Evaporation losses from Herring Pond :

0.66 m/yr x 17.7 ha = 116,820 cu. m/yr.

e.) Calculations :

323,300 + 170,451 - 116,820 = 376,931 cu. m/yr.

270,300 + 170,451 - 116,820 = 323,931 cu. m/yr.

f.) Range of net flow estimates = 0.62 - 0.72 cu. m/min.

Calculation of Groundwater Inputs into Herring Pond
Based on Seepage Meter Measurements

Procedure and Assumptions:

1. Place seepage meters at regular intervals around the periphery of the lake. Get groundwater seepage rates from meters.

2. Measure distance (m) between adjacent seepage meter transect locations. Determine shoreline lengths between the midpoints between meter transects. This gives a shoreline distance with the seepage transect approximately centered. Assume that all seepage in this shoreline length is uniform.

3. Estimate distance from shoreline that seepage flows will occur. This is somewhat subjective, but takes into account shoreline relief, slope of bottom, and nature and depth of bottom sediments.

4. Determine seepage flows along the transect into lake. This can be done by assuming a linear or exponential function from shoreline to farthest distance. Since this is usually based only on 2 data points, an exponential function, although theoretically better, can lead to extreme values, and is usually not used. If a linear function is assumed, the amount of seepage is integrated over the length of the seepage distance. This value can be divided by the length of the seepage distance to give an average seepage rate. Note that if the two seepage meters are placed about equidistantly from themselves and the ends of the seepage distance, averaging of their seepage rates approximates the linear function method.

5. Calculate the hydrologic contribution of each shoreline length and convert to flow measurements. Sum flow contributions from all shoreline lengths to get total yearly groundwater seepage to the lake.

6. Calculations :

   Shoreline length x transect length x average seepage rate x time units

   = Groundwater seepage flow along shoreline length.

   Sum all groundwater seepage from all shoreline segments.

   = Groundwater seepage flow to the lake.

   Sample Calculation :

   75 m x 25 m x 5 l/sq. m/day x 1 cu.m/10^3 l x day/24 hr x hr/60 min

   = 0.0065 cu.m/min. [GW flow from one shoreline length].

NUTRIENT BUDGET CALCULATIONS

Assumption: Phosphorus and nitrogen loads = (average concentration x volume x flushing rate).

Calculations:

Phosphorus: 29.1 ug/l x 1.085 10^9 l x 0.26-0.625 =

8.2 to 19.7 kgP/yr.

Nitrogen: 0.57 mg/l x 1.085 10^9 l x 0.26-0.625 =

160.8 to 386.5 kgN/yr.

ESTIMATION OF INTERNAL LOADING COMPONENTS TO HERRING POND

Phosphorus

1. Anoxic Loading:
   Based on a survey of eight lakes under conditions of anoxia (<1ppm) phosphorus release rates from sediments ranged from 0.1 to 8.1 mg/m^2/d (Nurnberg, 1987). The actual internal load to the lake (mgP/m^2/summer) depends on the release rate (mgP/m^2/d) and the anoxic factor (Nurnberg, 1987).

   Internal load = release rate x anoxic factor

   The anoxic factor is a function of anoxic area, duration of anoxia, and lake surface area:

   Anoxic factor = (duration x anoxic sediment area) / lake area

   In Herring Pond, during stratification approximately 50% of the sediment area is overlain by anoxic water. Duration of stratification is about 80 days. Therfore:

   Anoxic factor = ((80 days x 88,500 m^2) / 177,000 m^2) = 40

   In Herring Pond the release rate is likely to be rather low due to the relatively low concentration of phosphorus in the sediments (Table X). Assuming a mean release rate of 3.0 mg/m^2/d

   Internal load = 3.0 mg/m^2/d x 40 = 120 mg/m^2/summer, or

   21.24 kgP/yr

   Epilimnetic oxygen concentrations during the study year were always at or above 1ppm. Jones and Bowser (1978) found that oxygen values at the sediment-water interface of 1ppm were effective in preventing soluble ferrous (Fe II) phosphate from diffusing out of deeper anoxic layers. Therefore, internal loading from sediments not associated with hypolimnetic zones is ignored.

2. Macrophyte Pumping/Decay:
Approximately 35 percent of Herring Pond was found to have dense macrophyte cover (50-100%). Potential release rates for eurasian milfoil (Myriophyllum spicatum) are estimated at $2g/m^2/yr$ (Smith and Adams, 1986).

For Herring Pond:

$$0.35 \times 177{,}000\ m^2 \times 2g/m^2/yr = 124\ kg/yr\ \text{possible.}$$

In Herring Pond, although bottom coverage in areas was complete, the contributing macrophytes did not constitute substantial biomass. The maximum observed fresh weight was $2.6\ kg/m^2$. Much of the area was covered by species constituting lesser biomass than eurasian milfoil, which was not present. Therefore, actual pumping rates are likely to be less (assume 10-20% of total possible) than estimated by Smith and Adams (1986).

12.4 to 24.8 kgP/yr

3. Sediment Resuspension:
Probably non-applicable in Herring Pond due to the predominantly oxic conditions in shallow zones and limited motorized boat traffic. Upon resuspension, conditions would be unfavorable for remineralization processes (i.e., high iron, high oxygen) to occur.

Summary:

It appears that only two of the three major internal loading components are likely to contribute to the Herring Pond phosphorus budget. The maximum available is assumed to be:

39.8 kgP/yr

If 10% of internal load is available, have	4.0 kg/yr
at 25% ------->	10.0 kg/yr
at 50% ------->	19.9 kg/yr
at 75% ------->	29.9 kg/yr

As an approximation, the internal load will be assumed to provide:

10.0 to 20.0 kgP/yr

ESTIMATE OF INTERNAL LOADING COMPONENTS TO HERRING POND-CONTINUED

Nitrogen

Nitrogen is usually not assumed to have an internal component, but macrophyte actions should provide some nitrogen in Herring Pond.

Assume macrophytes contain or pump 12 x as much nitrogen as phosphorus, but lose only a third as much (nitrogen is better bound than phosphorus), then have:

12 x 124 kg as N (from above) = 1488 kg/yr (pumped) x 0.33 = 491 kgN/yr.

If 10% of internal load is available, have	49.1 kgN/yr
At 25 % ------>	122.7 kgN/yr
At 50 % ------>	245.5 kgN/yr
At 75 % ------>	368.3 kgN/yr

Assuming the same restrictions apply to nitrogen pumping as apply to phosphorus pumping (i.e., minimal unit biomass),

As an approximation, the internal load will be assumed to provide:

49.1 to 98.2 kgN/yr

Herring Pond Detention Time

Assume that flow through the system = 0.736 cu.m/min (Table 14)
Assume lake volume equals 1,085,000 cu.m (Table 2)
Mean annual output = 386,842 cu.m/yr

$$\frac{1{,}085{,}000 \text{ cu.m}}{386{,}842 \text{ cu.m/yr}} = 2.80 \text{ yr} \times 365 \text{ day/yr} = \underline{1{,}022 \text{ days}}.$$

Herring Pond Response Time

$$\text{Half Life Response Time} = t_{1/2} = \frac{\ln 2}{\frac{1}{T} + \frac{10}{Z}}$$

Where: **t 1/2** = half life concentration time (yr) for Herring Pond.
T = lake residence time (yr)
Z = average lake depth (m)

$$t_{1/2} = \frac{0.6931}{\frac{1}{2.80} + \frac{10}{6.2}} = \underline{0.35 \text{ yr}}.$$

The lake's response time is estimated at 3x-5x the concentration half life of Herring Pond or (0.35 x 3 or 5 = 1.05 or 1.75 yr) 383 - 639 days.

Calculation of Phosphorus Loading by Atmospheric Deposition and Wildlife

Atmospheric Deposition

An atmospheric deposition factor of 0.20 kg P/ha/yr was used, due to the predominance of low density residential and forested land use in the Eastham airshed. Representative deposition factors were selected from Reckhow et al. 1980. The area of the pond is approximately equal to 17.7 hectares. Thus, direct atmospheric deposition = 0.20 kg P/ha/yr x 17.7 ha = 3.54 kg P/yr.

Wildlife Deposition

The prevailing wildlife in the lake is waterfowl. Observations during the study year noted some resident ducks and gulls, and the salt marsh to the west of the pond is potential habitat for migratory waterfowl. Assume a yearly density of 1 bird per hectare over the year, or 18 birds. Using a mean value of 0.145 kg P/bird/yr selected from Brezonik (1973), the wildlife input = 18 birds x 0.145 kg P/bird/yr = 2.61 kg P/yr.

Herring Pond Determination of Permissible and Critical Loading

Phosphorus Vollenweider Loading Analysis

$\frac{Z}{td} = \frac{6.2}{2.80} = 4.82$ where: Z = mean depth (m)
td = detention time (yr)
Area of Lake = 17.7 ha = 177,000 sq.m

for permissible (oligotrophic) loading:
0.148 g P/sq.m/yr x 177,000 sq.m = 26.2 kg P/yr.

for critical (eutrophic) loading:
0.296 g P/sq.m/yr x 177,000 sq.m = 52.4 kg P/yr.

Herring Pond Phosphorus/Chlorophyll/Secchi disk transparency.

Prediction of chlorophyll (chl) from surface in-lake total phosphorus (P) concentration (Vollenweider, 1982)

$$[chl] = .28 * [P]^{0.96}$$

in-lake (HP-2S) TP = 27 ug/l (range = 10-60)

for TP = 27; chl a = 6.6 ug/l
TP = 10; chl a = 2.6 ug/l
TP = 60; chl a = 14.3 ug/l

Compare with actual HP-2S mean chlorophyll value of 2.1 ug/l and a range of 0.7 - 4.6 ug/l

Prediction of Secchi disk transparency from chlorophyll a values [from Vollenweider (1982)]

$$\overline{[Secchi]} = 9.33 * \overline{[chl\ a]}^{-0.51}$$

in-lake [chl a] = 2.1 ug/l
range = 0.7 - 4.6 ug/l

with chl a = 2.1; SDT = 6.4 m
chl a = 0.7; SDT = 11.2 m
chl a = 4.6; SDT = 4.3 m

Compare with actual HP-2S mean Secchi disk transparency of 4.4 m and a range of 3.0 - 6.6 m.

Calculation of Phosphorus Loading from Groundwater into Herring Pond

Groundwater contribution of total phosphorus was determined by calculating the total daily loading (Kg/day) of this nutrient during the May and August survey. Daily total phosphorus loading was calculated by multiplying the seepage values (L/D) times the corresponding littoral interstitial porewater (L.I.P.) concentration for each seepage meter transect. These values were averaged and converted to annual loads (Kg/yr).

Mean Daily load = (0.228 Kg/D (May) + 0.037 Kg/D (August))/2 = 0.1325 KgP/D.

Annual Load = 0.1325 KgP/D x 365 days/yr = 48.36 KgP/yr.

Assumption: The relatively high Fe:P ratios found in the water column and sediment (@ 2:1 and > 7:1, respectively) likely act to prevent the release of phosphorus from the interstitial water to overlying waters (Stauffer, 1981; Holdren and Armstrong, 1986; Armstrong et al., 1987)

For simplification, it will be assumed that inseeping groundwater contribution of phosphorus to Herring Pond is:

12 to 24 kgP/yr

Note: Due to the localized nature of groundwater inputs, it was assumed that a portion of the measured interstitial phosphorus may exhaust local iron supplies, allowing some of the phosphorus (@ 25 to 50%) to enter Herring Pond uncomplexed.

Total phosphorus loading via groundwater to Herring Pond May-August 1988

May 23, 1988

Meter Transect	Seepage L/D	L.I.P. Zone	T.F.P. (mg/l)	Daily Load (Kg/D)
1-2	76449	PW-1	.290	.022
3-4	261777	PW-2	.300	.079
5-6	53689	PW-3	.390	.021
7-8	-124552	PW-4	.350	-.044
9-10	225822	PW-5	.270	.061
11-12	27095	PW-6	.240	.007
13-14	10063	PW-7	.360	.004
15-16	75659	PW-8	.390	.030
17-18	89731	PW-9	.280	.025
19-20	23610	PW-10	.170	.004
21-22	27345	PW-11	.220	.006
23-24	56024	PW-12	.260	.015
			Net Total Load (Kg/D)	.228

August 8, 1988

Meter Transect	Seepage L/D	L.I.P. Zone	T.F.P. (mg/l)	Daily Load (Kg/D)
1-2	19712	PW-1	.150	.003
3-4	74674	PW-2	.020	.001
5-6	96351	PW-3	.130	.013
7-8	15731	PW-4	.090	.001
9-10	-61175	PW-5	.050	-.003
11-12	221542	PW-6	.090	.020
13-14	-554	PW-7	.050	-.000
15-16	38808	PW-8	.030	.001
17-18	-14006	PW-9	.030	-.000
19-20	-11754	PW-10	.020	-.000
21-22	-4318	PW-11	.040	-.000
23-24	20470	PW-12	.080	.002
			Net Total Load (Kg/D)	.037

Calculation of Nitrogen Loading from Groundwater into Herring Pond

Nitrogen

Groundwater contributions of inorganic nitrogen to Herring Pond was calculated in the same manner as phosphorus. Annual loading rates of both ammonia and nitrate nitrogen were determined.

Daily Load (KgN/D) (May) = 0.254 kg/D (NH_3) + 0.055 Kg/D (NO_3)

= 0.309 KgN/D

Daily Load (KgN/D) (August) = 0.306 Kg/D (NH_3) + 0.085 Kg/D (NO_3)

= 0.391 KgN/D

Mean Daily Load (KgN/D) = (0.391 KgN/D + 0.309 KgN/D)/2

= 0.350 KgN/D

Mean Annual Load (KgN/yr) = 0.350 KgN/D x 365 days/yr = 127.8 KgN/yr
(Range: 112.6 - 142.4 KgN/yr)

There are no complexation reactions for nitrogen such as apply to phosphorus. In addition nitrogen tends to move quite freely through soils.

Assume the nitrogen (NO_3 and NH_3) contribution from inseeping groundwater in Herring Pond to be 95 to 100% of mean total, or:

121.4 to 127.8 kgN/yr

These estimated load values, however, are substantially less than the estimated load generated form septic systems alone. Possible explanations include:

1. Nitrogen is released from septic systems at a rate of approximately 20% per year, most of which is organic and subject to decay.

2. Much of the groundwater may simply by-pass the pond by rapid vertical percolation as opposed to lateral seepage towards the pond.

3. There is some nitrogen (probably +/- 10%) uptake by plants and soil microbes.

Ammonia-Nitrogen loading via groundwater to Herring Pond May-August 1988

May 23, 1988

Meter Transect	Seepage L/D	L.I.P. Zone	NH3 (mg/l)	Daily Load (Kg/D)
1-2	76449	PW-1	.010	.001
3-4	261777	PW-2	.220	.058
5-6	53689	PW-3	.020	.001
7-8	-124552	PW-4	.010	-.001
9-10	225822	PW-5	.280	.063
11-12	27095	PW-6	.240	.007
13-14	10063	PW-7	.070	.001
15-16	75659	PW-8	.460	.035
17-18	89731	PW-9	.010	.001
19-20	23610	PW-10	.010	.000
21-22	27345	PW-11	.540	.015
23-24	56024	PW-12	1.333	.075
			Net Total Load (Kg/D)	.254

August 8, 1988

Meter Transect	Seepage L/D	L.I.P. Zone	NH3 (mg/l)	Daily Load (Kg/D)
1-2	19712	PW-1	1.900	.037
3-4	74674	PW-2	.110	.008
5-6	96351	PW-3	.230	.022
7-8	15731	PW-4	.410	.006
9-10	-61175	PW-5	.060	-.004
11-12	221542	PW-6	.990	.219
13-14	-554	PW-7	.820	-.000
15-16	38808	PW-8	.200	.008
17-18	-14006	PW-9	.180	-.003
19-20	-11754	PW-10	.160	-.002
21-22	-4318	PW-11	.170	-.001
23-24	20470	PW-12	.660	.014
			Net Total Load (Kg/D)	.306

Nitrate-Nitrogen loading via groundwater to
Herring Pond May-August 1988

May 23, 1988

Meter Transect	Seepage L/D	L.I.P. Zone	NO3 (mg/l)	Daily Load (Kg/D)
1-2	76449	PW-1	.320	.024
3-4	261777	PW-2	.020	.005
5-6	53689	PW-3	.090	.005
7-8	-124552	PW-4	.020	-.002
9-10	225822	PW-5	.020	.005
11-12	27095	PW-6	.020	.001
13-14	10063	PW-7	.020	.000
15-16	75659	PW-8	.020	.002
17-18	89731	PW-9	.020	.002
19-20	23610	PW-10	.020	.000
21-22	27345	PW-11	.020	.001
23-24	56024	PW-12	.230	.013
			Net Total Load (Kg/D)	.055

August 8, 1988

Meter Transect	Seepage L/D	L.I.P. Zone	NO3 (mg/l)	Daily Load (Kg/D)
1-2	19712	PW-1	.120	.002
3-4	74674	PW-2	.920	.069
5-6	96351	PW-3	.020	.002
7-8	15731	PW-4	.020	.000
9-10	-61175	PW-5	.020	-.001
11-12	221542	PW-6	.020	.004
13-14	-554	PW-7	.020	-.000
15-16	38808	PW-8	.040	.002
17-18	-14006	PW-9	.250	-.004
19-20	-11754	PW-10	.030	-.000
21-22	-4318	PW-11	.020	-.000
23-24	20470	PW-12	.510	.010
			Net Total Load (Kg/D)	.085

Calculation of Phosphorus and Nitrogen Loading from Septic Systems into Herring Pond

Assumptions:

1. 24 residences within 250′ of pond involved, all with active on-site wastewater systems (100 %).

2. Average unit residency = 2.6 people/residency (Table 11, this report).

3. Residency span factor = 0.70; most part-time residents (Table 11).

4. Average P loading coefficient = 1.5 kg/resident/yr.
   Selection of coefficient from range of 0.74 - 3.0 kgP/resident/yr; (Reckhow et al., 1980) with "typical" value of 1.5 kgP/yr. Coefficient of 1.5 kgP/yr assumed for calculations.

   Average N loading coefficient = 4.60 kg/resident/yr.
   Selection of coefficient from range of 2.15-8.20 kgN/resident/yr; (Reckhow et al., 1980). Median value selected.

5. Baseline groundwater loading is equivalent to the lowest reasonable interstitial porewater concentration multiplied by measured annual groundwater inseepage.

Calculations

Phosphorus-loading :

24 residences x 2.6 people/residence x 0.70 residency factor x 1.00 septic system usage factor x 1.50 kgP/person/yr = 65.5 kgP/yr possible.

Baseline loading = 40 ugP/l x 1000 l/cu.m x 0.416 cu.m/min. = 8.75 kgP/yr

Subtracting from range calculated in previous section for groundwater,
Phosphorus loading from septic systems = 3.25 - 15.25 kgP/yr

Average Soil Retention Efficiency is therefore,

$$\frac{65.5\ \text{kgP/yr} - ((3.25 + 15.25\ \text{kgP})/2)}{65.5\ \text{kgP/yr}} = \frac{56.25\ \text{kgP/yr}}{65.5\ \text{kgP/yr}} = 85.9\%$$

Nitrogen-loading :

24 residences x 2.6 people/residence x 0.70 residency factor x 1.00 septic system usage factor x 4.60 kgN/person/yr = 200.9 kgN/yr possible.

Baseline loading = 0.030 mg/l x 1000 l/cu.m x 0.416 cu.m/min. = 6.6 kgN/yr

Subtracting from range calculated in previous section for groundwater,
Nitrogen loading from septic systems = 114.8 - 121.2 kgN/yr

QUALITY CONTROL DATA

BERKSHIRE ENVIRO-LABS: KETTLEHOLE PONDS DATA

QUALITY CONTROL PROGRAM SAMPLES: SUMMARY STATISTICS

PARAMETER	UNITS	STD.ERR.	AVG%DIF	MAX.VALUE	MIN.VALUE
AMM-N	(mg/l)	.05	56.54	.850	.010
NITRATE-N	(mg/l)	.02	81.76	.550	.010
KNITRO	(mg/l)	.08	54.72	1.650	.250
ORTHO-P	(ug/l)	2.86	35.60	80.000	10.000
TOTAL P	(ug/l)	6.68	54.88	200.000	10.000
FEC.COLI	(#/100ml)	.30	16.67	8.000	2.000
FEC.STREP	(#/100ml)	.38	7.14	8.000	1.000
TALK	(mg/l)	1.42	46.26	21.000	.500
TSS	(mg/l)	1.42	124.76	22.100	.400
CHLORIDE	(mg/l)	1.64	78.45	53.800	2.100

ARNOLD GREENE TESTING LABS: PEMBROKE PONDS DATA

QUALITY CONTROL PROGRAM SAMPLES: SUMMARY STATISTICS

PARAMETER	UNITS	STD.ERR	AVG%DIF	MAX.VALUE	MIN.VALUE
AMM-N	(mg/l)	.004	39.52	.100	.010
NITRATE-N	(mg/l)	.008	47.99	.670	.020
KNITRO	(mg/l)	.014	13.01	.580	.250
ORTHO-P	(ug/l)	.780	10.02	29.000	10.000
TOTAL P	(ug/l)	6.492	43.39	96.000	18.000
FEC.COLI	(#/.1L)	7.662	12.98	250.000	10.000
FEC.STREP	(#/.1L)	738.018	31.66	14000.000	10.000
TALK	(mg/l)	1.552	96.69	22.000	1.850
TSS	(mg/l)	.313	44.71	9.600	.400
CHLORIDE	(mg/l)	1.627	11.49	51.000	18.000

APPENDIX D

EDUCATIONAL INFORMATION ABOUT LAND AND WASTEWATER MANAGEMENT FOR MINIMIZATION OF GROUNDWATER 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 importance of 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.

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. 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 need to 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.

APPENDIX E

ENVIRONMENTAL NOTIFICATION FORM

FORMS OF NOTICE

(1) PUBLIC NOTICE OF ENVIRONMENTAL REVIEW

PROJECT: HERRING POND MANAGEMENT PROJECT
(Brief description of project)

LOCATION: EASTHAM, MA

PROPONENT: EASTHAM BOARD OF SELECTMEN

The undersigned is submitting an Environmental Notification Form ("ENF") to the Secretary of Environmental Affairs on or before ______________________________.
(Date)

This will initiate review of the above project pursuant to the Massachusetts Environmental Policy Act ("MEPA", G.L. c. 30, secs. 61, 62-62H). Copies of the ENF may be obtained from:

____.
(Name, address, phone number of proponent or proponent's agent)

Copies of the ENF are also being sent to the Conservation Commission and Planning Board of ______________,
(Municipality)

where they may be inspected.

The Secretary of Environmental Affairs will publish notice of the ENF in the Environmental Monitor, will receive public comments on the project for twenty days, and will then decide, within ten days, if an Environmental Impact Report is needed. A site visit and consultation session on the project may also be scheduled. All persons wishing to comment on the project, or to be notified of a site visit or consultation session, should write to the Secretary of Environmental Affairs, 100 Cambridge Street, Boston, Massachusetts 02202, Attention: MEPA Unit, referencing the above project.

By ______________________________
(proponent)

ENVIRONMENTAL NOTIFICATION FORM

I. SUMMARY

A. Project Identification

1. Project Name HERRING POND MANAGEMENT PROJECT
   Address/Location ______

   City/Town EASTHAM, MA
2. Project Proponent EASTHAM BOARD OF SELECTMEN
   Address TOWN HALL, RTE. 6, EASTHAM, MA 02640
3. Est. Commencement WINTER, 1992. Est. Completion WINTER, 1995.
   Approx. Cost $ Up to 50,000. Status of Project Design 0 % Complete.
4. Amount (if any) of bordering vegetated wetlands, salt marsh, or tidelands to be dredged, filled, removed, or altered (other than by receipt of runoff) as a result of the project.
   0 acres 0 square feet.
5. This project is categorically included and therefore requires preparation of an EIR.
   Yes ______ No X ?

B. Narrative Project Description
   Describe project and site.

A mesh bottom cover (i.e., Aquascreen) will be installed in the Town swimming area to prevent macrophyte proliferation. If necessary, limited manual harvesting of macrophytes will be conducted in localized areas where plant densities attain nuisance levels. Public education and the enactment of Town ordinances are viewed as the major courses of action to control land use and protect water resources. A three-year monitoring program is planned to assess groundwater and pond conditions. A long-term monitoring program is desirable. The fishway maintenance program carried out by the Eastham Natural Resource Department should continue. If pond conditions worsen over the next decade, the pond should be treated with Alum to precipitate and/or inactivate phosphorus in the water column and sediments.

Copies of the complete ENF may be obtained from (proponent or agent):
Name: Board of Selectmen Firm/Agency: ______
Address: Town Hall, Rte. 6 Eastham, MA 02640 Phone No. ______

1987 THIS IS AN IMPORTANT NOTICE. COMMENT PERIOD IS LIMITED.
For Information, call (617) 727-5830

C. List the State or Federal agencies from which permits or other actions have been/will be sought:

Agency Name	Permit	Date filed; file no.

D. List any government agencies or programs from which the proponent will seek financial assistance for this project:

Agency Name	Funding Amount

E. Areas of potential impact (complete Sections II and III first, before completing this section).

1. Check all areas in which, in the proponent's judgment, an impact of this project may occur. Positive impacts, as well as adverse impacts, may be indicated.

	Construction Impacts	Long Term Impacts
Inland Wetlands	X	X
Coastal Wetlands/Beaches		
Tidelands		
Traffic		
Open Space/Recreation	X	X
Historical/Archaeological		
Fisheries/Wildlife	X	X
Vegetation/Trees		
Agricultural Lands		
Water Pollution		
Water Supply/Use		
Solid Waste		
Hazardous Materials		
Air Pollution		
Noise		
Wind/Shadow		
Aesthetics	X	X
Growth Impacts		
Community/Housing and the Built Environment		
Other (Specify)		

2. List the alternatives which have been considered.

   a. No action

   b. Herbicide treatment

   c. Dyes

   d. Dredging

F. Has this project been filed with EOEA before? No __X__ Yes ______ EOEA No. ______

G. WETLANDS AND WATERWAYS

1. Will an Order of Conditions under the Wetlands Protection Act (c.131s.40) or a License under the Waterways Act (c.91) be required?
   Yes __X__ No ______
2. Has a local Order of Conditions been:
   a. issued? Date of issuance ______; DEQE File No. ______.
   b. appealed? Yes ______; No ______.
3. Will a variance from the Wetlands or Waterways Regulations be required? Yes ______; No __X__.

II. PROJECT DESCRIPTION

A. Map; site plan. Include an original 8½ x 11 inch or larger section of the most recent U.S.G.S. 7.5 minute series scale topographic map with the project area location and boundaries clearly shown. If available, attach a site plan of the proposed project.

B. State total area of project: __0.5__ acres.
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 __0.5__ acres
3. Wetlands .... __0.5__ acres
4. Floodplain .... __0__ acres
5. Coastal Area .... __0__ acres
6. Tidelands .... __0__ acres
7. Productive Resources
   Agriculture .... __0__ acres
   Forestry .... __0__ acres
8. Other .... __0__ acres

C. Provide the following dimensions, if applicable: N/A

	Existing	Increase	Total
Length in miles			
Number of Housing Units			
Number of Stories			
Gross Floor Area in square feet			
Number of parking spaces			
Total of Daily vehicle trips to and from site (Total Trip Ends)			
Estimated Average Daily Traffic on road(s) serving site			
1.			
2.			
3.			

D. TRAFFIC PLAN. If the proposed project will require any permit for access to local roads or state highways, attach a sketch showing the location and layout of the proposed driveway(s).

III. ASSESSMENT OF POTENTIAL ADVERSE ENVIRONMENTAL IMPACTS

Instructions: Explain 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. Positive impact may also be listed and explained.

Also, state the *source* of information or other basis for the answers supplied. Such environmental information should be acquired at least in part by field inspection.

Source for all information unless otherwise noted: BEC, 1991 Diagnostic/Feasibility Study for the Management of Herring Pond

A. Open Space and Recreation

1. Might the project affect the condition, use, or access to any open space and/or recreation area? Yes

Explanation and Source:
Actual construction or treatment will be in the off-season. Swimming (and diving) condition will be enhanced.

2. Is the project site within 500 feet of any public open space, recreation, or conservation land?

Explanation and Source: Yes. Treatment or construction may occur at public beach/boat launch area.

B. Historic and Archaeological Resources

1. Might any site or structure of historic significance be affected by the project? (Prior consultation with Massachusetts Historical Commission is advised.)

Explanation and Source: Unlikely - See Below

2. Might any archaeological site be affected by the project? (Prior consultation with Massachusetts Historical Commission is advised.)

Explanation and Source: Yes. MHC suspects that well-drained deposits in the vicinity of the pond may contain Indian occupations spanning approximately 8,000 years of pre-history. Although those may possibly be in close proximity to the Pond, all projected work will occur in the pond itself and should not adversely impact areas suspected as an archaeological site.

C. Ecological Effects

1. Might the project significantly affect fisheries or wildlife, especially any rare or endangered species? (Prior consultation with the Massachusetts Natural Heritage Program is advised).

Explanation and Source: None known at this time. However, if alum treatment is attempted in the future, close monitoring of pond pH is advised to prevent release of toxic aluminum from occurring.

2. Might the project significantly affect vegetation, especially any rare or endangered species of plant? (Prior consultation with the Massachusetts Natural Heritage Program is advised.)

(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 known to be involved.

3. **Agricultural Land. Has any portion of the site been in agricultural use within the last 15 years? If yes, specify use and acreage.**

Explanation and Source: NO

D. Water Quality and Quantity

1. **Might the project result in significant changes in drainage patterns?**

Explanation and Source: NO

2. **Might the project result in the introduction of any pollutants, including sediments, into marine waters, surface fresh waters or ground water?**

Explanation and Source: NO

3. **Does the project involve any dredging? No X Yes ____ Volume ____ . If 10,000 cy or more, attach completed Standard Application Form for Water Quality Certification, Part I (314 CMR 9.02(3), 9.90, DEQE Division of Water Pollution Control).**

4. **Will any part of the project be located in flowed or filled tidelands, Great Ponds, or other waterways? (Prior consultation with the DEQE and CZM is advised.)**

   Explanation and Source: Yes. All activity to occur in Herring Pond classified as a Great Pond

5. **Will the project generate or convey sanitary sewage? No __X__ Yes _____**
   If Yes, Quantity: ________ gallons per day
   Disposal by: (a) Onsite septic systems .... Yes _____ No _____
   (b) Public sewerage systems (location; average and peak daily flows to treatment works) .... Yes _____ No _____

   Explanation and Source:

6. **Might the project result in an increase in paved or impervious surface over a sole source aquifer or an aquifer recognized as an important present or future source of water supply?**

   Explanation and Source: NO

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

   Explanation and Source: NO

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

   Explanation and Source: YES. All area residents are served by wells, but the proposed project will have no effect on them.

9. Does the operation of the project result in any increased consumption of water? NO
   Approximate consumption ________ gallons per day. Likely water source(s) ________
   Explanation and Source:

E. Solid Waste and Hazardous Materials

1. Estimate types and approximate amounts of waste materials generated, e.g., industrial, domestic, hospital, sewage sludge, construction debris from demolished structures. How/where will such waste be disposed of?
   Explanation and Source: NONE

2. Might the project involve the generation, use, transportation, storage, release, or disposal of potentially hazardous materials?
   Explanation and Source: NO

3. Has the site previously been used for the use, generation, transportation, storage, release, or disposal of potentially hazardous materials?
   Explanation and Source: NO

F. Energy Use and Air Quality

1. Will space heating be provided for the project? If so, describe the type, energy source, and approximate energy consumption.
   Explanation and Source: NO

2. **Will the project require process heat or steam? If so, describe the proposed system, the fuel type, and approximate fuel usage.**

   Explanation and Source: NO

3. **Does the project include industrial processes that will release air contaminants to the atmosphere? If so, describe the process (type, material released, and quantity released).**

   Explanation and Source: NO

4. **Are there any other sources of air contamination associated with the project (e.g. automobile traffic, aircraft traffic, volatile organic compound storage, construction dust)?**

   Explanation and Source: YES. If treatment of pond water and sediments with alum is conducted, temporary exhaust emissions from application equipment may occur. Alum treatment is a remote contingency, however.

5. **Are there any sensitive receptors (e.g. hospitals, schools, residential areas) which would be affected by air contamination caused by the project?**

   Explanation and Source: NO

G. Noise

1. **Might the project result in the generation of noise?**

   (Include any source of noise during construction or operation, e.g., engine exhaust, pile driving, traffic.)

   Explanation and Source: YES. Engine exhaust noise possible. See F4 above Not a primary management action, however.

2. Are there any sensitive receptors (e.g., hospitals, schools, residential areas) which would be affected by any noise caused by the project?

Explanation and Source:

The area around the pond is a low density largely seasonal residential area. All noise-producing activity would be conducted during off-season.

3. Is the project a sensitive receptor, sited in an area of significant ambient noise?

Explanation and Source: NO

H. Wind and Shadow

1. Might the project cause wind and shadow impacts on adjacent properties?

Explanation and Source: NO

I. Aesthetics

1. Are there any proposed structures which might be considered incompatible with existing adjacent structures in the vicinity in terms of size, physical proportion and scale, or significant differences in land use?

Explanation and Source: NO

2. Might the project impair visual access to waterfront or other scenic areas?

Explanation and Source: NO

IV. CONSISTENCY WITH PRESENT PLANNING

Discuss consistency 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 Herring Pond. Relevant agencies requested to review the BEC Report and are in agreement with its findings and recommendations. MHC, however, requested the opportunity to review any proposed work which would result in impacts to well-drained deposits in the vicinity of the pond; none are anticipated, however.

V. FINDINGS AND CERTIFICATION

A. The public notice of environmental review 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 301 CMR 11.24.

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

APPENDIX F

COMMENTS BY INTERESTED PARTIES AND SAMPLE SURVEY QUESTIONNAIRE

SUMMARY OF FIRST PUBLIC MEETING FOR HERRING POND

On Monday, August 8, 1988, representatives of Baystate Environmental Consultants, Inc. met with concerned citizens at the Eastham Town Hall. The meeting was advertised in an earlier edition of The Cape Codder, and notices were distributed to watershed residents the week prior to the meeting. The meeting was opened at 7:30 p.m. and was attended by about 25 residents, including selectmen Mr. Ralph Earle and Mr. David Humphrey. Dr. Kenneth Wagner, Project Manager for Bec, summarized the findings of the study to date. At the conclusion of the presentation opportunity was given to attendees to raise questions and make comments. Questions and comments can be summarized as follows:

1. Is there a saltwater influence on the pond? (Yes, it does appear so).

2. Access to the public beach was discussed as a concern. The beach parking lot is frequently crowded and is situated in a dangerous area of Herring Brook Road. Additional low-impact access is desired.

3. The Horton property and its influence on the pond was discussed. It was mentioned that the Town is attempting to purchase the property to create a similar parking area and beach.

4. The macrophyte growths in the pond were discussed. Distribution is generally good, but some control of nearshore growths is desired.

5. The condition of the ponds fishery was discussed. No bass seen in several years. Trout fishing in the pond is desired. Necessary maintenance of the herring run was discussed.

6. The impact of on-site wastewater treatment system on the pond was discussed. The watershed as a whole system (incl. groundwater, stormwater, and fertilizers) was discussed.

7. Storm impact on taste and appearance of well water was noted.

8. The preservation and protection as opposed to the restoration of the pond was discussed.

9. Dr. Wagner described the Clean Lakes Program process to the public.

10. Dr. Wagner stated that the generally good environmental approach by the Town and residents has kept the pond in relatively good condition. There are no existing storm drains discharging into the pond, relatively few septic systems around the pond, and muck depths in the pond are not great.

11. The issue of water clarity, which is quite good, was discussed.

Dear Watershed Resident:

As part of our effort to assess conditions and their causes in your lake and watershed, BEC requests that you fill out the attached questionnaire and return it to either the BEC office (296 N. Main St., East Longmeadow, MA 01028, Att. Lakes Section) or the designated representative in your area. Your cooperation will be greatly appreciated, and will contribute to our analysis of the lake and the development of a management strategy for it. All information will remain confidential; we ask for a name and address only for follow-up/clarification purposes, and will not release this information to anyone outside our office. If you are uncomfortable providing a name and address, simply leave that space blank. The results of the questionnaire survey will be tallied and presented as a table in which responses to specific questions will be expressed as a number or percent of the total. For example, listings will include the percent of respondents favoring each listed lake use, the average age of waste water disposal systems, and the percent of households using washing machines. No individual data will be given. Again, it is very important that we receive enough questionnaires to perform a valid analysis. Please assist us by taking the time to fill out this form and returning it.

Thank you for your cooperation,

for the BEC staff

QUESTIONNAIRE FOR WATERSHED RESIDENTS

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 the lake?

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

5. Preferred activities on the lake?

   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.

MASSACHUSETTS ★ HISTORICAL ★ COMMISSION ★
★ A CommonWealth to Keep ★

April 13, 1990

William J. Monagle
BEC, Inc.
296 North Main Street
East Longmeadow, MA 01028

Re: Herring Pond Diagnostic/Feasibility Study, Eastham

Dear Mr. Monagle:

Thank you for your recent inquiry regarding historical and archaeological resources in the vicinity of Herring Pond, Eastham. MHC staff have reviewed the materials which you submitted.

Review of the MHC's files indicates that a potentially significant archaeological site (MHC Inventory # 19-BN-416) has been identified to the west of the pond. This site is expected to contain a variety of prehistoric Indian occupations spanning approximately 8,000 years of prehistory. Since the area has not been systematically examined by professional archaeologists, other sites may be present as well.

MHC requests the opportunity to review any proposed work which would result in impacts to well drained deposits in the vicinity of the pond. MHC looks forward to receiving the results of the diagnostic/feasibility study.

If you have any qestions, please feel free to contact me.

Sincerely,

Peter R. Mills

Peter Mills
Preservation Planner
Massachusetts Historical Commission

Commonwealth of Massachusetts

Division of Fisheries & Wildlife

Wayne F. MacCallum, *Director*

April 30, 1990

Mr. William J. Monagle
Baystate Environmental Consultants, Inc
296 North Main Street
East Longmeadow, MA 01028

RE: Herring Pond, Eastham MA
Diagnostic/Feasibility Study Draft Report

Dear Mr. Monagle:

Thank you for forwarding a copy of "A Diagnostic/Feasibility Study for the Management of Herring Pond, Eastham, Massachusetts" for our review and comment. This report has also been reviewed by Mr. Steve Hurley, fisheries manager of our Southeast Wildlife District office located in the Town of Bourne. The following comments relative to fisheries and wildlife matters are offered:

(1) Installation of benthic barriers in selected littoral areas: we have no objection to the installation of such devices in selected areas, however, as stated on page 51 "... a healthy fishery requires some measure of macrophyte cover."

(2) Limited low-tech harvesting of macrophytes in localized areas: where possible, areas supporting a diverse aquatic plant community should remain untouched to provide habitat for the many forms of aquatic life.

(3) Preparation of an educational brochure: we support this effort at informing watershed residents and all users of the lake of the importance of minimizing pollutant loading of the pond.

(4) Maintain an unobstructed fishway so that alewives may find their way into Eastham Pond and spawn: the alewive can serve as a valuable and highly desirable food fish for such species as the yellow perch, chain pickerel and trout. The Herring Pond alewife run is under the jurisdiction of the Division of Marine Fisheries.

Division of Fisheries & Wildlife
Field Headquarters, One Rabbit Hill Road, Westboro, MA 01581 (508) 366-4470
An Agency of the Department of Fisheries, Wildlife & Environmental Law Enforcement

(5) A possible alum treatment to precipitate and/or inactivate phosphorus in the water column: consideration needs to be given to the possibility of releasing toxic aluminum from the addition of aluminum salts, especially when the pH level is below 6.0 (a frequent occurrence at Herring Pond).

(6) Monitoring of groundwater and pond condition to evaluate improvements and facilitate informed future management decisions: we fully support the inclusion of a monitoring program in any lake restoration project.

We hope that you will find these brief comments useful. Please do not hesitate to contact me should you have any questions or require additional input from this agency.

Sincerely,

Robert P. Madore

Robert P. Madore
Aquatic Biologist II

cc. Steve Hurley, MDFW-SED

APPENDIX G

GENERAL AQUATIC GLOSSARY

GENERAL AQUATIC GLOSSARY

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

Acid precipitation - 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.

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

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

Alkalinity - 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).

Ammonia Nitrogen - 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 form and is an important aquatic plant nutrient because it is readily available.

Anadromous - 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.

Anoxic - Without oxygen.

Aphotic Zone - 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.

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

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

Assimilative Capacity - 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 - (BMP's) State-of-the-art techniques and procedures used in an operation such as farming or waste disposal in order to minimize pollution 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).

Dissolved Oxygen (D.O.) - Refers to the uncombined oxygen in water which is available to aquatic life. 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 $44.5^{o}C \pm 0.2^{o}C$ 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 $35^{o}C \pm 1.0^{o}C$ 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 substances are removed from matter (usually soil or vegetation) by water. Most 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 of chemical constituents in solution as mass (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per 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 organisms. The classification of organisms is based upon a hierarchical scheme beginning with Kingdom and progressing 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.