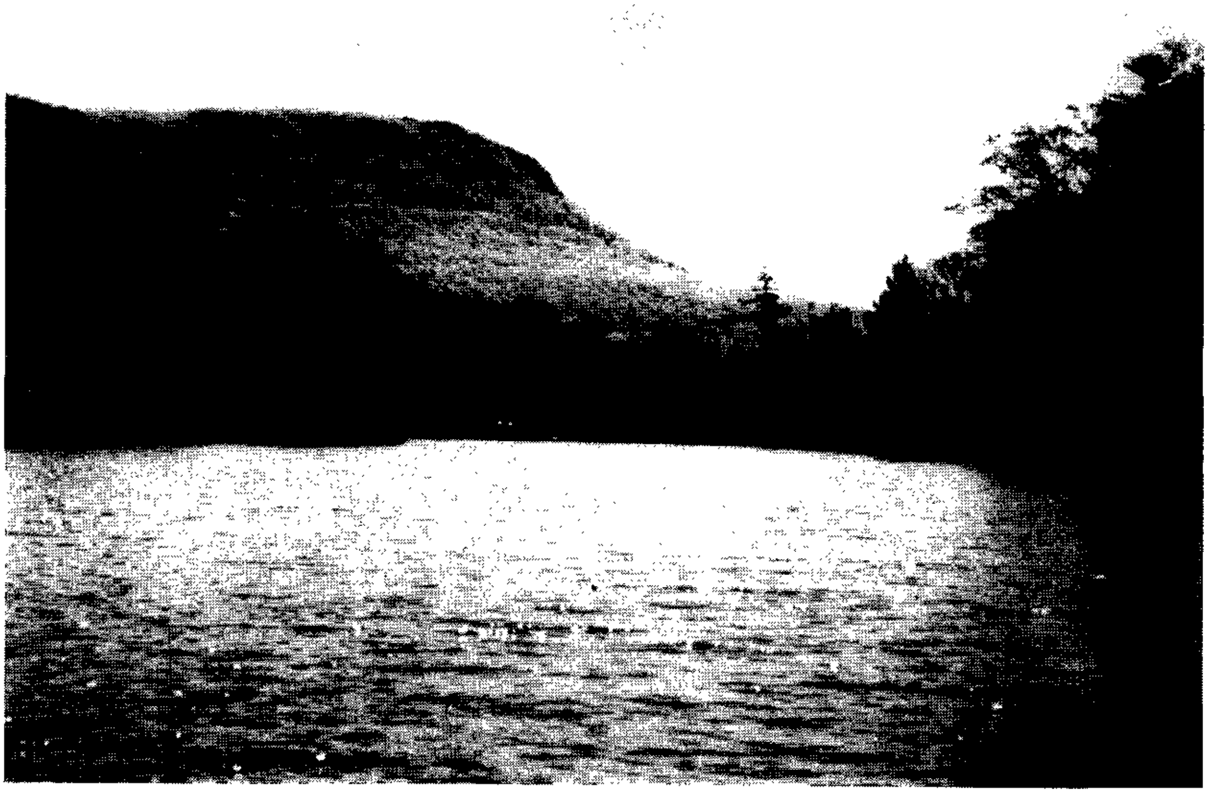
A DIAGNOSTIC / FEASIBILITY STUDY FOR THE MANAGEMENT OF NASHAWANNUCK POND EASTHAMPTON, MASSACHUSETTS



BAYSTATE
ENVIRONMENTAL
CONSULTANTS
INC

DIAGNOSTIC/FEASIBILITY STUDY
FOR THE MANAGEMENT OF
NASHAWANNUCK POND

PREPARED FOR THE
TOWN OF EASTHAMPTON
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

FINAL REPORT
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PROJECT SUMMARY

Nashawannuck Pond and its watershed was the subject 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 Easthampton. The Diagnostic/Feasibility study's primary goals were to determine the historic and present water quality conditions in the lake, identify the major sources of nutrient loadings in the watershed and provide appropriate recommendations for improvement of the water resource. The major problems of concern were decreasing water quality and recreational impairment caused by prolific growths of aquatic macrophytes. The period of routine sampling and data collection was from April 1987 to March 1988, with stormwater sampling continuing until June 1988.

The results of the Diagnostic portion of the study indicated that Nashawannuck Pond is undergoing advanced cultural eutrophication, mainly due to nutrient inputs from its extensive (10.35 sq. mi) watershed. Phosphorus was the most important limiting nutrient for primary production in the pond. The phosphorus contributions of the three surface tributaries, Broad Brook, Wilton Brook and White Brook, correlates well with the size of the sub-drainage basins. The high nutrient content and shallow depth of the pond makes it ideal for growth of rooted macrophytes, which flourish there in high profusion. The biota which exists under these conditions contains many undesirable plant and animal species, in terms of water quality and recreational function.

The Feasibility portion of the study considered and eliminated lake management options not appropriate or feasible for Nashawannuck Pond. The recommended options were water level control, hypolimnetic release, education on watershed management, storm drain redesign, installation of gabion weirs, excavation of sediments, urban "housekeeping" education, and rehabilitation and improvement of access points. Implementation of all the management options would reduce the phosphorus budget to a more reasonable level. The greatest benefit is in increased recreational function, closely associated with improvement of the the Nonotuck Park - Nashawannuck Pond relationship. A detailed description and cost estimate for each recommended alternative is provided. Costs of all recommended options total to \$1.33 to \$1.56 million with local support (Easthampton) of \$346-421,000. However, less expensive option packages are also discussed. The majority of the funds are being sought from the MA Clean Lakes Program.

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PART I.
DIAGNOSTIC EVALUATION

INTRODUCTION

The establishment of the Massachusetts Clean Lakes Program under Chapter 628 of the Acts of 1981 enabled many municipalities and lake associations to acquire funding for study and restoration of their lakes. As an environmentally aware and concerned community, the Town of Easthampton applied for a grant for a Phase I Diagnostic/Feasibility study of Nashawannuck 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 Nashawannuck Pond has prompted the request for a study. Eutrophication has led to extremely dense macrophyte growths in the pond; with subsequent loss of much of the recreational utility of this water body. The water quality impacts of development activities in the Nashawannuck Pond watershed were also a concern. Restoration of recreational activities and mitigation of present and future negative influences on the lake were desired.

DATA COLLECTION METHODS

Previous studies of Nashawannuck Pond and water bodies in the watershed were reviewed, as were historical records of lake water quality. Maps prepared by the United States Geological Survey (USGS) and the Soil Conservation Service (SCS) were used to initially assess watershed characteristics and establish hydrologic connections. Of particular use was the USGS (1979 photorevised) Easthampton Quadrangle Sheets from the 7.5 minute series, the Public Works Bedrock Geologic Map (Zen, 1983), and the soil survey reports prepared by SCS. Land use and vegetation cover maps were obtained from the (University of Massachusetts, 1975) Massachusetts Map Down program. Contemporary land use information was provided by infrared (1985 survey) aerial photography obtained from the National Cartographic Information Center (NCIC). Land use was confirmed by windshield surveys. Additional information came from maps provided by the Easthampton Planning Board, Department of Public works and Conservation Commission. Areal measurements were made with a Planix Electronic Planimeter. Determinations made from maps were verified by field inspection by staff engineers and biologists.

Historical lake and land use were investigated through conversations with watershed residents, newspaper and technical and field inspection. Mr. William Carroll of the Easthampton Historical Commission provided a history of the pond; while Mr. William Burgart supplied old photographs. Other useful photos were obtained from the Department of Public Works. Mr. Peter Klejna provided excellent liaison with the Town of Easthampton. Mr. Roland Laramie was very cooperative and effective in supplying engineering information. Mr. Edward Piezak of the Parks and Recreation Department was helpful in allowing us access to Nonotuck Park at off-hours. The interest and efforts of Mr. Michael Tautznik and Robert Pinkos of the Pasacommuck Trust should be especially noted. Other helpful persons were Ms. Carol Kamm of Landuse, Inc. and Mr. Robert Faivre of the Williston-Northampton Academy.

The Nashawannuck Pond bathymetric map was prepared from Uniden fathometer data, which was compared to that made by the Massachusetts Division of Water Pollution Control (MDWPC) 1984). Soft sediment depth was assessed by driving a probe to first refusal. Notes were made about the underlayment and other characteristics. These soft sediments at the deep hole were checked by a SCUBA diver in conjunction with the macrophyte check.

A comprehensive monitoring and investigative research program was instituted to assess the physical, chemical, and biological characteristics of Nashawannuck Pond. Regular sampling stations were selected from field inspection. These stations are described and shown in Figure 1. The in-lake stations were regularly sampled at surface and bottom and at the metalimnion when stratification was in evidence. All stations were sampled approximately biweekly between spring and fall turnover and monthly thereafter until the following late winter.

Fifteen parameters were routinely assessed at all sampling locations. Temperature and dissolved oxygen levels were measured with a Yellow Springs Instrument (YSI) model 57 meter, with vertical profiles obtained at the in-lake stations (0.5m intervals at NP-4; 1.0 m intervals at NP-5). The pH was measured with an Orion model SA250 pH meter and conductivity was assessed with a YSI model 33 meter. A four liter water sample was taken at each sampling location and transported to Arnold Greene Testing Laboratories in Natick, MA for analysis of suspended solids, turbidity, total alkalinity, chlorides, total Kjeldahl nitrogen, nitrate nitrogen, ammonia nitrogen, total phosphorus, and orthophosphorus by accepted standard methods (e.g., Kopp and McKee, 1979; APHA et al., 1985). Separate bacterial samples were collected for fecal coliform and fecal streptococci analyses, also performed by Arnold Greene Testing Laboratories by standard methods (membrane filter technique).

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

Sediment samples were obtained from the in-lake stations with an Ekman benthic dredge. Samples were analyzed by Arnold Greene Testing Laboratories for total Kjeldahl and nitrate nitrogen, total phosphorus, organic/inorganic fraction, heavy metals (As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, V), and oil and grease.

Macrophyte species composition and areal extent of cover were assessed by visual inspection from the boat and limited transects by SCUBA divers. The distribution of summer bottom cover was mapped, noting dominant species in each area. Qualitative notes

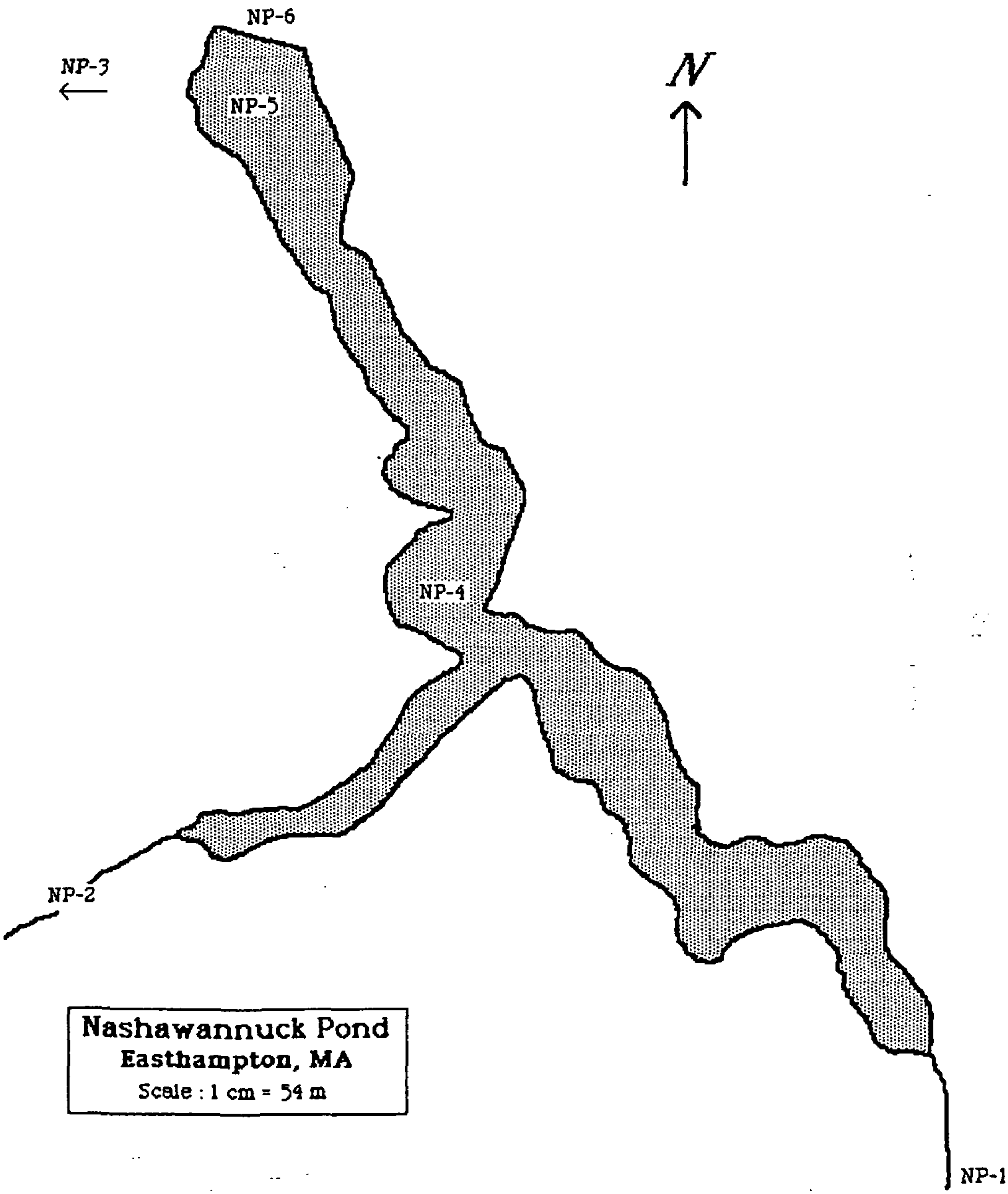


Figure 1. Regular Sampling Stations at Nashawannuck Pond, Easthampton, MA.

were made on the subsurface density, composition, and distribution of macrophyte stands by the diver. Determination and mapping of macrophyte characteristics were made in August, 1987.

Fish were collected for determination of the fishery composition and age structure. This survey was conducted on 10/16/88. Fish were collected with a 150 ft gill net and use of a 100 ft seine net for shoreline hauls. Fish were typed, measured, and a scale sample taken. Fish were aged through counting of the annulae on the scales under a microscope.

Groundwater seepage measurements were made with seepage meters, according to the method outlined in Mitchell et al. (1988). These seepage meters are essentially portions of standard 55-gallons drums which are fitted with a spout and bags to measure the incoming or exiting water in the bounded benthic area. The seepage meters were placed at regular intervals around the lake to determine the actual amount of inflow or outflow. Multiplying this value times the shoreline length computes seepage for each segment of shoreline (see Appendix for calculation sheet). Seepage at Nashawannuck Pond was sampled during July 1987.

Stormwater samplings were made three times (10/87; 5/88; 6/88) to assess the potential contributions of these inputs to water quality. Stations at NPS-1-4, NPS 6-7 were sampled. In the initial sampling, water samples were taken and flows recorded for intervals specified by the contract for a total of two hours. Composite samples were made and analyzed for the usual water quality parameters as well as heavy metals (Cd, Cr, Cu, Fe, Pb, Mn, Zn) and oil and grease. Following consultation with the Massachusetts Division of Water Pollution Control, time series samplings for water quality were made of NPS-2 and NPS-4, at intervals specified by the contract (0, 10, 20, 30, 45, 60, 75, 90, 105, 120 minutes), with an additional composite made for heavy metal analysis.

LAKE AND WATERSHED DESCRIPTION AND HISTORY

Lake Description

Nashawannuck Pond is located in the Town of Easthampton, Hampshire County, Massachusetts. It lies in the Connecticut River Basin at latitude 42 degrees and 16 minutes north and longitude 72 degrees and 40 minutes west (MDWPC, 1986). Nashawannuck Pond is essentially Y-shaped, with the two lower arms formed by the confluence of Broad and White Brooks (Figure 1). The pond has an area of 12.7 hectares (31.3 acres). The shoreline length is approximately 3,650 m (2.27 mi). The irregularity of the shoreline is reflected by the high value for shoreline development of 2.89 (Table 1). [Note that a perfect circle would have a value of 1.0]. The greatest distance in any one direction (or longest fetch) is 610 m (0.38 mi).

The pond consists of a man-made impoundment of three tributary streams (Figure 2). The deepest point in the pond was determined to be 4.7 m (15.4 ft), and is located within the basin near the outlet (Figure 3). The depth-areal relationship shown by the hypsographic curve projects a rather uniform decrease in area until 3 m (10 ft), with a more rapid dropoff at greater depths (Figure 4). The full volume of the pond was calculated to be 234,900 cu. m (or 190.5 acre-feet). Based on available data about hydrologic inputs, an annual average input of 23.4 cu.m/min (13.8 cubic feet per second) is expected (for details consult Hydrologic Budget section). Thus, the average detention time for water in Nashawannuck Pond is 0.019 yr or 7 days.

Nashawannuck Pond is maintained by water from three surface tributaries, stormwater inputs, direct precipitation, and groundwater seepage. The major tributaries, in order of decreasing flow are Broad Brook, Wilton Brook and White Brook (Figure 2). Broad Brook flows into the eastern lower arm of Nashawannuck Pond, while White Brook goes into the western arm. Wilton Brook enters via a submerged pipe from Rubberthread Pond, located to the west of the northern end of Nashawannuck.

The impounding structure on Nashawannuck Pond is a wide dam with water level controlled by an adjustable bascule gate. Water spills over the gate into a concrete sluiceway which passes under Route 141 (Cottage St.). Downstream, the outflow passes under and through a brick factory complex into Lower Millpond. From there flow goes to the Manhan River and eventually into the Connecticut River, via the Oxbow.

The Town of Easthampton owns land near the head of the impoundment, as well as the dam structure. Public access is off Water Lane at the site of the former town beach. The area

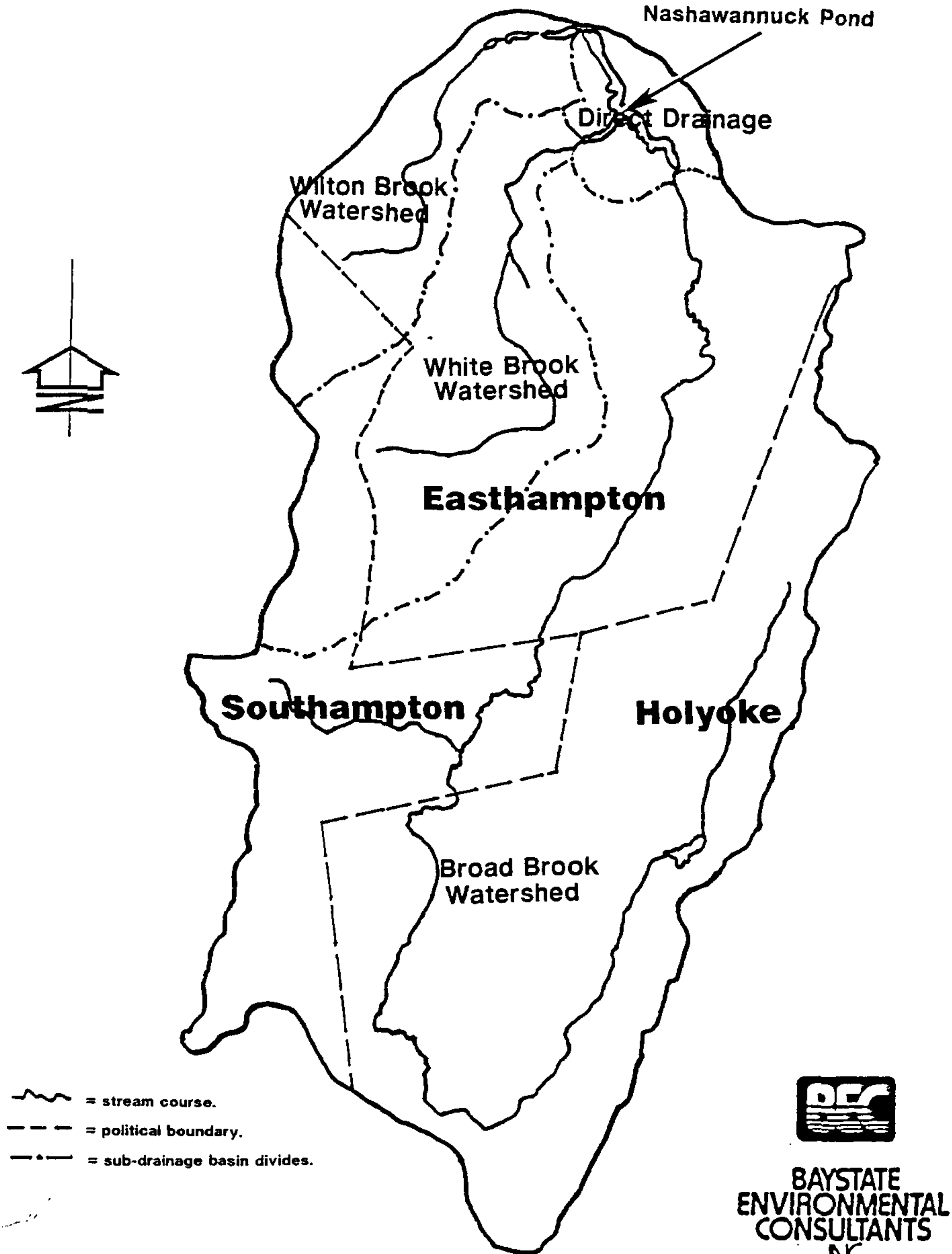
TABLE 1

CHARACTERISTICS OF NASHAWANNUCK POND AND ITS WATERSHED

Location: Towns of Easthampton, Southampton and Holyoke; Hampshire and and Hampden Counties. 42°35'40" N. lat. 71°31'45" W. long.

Area:	12.7 ha	(31.3 acres)
Depth: Mean	1.6 m	(5.3 ft.)
Maximum	4.7 m	(15.4 ft)
Volume:	234,900 m^3	(190.5 acre-ft.)
Detention Time:	0.019 yr	(7 days)
Maximum Length:	0.61 km	(0.38 mi)
Maximum Width:	0.14 km	(0.09 mi)
Shoreline Length:	3.65 km	(2.27 mi)
Shoreline Development:	2.89	
Watershed Area: (excluding NP)	2,686 ha	(10.35 sq. mi)
Watershed Area/Lake Area:	212:1	

Figure 2. Watershed of Nashawannuck Pond and sub-drainage basins.



Modified from Easthampton (1979) and Mount Tom (1972) U.S.G.S. quadrangle maps.

Scale : 1 = 38,120.

Figure 3. Bathymetric Map of Nashawannuck Pond.

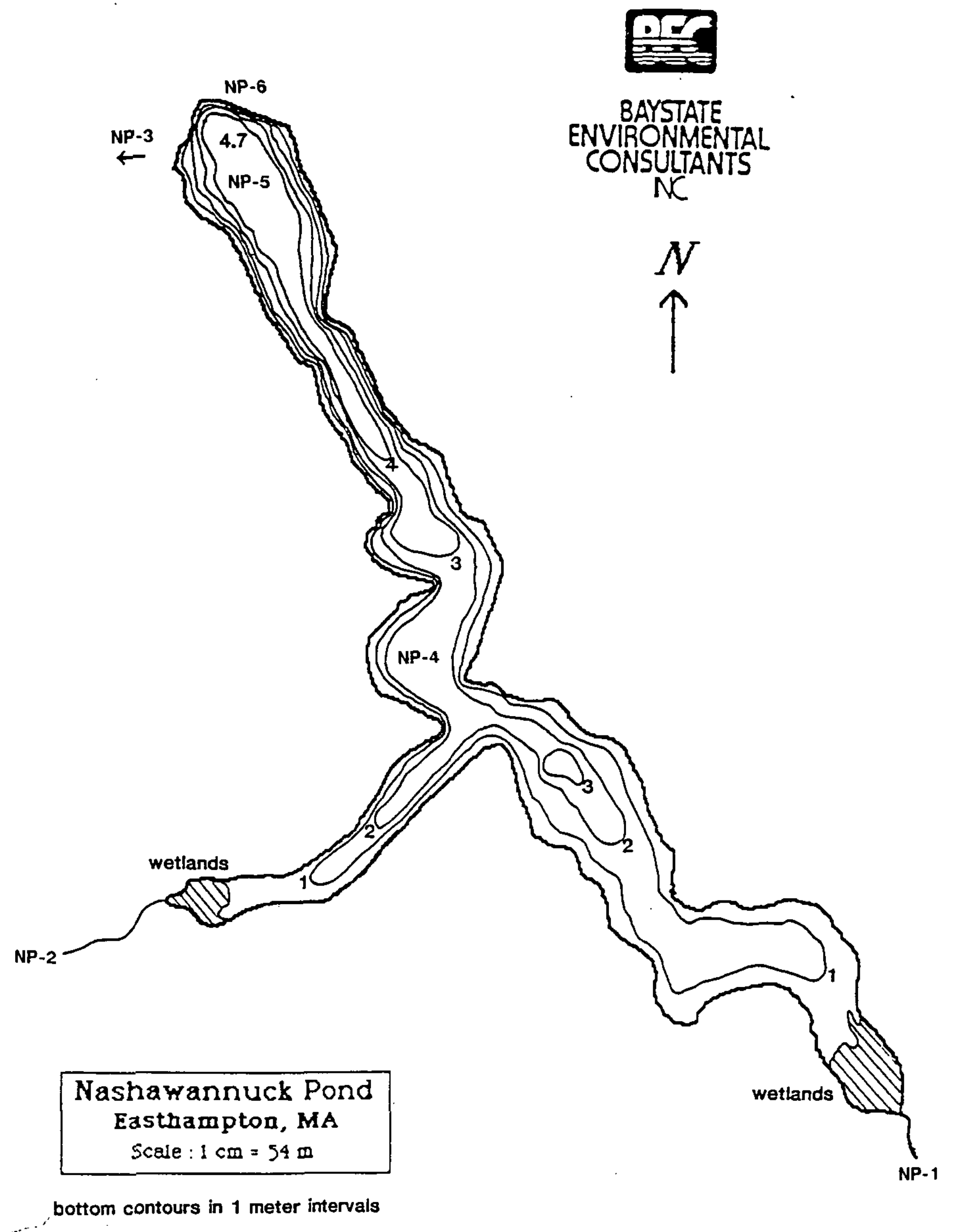
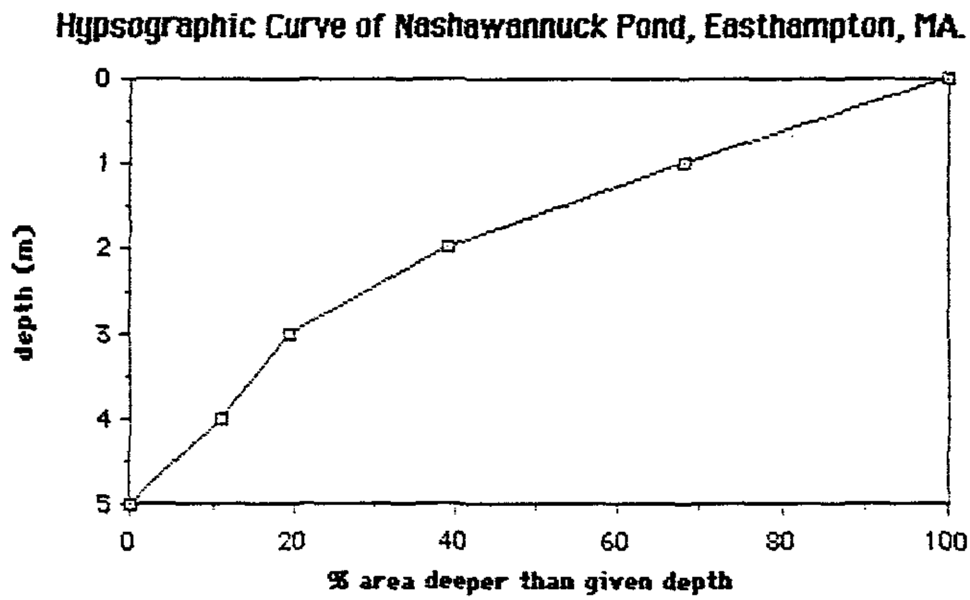


Figure 4. Hypsographic Profile of Nashawannuck Pond.



bordering the lake on the east is essentially residential in nature; while the western side is occupied to the south by Nonotuck Park, and to the north by Brookside Cemetery.

Watershed Description

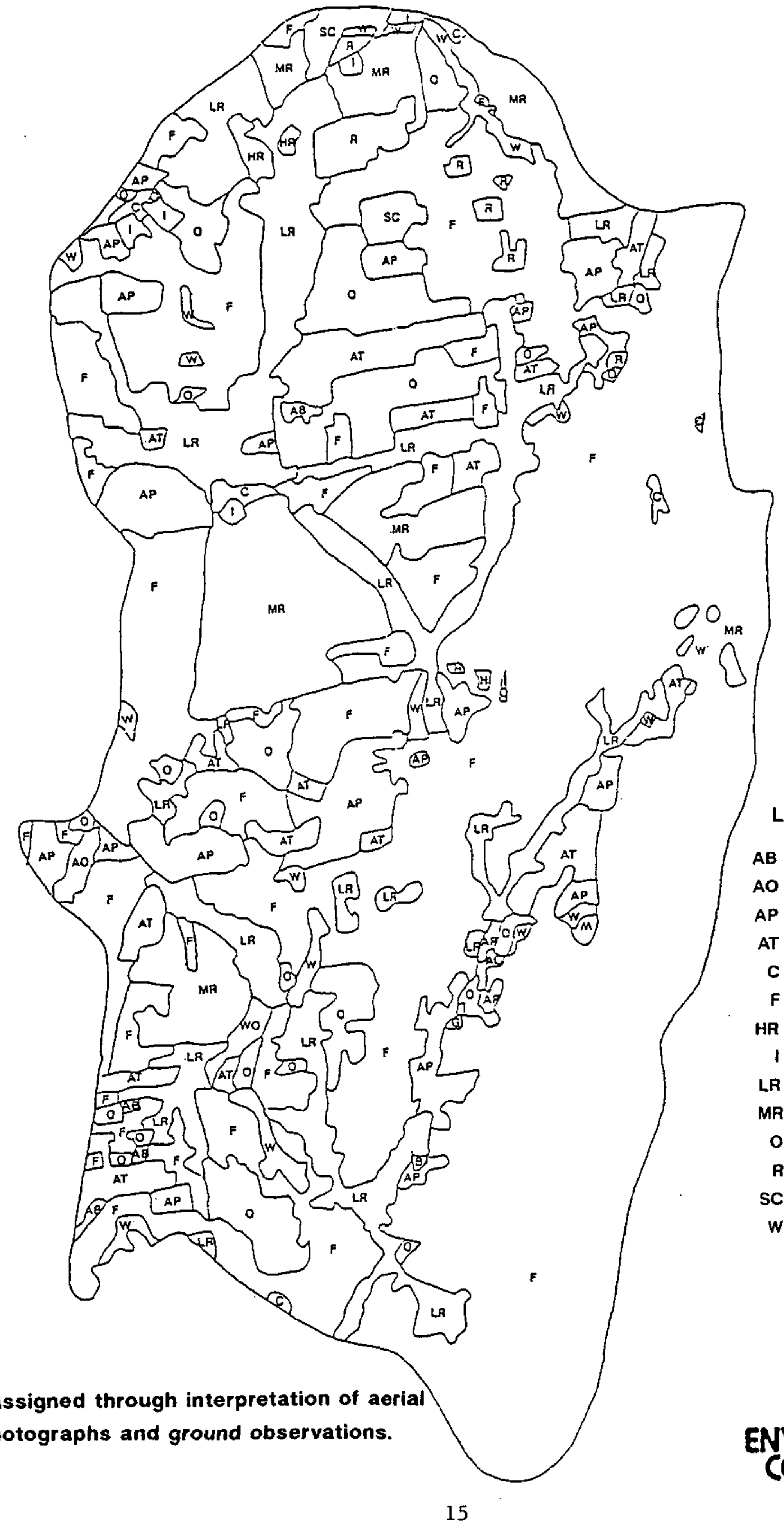
The watershed of Nashawannuck Pond covers an area of 2,686.2 ha (10.35 sq. mi), located in the towns of Easthampton, Southampton and Holyoke (Figure 2). Measurements were based on information from the United States Geological Survey topographic map (7.5 minute series) of Easthampton (USGS, 1979) and Mount Tom (USGS, 1972). The watershed shape is broadly elongate, with the limits roughly delineated on the northeast by the town of of Easthampton; to the east by the Mount Holyoke Range (with Mount Tom); to the south by the Pequot Ponds; to the southwest by Whiteloaf Mountain; and to the west by the Manhan River drainage. The sub-drainage basins for the tributary streams in the watershed are as follows : Broad Brook, 1771.2 ha or 66% of the total watershed; White Brook, 563.5 ha, 21%; Wilton Brook, 261.6 ha, 10%; and direct drainage to the pond, 76.2 ha, 3%.

The surface watershed area to pond area ratio is approximately 212:1. This indicates the importance of the watershed in determining water quality in Nashawannuck Pond. Most sources of pollution are more effectively manageable when the watershed is small in the absolute and relative senses. At lake-to-watershed ratios of 10 or more, management of water quality becomes difficult by just in-lake measures. At ratios of 50 or more, it becomes very difficult to economically control water quality at all times, due to the large influence of the watershed. However, local geology, soils, flow patterns and land use can greatly affect the relationship between watershed : lake area ratio and water quality.

Groundwater in the Nashawannuck Pond watershed has been recently studied (IEP, 1988). Groundwater movement is generally from south-southwest to the north-northeast with flow along the eastern and western boundaries directed toward the center of the watershed before moving to the north. Groundwater flow in the southern end of the watershed is horizontal, through an unconfined aquifer. This aquifer becomes confined to the north, providing for artesian flow at water pumping stations at Nonotuck Park and Hendrick Street (along Broad Brook). The unconfined area to the south forms the major recharge zone for the aquifer found in the northern portion of the watershed.

Land use in the Nashawannuck Pond watershed is very diverse (Figure 5). The majority of land use is forested (56.3%); with residential (21.3%), agricultural (10.7%), and open (7.1%) land types figuring prominently. Other important land uses and their

Figure 5. Land use in the Nashawannuck Pond watershed.



Land Use Key.

AB = Farm buildings
AO = Orchards
AP = Pasturage
AT = Row crops
C = Commercial
F = Forest
HR = High density residential
I = Industrial
LR = Low density residential
MR = Medium density residential
O = Open
R = Recreational
SC = School
W = Wetlands

Land uses assigned through interpretation of aerial infrared photographs and ground observations.

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respective percent of the watershed are : marsh/wetland, 1.8%; recreational, 1.2%; institutional, 0.6%; commercial, 0.5% and industrial, 0.5%. The relative proportion of each major land use is shown in Figure 6.

Land use varies between the sub-drainage basins. The Broad Brook watershed is predominantly forested, with low-density residential and agricultural land uses also important. The White Brook watershed is more residential in nature, although it still contains significant agricultural land use. The Wilton Brook watershed is the most urbanized of the three watersheds and contains less agricultural and more commercial and industrial land uses. The exact breakdown of land uses according to sub-drainage basin is given in a table in Appendix D.

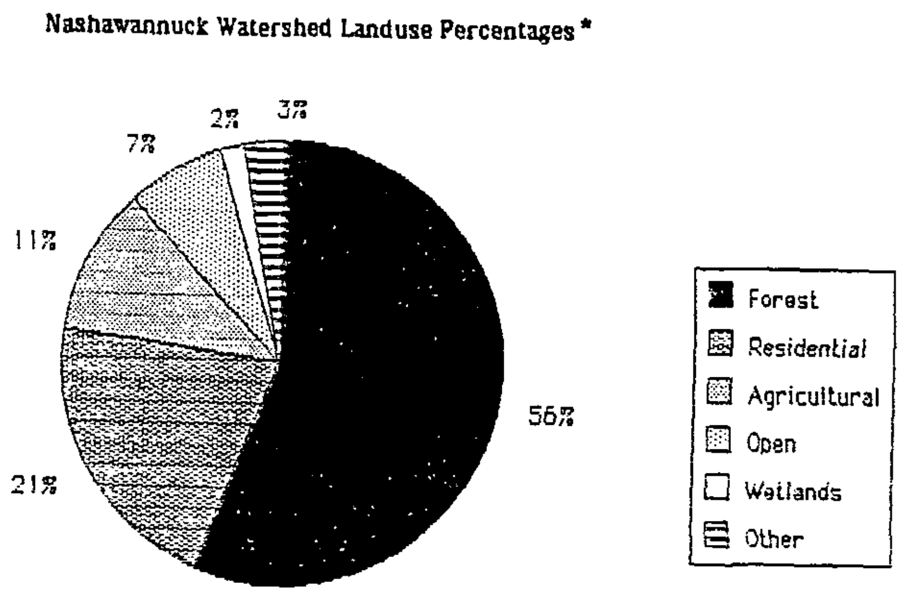
Watershed Geology and Soils

The Nashawannuck Pond watershed is underlain by tilted and faulted sedimentary and igneous rocks of the Newark Series of the upper Triassic to Lower Jurassic Age. The Jurassic rocks which comprise the sedimentary New Haven formation are arkose, arkosic sandstone, and siltstone. These rocks have low resistance to weathering, and thus are not usually found exposed. The Jurassic igneous rock in the area is the Holyoke Basalt, comprised of basalts, with minor amounts of breccia and tuff. The most notable example of this group is the ridge of resistant basalt which forms the impressive western cliffs on Mount Tom and one of Easthampton's most scenic views. The origin of these basalts was as fissure eruptions and lava flows, some extruded beneath water to form pillow lava. The cooling of the lava flow deposits led to the development of the columnar joint pattern seen on the cliffs. The joints are important conduits for groundwater and surface water recharge.

The effect of bedrock on water quality is somewhat subdued by the influence of the Quartenary geology of the area. The features of the Nashawannuck Pond watershed are dictated by the extent and location of glacial lakes, notable Lake Hitchcock and Lake Manhan (Larson and Stone, 1980). By and large, the watershed and its soils are a product of these glacial events. Glacial deposits in the area consist of till, outwash deposits, fine-grained glacio-lacustrine sediments and eolian (wind-derived) deposits forming the upper few feet of the present day soils.

The southern part of the watershed (south of Plain St.) is a glacial outwash plain with isolated islands of till and stream terrace deposits. The northern portion (north of Plain St.), is mostly glacial lake bottom deposits, which contain appreciable silts and clay. Recent (Post-Glacial) events, which have

Figure 6. Land Use Percentages in the Nashawannuck Pond Watershed.



*** Note: for listing of land-use by sub-watershed see Appendix D.**

dissected the lake floor through fluvial processes have produced alluvium and swamp deposits. The deposits in the northern end pose potential turbidity problems due to their silty nature and high clay content.

The major soil groups in the Nashawannuck Pond watershed were identified by the Soil Conservation Service (SCS, 1978; 1981). Like any large watershed, these soils form a complex mosaic of types and topography. The soil classifications and their locations are shown in Figure 7, along with a legend for the major soil types. In the southern part of the watershed, well-drained Merrimac soils are predominant along with less well-drained silt or fine sandy loams such as the Ninigret, Agawam, Scitico and Belgrade series. These last types are well suited to agricultural purposes due to their high moisture retention capabilities and cation exchange capacities. In the northern end, the Hinckley-Merrrimac-Windsor association is important. These are well drained outwash-derived soils, which are suitable for either residential or agricultural land use.

Historical Lake and Land Use

The history of Nashawannuck Pond dates from 1847, when Samuel Williston built a dam on Broad Brook to provide hydropower for developing the buttonmaking industry in Easthampton (Carroll, 1985). This original dam had an eight foot head and the resultant pool size was 50 acres. This button works was to became the National Button Company.

Since additional hydropower was available from this dam, a second mill was built for the manufacture of suspenders, organized under the name of the Nashawannuck Manufacturing Company. By utilizing vulcanized rubber in woven goods, this mill started the elastic fabric industry. The success of this venture prompted the building of another dam on Broad Brook in 1859, creating Lower Millpond. This dam provided power to a mill engaged in cotton manufacture, which was used by the suspender industry.

The period of greatest expansion was during the Civil War years, which saw the population of Easthampton greatly increase. The mills started to decline following the turn of the century, with the button company closing in 1922 and the suspender industry (under United Elastic Manufacturing Company) hanging until the 1930's.

The ownership of the water rights of the pond were traditionally associated with the mills. United Elastic held water rights to Nashawannuck Pond during the 1920's (MDFW, 1928). The most recent commercial owner is the J.P. Stevens, Company

Figure 7a. Soil Classifications in the Nashawannuck Pond Watershed.

Source : SCS, 1978; 1981.

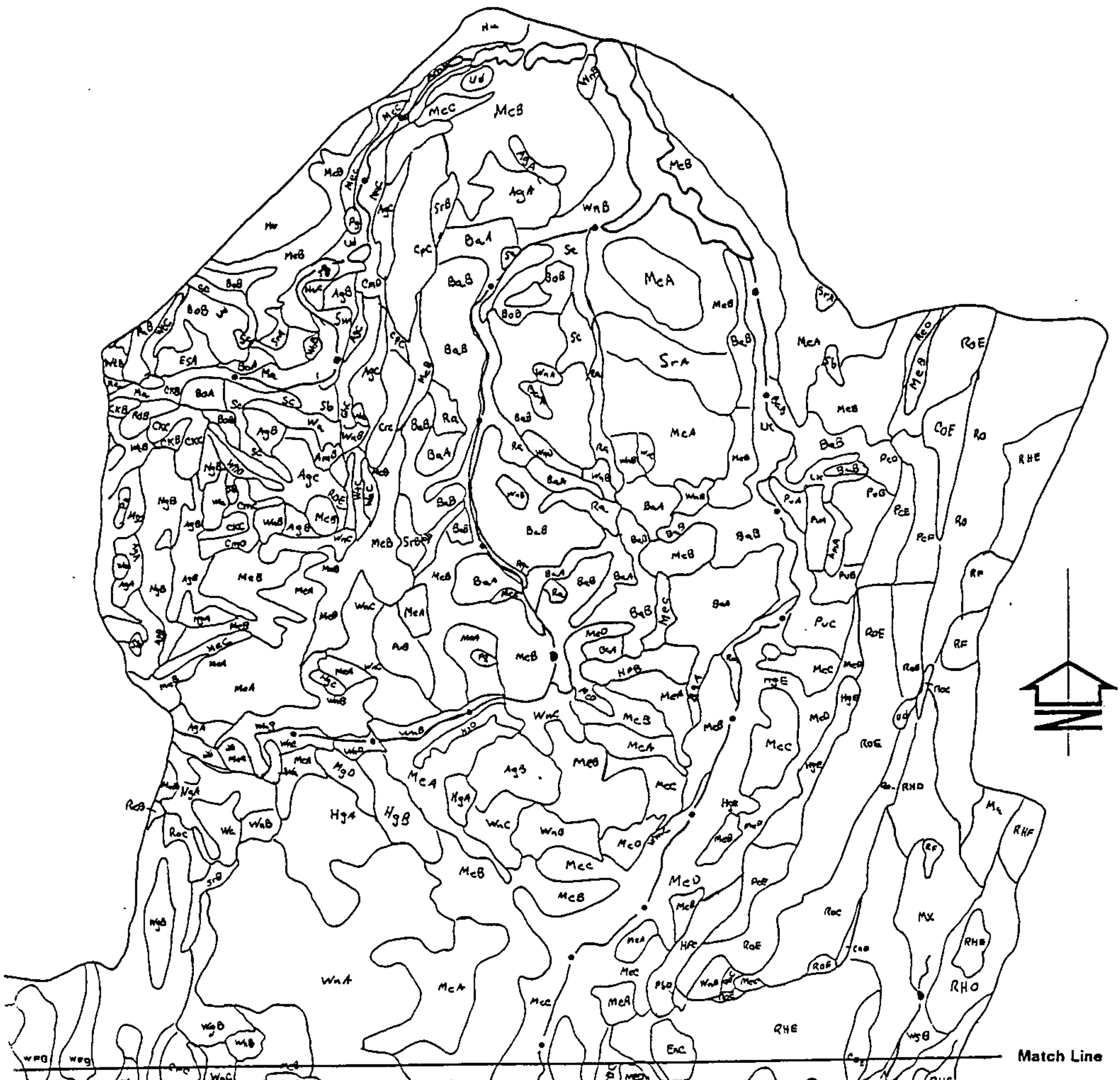
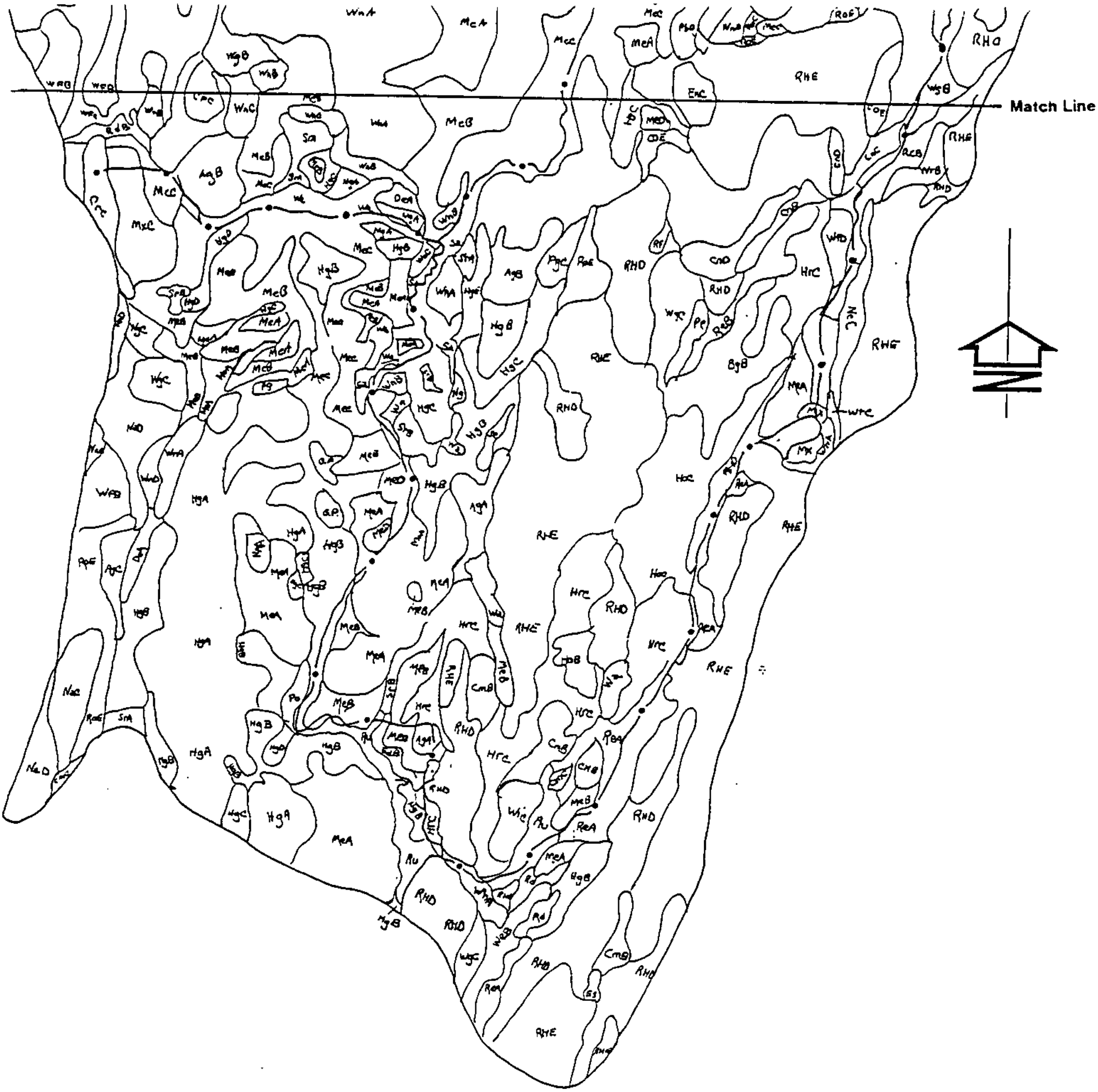


Figure 7b. Soil Classifications in the Nashawannuck Pond Watershed.

Source : SCS, 1978; 1981.



SOIL CLASSIFICATION IN THE NASHAWANNUCK POND WATERSHED
(Source : SCS 1978; 1981)

Designation	Soil Type
Ag	Agawam fine sandy loam
Am	Amostown fine sandy loam
Ba	Belgrade silt loam
Bo	Boxford silt loam
Ck,Cm,Cn,Cr,Cp	Charlton fine sandy loam
De	Deerfield loamy fine sand
Gh	Glouchester sandy loam
Hf	Haven fine sandy loam
Hg,Hn	Hinckley loamy sand
Lk	Limerick silt loam
Ma	Maybid silt loam
Mc	Meckesville extremely stony loam
Me	Merrimac fine sandy loam
Mg	Manchester gravelly sandy loam
Mx	Montauk fine sandy loam
Na	Narragansett fine sandy loam
Ng	Ninigret fine sandy loam
Pc,Pg	Paxton fine sandy loam
Pu	Pollux fine sandy loam
Ra	Raynham silt loam
Rd,Re	Ridgebury fine sandy loam
Ro	Rock outcrop
Ru	Rumney fine sandy loam
Sa	Saco silt loam
Sb	Scarboro muck
Sc	Scitico silt loam
Sr	Sudbury fine sandy loam
Sw	Swansea organic muck
Ud	Udorthents
Wa	Walpole fine sandy loam
We,Wf,Wg	Wethersfield fine sandy loam
Wn	Windsor loamy sand
Wr,Wt	Woodbridge fine sandy loam

(MDFW, 1979). Presently, the town of Easthampton has ownership of the water rights.

The cutting and storage of ice was another commercial activity on Nashawannuck Pond. It is not known when the pond was first used for this purposes, but the mill workers would provide a ready market. An ice house on Nashawannuck Pond, located at Pine and Gaugh Streets was mentioned in 1873. This same ice house was reported destroyed by fire in 1887. Another ice house was built, just to the north of the old town beach. This ice house was in operation from 1895 till the mid- 1930's. The fate of this building is not known, although some foundations still remain.

To the south of this ice house a private boat launch was operated by a Mr. Wagner. Boating and fishing were noted as popular activities during the early part of this century (MDFW, 1912). The Wagner boat house and adjoining beach later became publically owned by Easthampton. This town beach was a popular swimming location until decreasing water quality forced its permanent closure in the early 1970's. Remnants of the sandy beach still remain on the shore and in the water. At the same location, a wooden bridge once provided access to Nonotuck Park. This bridge has been gone for many years and little trace of it remains. Another defunct boat house, established by the Nonotuck Club, was located on the western shoreline near Brookside Cemetery. Brookside Cemetery was established on land purchased by the Town of Easthampton in 1873.

Nonotuck Park was established in 1923 from land purchased from several estates (including the Hendrick and Wright estates). Major improvements in this park were made during the Depression through projects under the Emergency Relief Administration. This park is the most heavily-used recreational resource in Easthampton, and along with Daley Fields, it contains over 200 acres of parkland.

One of the more important changes in Nashawannuck Pond was the destruction of the dam by the flood caused by the hurricane of August, 1955. The dam works was replaced by the present bascule gate and three flanking outlet gates. At that time, the inlet from Rubberthread Pond was redesigned and placed at a lower depth. Old photographs show that the pond drained extremely well during the period when the dam was being repaired. The pond was also drained in the spring of 1969, for unknown reasons.

The present uses of Nashawannuck Pond are mainly fishing, boating, waterfowl observing and aesthetics. Fishing is by far the most preferred use of Nashawannuck Pond. Trout are stocked by the state and heavily sought for by shoreline anglers in the spring. The rapid drop-off of the pond makes this a particularly good shoreline fishing pond. The easy access to the pond makes this a very popular weekday activity. There is an annual fishing derby sponsored by local groups around the Memorial Day weekend. With the coming of summer months and the encroachment of rooted aquatic plants, fishing activity declines, although there is usually the odd angler trying for the few trout that survive the warmer water temperatures.

Boating is primarily to rowboats, canoes or electrically-powered motors. Boating is restricted to the spring and late fall, as the water weeds seriously impede any type of craft in the lower part of the lake during the summer. A pontoon boat is used during the annual boat tours of Nashawannuck run by the Pascommuck Trust every fall to increase town awareness of the pond.

Activities during the winter center upon skating and ice-fishing. The good accessibility to the pond makes this a popular, if not too productive ice fishery. Informal skating and hockey rinks are established on the ice during the winter months. The existence of open water near the dam attracts a considerable flock of Canada geese during the winter months. Watching and feeding these birds provides additional enjoyment to the public.

While the pond was and continues to be the center of many recreational activities, little attempt has been made to manage the pond. The growth of Easthampton (>16% increase since 1970) has placed increasing stress on the water quality of streams going into the pond. Town attempts to check the weeds are not well documented. Currently, individual abutters do not practice management of their shorelines, and town property is similarly treated. At this point in time, public attention is being increasingly focused on this water resource and the best way to manage it.

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) sought to understand the Nashawannuck Pond ecosystem and to identify those factors which are critical to its maintenance. A considerable data base is generated through the course of this yearlong 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, in the interest of brevity, most raw data has been incorporated into the appendices of this report. Included in these appendices are calculation sheets which detail the derivation of useful values and other information of secondary importance.

Flow and Water Chemistry

The waters of Nashawannuck 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 source to Nashawannuck Pond is dependent on both their concentration and the measured volume of water containing these substances which flows into the pond. Flow characteristics are thus of major potential importance in any system.

Nashawannuck Pond is an artificial pond created by the impoundment of the waters of three surface tributaries : Broad Brook, Wilton Brook and White Brook. The flow of these tributaries during the study year was determined by time-weighting to compensate for the different amounts of days between sampling dates (Table 2). The most important of these, Broad Brook (NP-1) had a mean flow of 17.0 cu. m/min. (10.0 cfs). Wilton Brook (NP-3) had a mean flow of 4.4 cu. m/min. (2.6 cfs), while White Brook (NP-2) added 1.6 cu. m/min. (0.94 cfs). The summed total of these tributaries was 23.0 cu. m/min. The measured mean outflow (NP-6) was 23.2 cu m/min.

There are additional water inputs from other sources including direct precipitation, stormwater drain flows, overland flows, and groundwater seepage. Losses from the pond include evaporation. Derivation of groundwater, precipitation and stormwater inputs, as well as evaporative losses, are detailed in the Hydrologic Budget section of this report.

TABLE 2. VALUES OF MONITORED PARAMETERS IN THE NASHAWANNUCK POND SYSTEM (4/87 - 3/88).

PARAMETER	UNITS	VALUE TYPE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
FLOW	CU.M/MIN	MEAN (1)	17.0	1.6	4.4						23.2
		MAXIMUM	39.1	5.1	9.2						58.0
		MINIMUM	6.1	.1	.5						0.0
TOTAL PHOSPHORUS	UG/L	MEAN (2)	50	66	59	47	75	53	61	86	53
		MAXIMUM	124	117	127	95	240	120	90	209	104
		MINIMUM	25	31	30	17	34	21	34	33	17
ORTHOPHOSPHORUS	UG/L	MEAN (2)	15	27	17	15	21	17	19	36	19
		MAXIMUM	24	80	39	30	51	31	25	88	40
		MINIMUM	10	17	10	10	10	10	10	10	10
AMMONIA NITROGEN	MG/L	MEAN (2)	.03	.04	.08	.05	.06	.06	.09	.12	.05
		MAXIMUM	.12	.22	.32	.19	.29	.23	.20	.58	.15
		MINIMUM	.01	.01	.01	.01	.01	.01	.01	.01	.01
NITRATE NITROGEN	MG/L	MEAN (2)	1.11	2.04	.91	.89	.80	.78	.35	.74	.83
		MAXIMUM	3.40	3.83	3.40	1.90	1.60	1.60	.52	1.50	1.60
		MINIMUM	.47	.19	.02	.05	.11	.16	.25	.16	.15
TOTAL KJELDAHL NITROGEN	MG/L	MEAN (2)	.22	.44	.37	.39	.49	.43	.73	.71	.34
		MAXIMUM	.42	.68	1.3	.76	2.83	1.3	1.32	2.2	.59
		MINIMUM	.04	.03	.03	.01	.01	.19	.05	.14	.06
NITROGEN:PHOSPHORUS RATIO	NONE	MEAN	76	89	44	61	48	60	44	45	51
		MAXIMUM	238	253	139	126	110	187	80	121	140
		MINIMUM	24	8	15	19	13	22	28	6	12
TEMPERATURE	CELSIUS	MAXIMUM	12.0	16.0	21.5	25.7	17.1	25.2	18.3	13.3	25.2
		MINIMUM	-1.0	-1.5	-1.0	-1.0	0.0	-1.0	11.5	-.5	-1.0
DISSOLVED OXYGEN	MG/L	MEAN	11.1	10.4	11	12.5	7.8	11.3	6.3	3.5	10.9
		MAXIMUM	14.2	15.2	18.1	15.4	13.7	14.3	11.3	11	13.7
		MINIMUM	6.6	5.5	7.6	9.6	1.5	9	2.2	.2	8.2
D.O. SATURATION	%	MEAN	89	85	95	113	65	102	62	26	98
		MAXIMUM	102	113	148	150	128	132	120	86	134
		MINIMUM	58	56	71	87	14	81	20	2	72
TOTAL SUSPENDED SOLIDS	MG/L	MEAN (2)	6.1	6.2	2.9	2.5	16.4	7.3	5.6	16.6	10.5
		MAXIMUM	21.0	18.0	12.4	6.8	49.0	34.8	10.0	42.0	32.6
		MINIMUM	.4	.8	.4	.4	.4	.4	3.6	2.8	.4
TURBIDITY	J.T.U.	MEAN	1.6	4.4	3.1	2.1	3.8	2.1	7.4	5.8	2.6
		MAXIMUM	4	12.5	5.1	5.7	18.0	5.8	28.0	12.0	7.4
		MINIMUM	.3	.5	1.4	.3	.6	.3	.7	.9	.2
CONDUCTIVITY	UMHOS/CM	MEAN (2)	156	157	146	142	151	139	138	146	133
		MAXIMUM	229	249	232	197	202	192	148	199	192
		MINIMUM	119	41	95	101	108	100	124	97	99

TABLE 2. (CONTINUED)

PARAMETER	UNITS	VALUE TYPE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
pH		MEAN (3)	6.8	6.8	7.0	7.2	7.1	7.1	7.2	7.0	7.1
	S.U.	MAXIMUM	7.3	7.3	7.7	9.0	7.9	8.2	7.9	7.3	8.5
		MINIMUM	5.9	6.1	6.3	6.3	6.3	6.4	6.9	6.4	6.5
TOTAL ALKALINITY	MG/L	MEAN (2)	38	34	25	36	37	36	48	39	33
		MAXIMUM	51	74	38	51	48	45	56	59	45
		MINIMUM	30	8	19	15	22	20	41	22	17
CHLORIDE	MG/L	MEAN (2)	22	19	27	20	21	20	18	20	19
		MAXIMUM	44	33	56	26	34	33	21	32	26
		MINIMUM	15	7	15	13	15	16	14	16	15
FECAL COLIFORM	N/100ML	MEAN (4)	81	197	172	14		23			22
		MAXIMUM	400	3000	1000	200		100			6300
		MINIMUM	4	0	10	0		1			2
FECAL STREPTOCOCCI	N/100ML	MEAN (4)	2153	4675	3424	965		821			1109
		MAXIMUM	50000	100000	100000	29000		59000			100000
		MINIMUM	18	16	38	4		0			5
FC:FS RATIO	NONE	MEAN									
		MAXIMUM									
		MINIMUM									
CHLOROPHYLL A	UG/L	MEAN				4.3		7.8			
		MAXIMUM				16.6		19.3			
		MINIMUM				0		.5			
SECCHI DISK TRANSPARENCY	METERS	MEAN				2.2		2.2			
		MAXIMUM				2.5		3.1			
		MINIMUM				1.2		1.2			

NOTES

(1) = Time-weighted mean.
(2) = Tributaries (NP-1,NP-2,NP-3) and outlet (NP-6) time and flow- weighted means, all others time-weighted only.
(3) = Arithmetic mean of hydrogen ion concentration; converted back to negative logarithms.
(4) = Geometric mean applied instead of arithmetic mean.

The chemical constituents of water samples were assayed and summary statistics, including mean (average) value, minimum and maximum value, were established (Table 2). To compensate for differences in flow volumes and sampling intervals; the annual mean of the following chemical parameters were appropriately flow- and time-weighted (NP-1, NP-2, NP-3, NP-6) or time-weighted (all in-lake stations) : total phosphorus, orthophosphorus, ammonia nitrogen, nitrate nitrogen, kjeldahl nitrogen, total suspended solids, conductivity, total alkalinity, chloride and turbidity. These values were used in calculating nutrient or sediment loadings to the pond (kg/yr). Other instantaneous measurements such as dissolved oxygen, temperature, chlorophyll a, and secchi disk transparency are given as unweighted averages of sampling dates, as were the derived values of percent saturation and nitrogen to phosphorus ratios. Mean values of pH were calculated as the average of the absolute hydrogen ion concentrations, converted back into the pH (negative logarithm) format. Means values of fecal coliform and fecal streptococci were reported as log geometric means instead of arithmetic means.

In discussing the chemical composition of Nashawannuck Pond, it makes sense to start with the elements that are considered critical ones for pond productivity, namely phosphorus and nitrogen. Phosphorus is the element "limiting" primary productivity in temperate zone ponds, 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 pond is a good indicator of the degree of fertilization or eutrophication that the pond is receiving (Wetzel, 1983; Goldman and Horne, 1983).

Total phosphorus, as the name implies, refers to all the phosphorus in a volume of water, including dissolved and particulate forms. Total phosphorus in the surface waters in Nashawannuck Pond (NP-4S, NP-5S) had annual means of approximately 50 ug/l, as did water leaving the system (NP-6). This level reflects the mean in Broad Brook (NP-1) which is the major source of water in the system. Both White Brook (NP-2) and Wilton Brook (NP-3) had higher values 59-66 ug/l. The in-lake bottom stations (NP-4B, NP-5B) had distinctly higher means (75 to 86 ug/l) than the surface waters, which is a strong indicator of phosphorus remineralization occurring under anoxic bottom conditions. The mean (61 ug/l) of the mid-water station, NP-5M, was about midway between surface and bottom means.

Orthophosphate is the form of phosphorus most readily available for biological assimilation. In the pond, surface levels of this element ranged from 15 to 17 ug/l, while the range of all in-lake stations was 10 to 31 ug/l. The weighted mean orthophosphate level at the outlet was a little greater (19 ug/l). The slight increase in mean orthophosphate from lower to upper to outlet suggest the increasing influence of stormwater and benthic remineralization in these sections of the pond. Seasonally, these levels were generally lower in the summer months indicating the demand for phosphorus in this pond. The levels in the pond are related to levels in Broad Brook and Wilton Brook (15-17 ug/l). Orthophosphate levels were higher in White Brook (27 ug/l).

Levels of total phosphorus have been used to classify lakes and ponds with regard to their trophic state (i.e., condition of fertilization). This determination is usually not solely based on water chemistry but includes such biological and physical parameters as chlorophyll a and Secchi disk transparency (Wetzel, 1983). The total phosphorus concentrations in Nashawannuck Pond are indicate that the lake would be placed at the lower end of eutrophic conditions (Wetzel, 1983). [Note: this classification will be reviewed in the context of other parameters discussed below.]

Nitrogen is another important plant nutrient, and occurs in three major forms in aquatic systems : ammonia, nitrate and organic compounds (Table 2). 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 rapidly converted to nitrite and then nitrate in the presence of oxygen by naturally occuring bacteria, but the decline of oxygen during the summer in the deeper depths or wetland areas may promote the buildup of ammonia through decay processes. In Nashawannuck Pond the ammonia levels were fairly consistent throughout the surface stations at about 0.05 - 0.06 mg/l, with a range of 0.01 to 0.58 mg/l. The means for the tributaries was 0.03 to 0.08 mg/l with an overall range of values of 0.01 to 0.32 mg/l. High values in June (6/9/87) were observed following a day or rain, and may reflect watershed runoff of storm drainage. Similarly, high values were observed in winter (1/20/88) following days of precipitation (NOAA, 1988).

Overall, the highest mean values were routinely found in the deepest bottom waters (NP-5b). This is due to the lack of oxygen in the hypolimnion during summer months. Generally, levels at the surface stations were highest during the early spring and late fall and are indicative of the decomposition of organic material in the water column. Based on the levels of ammonia, in conjunction with pH and oxygen values, ammonia toxicity was not a threat to vertebrates found there.

Nitrate nitrogen was found in high concentrations in Nashawannuck Pond during the study year. Mean values for the year ranged from 0.78 to 0.89 mg/l within the pond; while the outlet averaged 0.83 mg/l. Nitrate was somewhat elevated in Broad and Wilton Brooks, with values from 0.91 to 1.11 mg/l. White Brook had the highest annual mean at 2.04 mg/l. Values greater than 1.0 mg/l are indicative of the influence of cultural activities. For comparison, an approximate value below 0.30 mg/l is considered useful when low algal density is desired (Sawyer, 1947). Nitrogen dynamics and loading are further discussed in the Nutrient Budget Section.

Total Kjeldahl nitrogen (TKN) exhibited in-pond surface mean values of 0.39 to 0.43 mg/l, and a range of 0.01 to 1.30 mg/l . The bottom waters at both stations had higher means (0.49 and 0.71 mg/l) and a range of 0.01 to 2.83 mg/l). The higher values are due to the settling of particles and accompanying decomposition occuring there. The means of the tributaries were lower at 0.22 to 0.44 mg/l, and had a range of 0.03 to 1.3. Influx of storm water into Nashawannuck Pond and subsequent settling may be responsible for the low values on June 25, 1987. The pond responded quickly to the disturbance with high values on the following sampling date (7/9/87). Overall, pond values of Kjeldahl nitrogen exhibited slightly higher values during the summer, indicative of the increased phytoplankton and macrophyte biomass. The resulting pattern between the various nitrogen fractions suggests that the pond is an area that biologically converts dissolved nitrate to particulate organic material.

The nitrogen : phosphorus ratio, calculated as atomic ratios {(TKN + nitrate nitrogen / total phosphorus) x 2.21}, indicates potential shifts in the chemical resources important to the primary producers. The annual mean surface in-pond ratio was about 60:1, and occasionally dipped below 22:1. Bottom N : P values were slightly lower, due to the greater amount of phosphorus available there.

These ratios have potential implications for the pond and its biological community. Examination of the empirical relationship between particulate carbon and nitrogen to phosphorus ratios suggests that at values lower than 22:1 (atomic ratio), the supply of nitrogen may limit phytoplankton growth

(Smith, 1982). Values greater than 55:1 are indicative of phosphorus-deficient ponds while those ponds whose ratios fall between these limits (i.e., >22:1 and < 55:1) may show variable patterns of limitation (Smith, 1982).

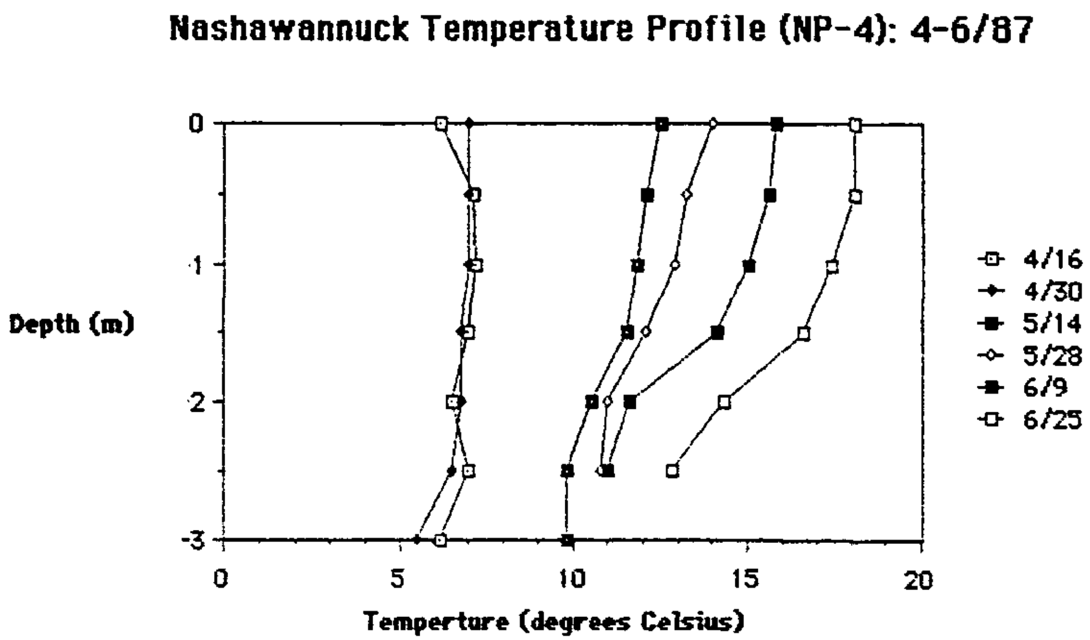
With regard to Nashawannuck Pond, as the majority of values are above 55:1, limitation by phosphorus is more likely over the entire year. However, during selected periods of the year, nitrogen was potentially limiting. For example, in late summer (8/06/87) dissolved nitrogen was very low at the in-pond stations and N:P ratios approached 20:1. In addition, the predominant phytoplankton species was Anabaena, a nitrogen-fixing form. The reduction of nitrogen levels between the NP-1 and NP-4 indicated great uptake of this element by the biota, most likely the dense macrophytes.

This episode of nitrogen limitation was probably more the exception than the rule, however. It is important to note that nutrient ratios alone do not provide conclusive proof of limiting factors, since other potentially limiting factors such as light availablity may be contributing. Other considerations include the relative movement of the water through the impoundment, relative to the time scale of internal recycling or microbial processes (e.g. nitrogen-fixation). However, phosphorus is likely to be a major control of biological growth in this system and the most appropriate target element for control in a pond management program. It is far easier to reduce or eliminate phosphorus inputs than to attempt to control other possible influences.

The temperature of water in Nashawannuck Pond demonstrated a typical temperate zone seasonal pattern (Figure 8a-d). The study year in April started with water temperatures nearly uniform from top to bottom (Figure 8a); a condition termed isothermal. This indicates that the pond was in a state of vernal or spring turnover (mixing) at the time.

With the increasing solar insolation (April through June), the upper waters of Nashawannuck Pond begin to warm and become increasingly differentiated from the bottom waters. This is clearly shown for both pond stations (NP-4,NP-5) in Figure 8a, but is more pronounced at NP-5. Stratification is less observable at the NP-4 station because of the shallowness and current observed here. The process of seasonal thermal stratification produces a warm upper layer of water (epilimnion) separated from cold bottom waters (hypolimnion) by a region of rapid temperature change with depth (thermocline). By the beginning of June, thermal stratification was well developed in Nashawannuck Pond.

Figure 8a. Temperature and Dissolved Oxygen Depth Profiles; April-June 1987.



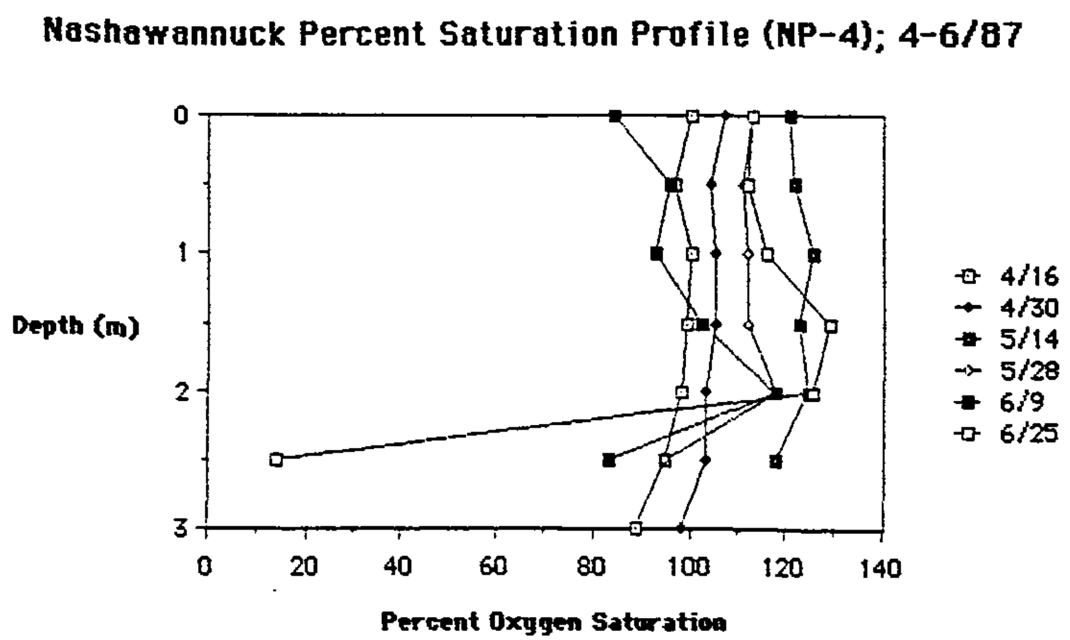
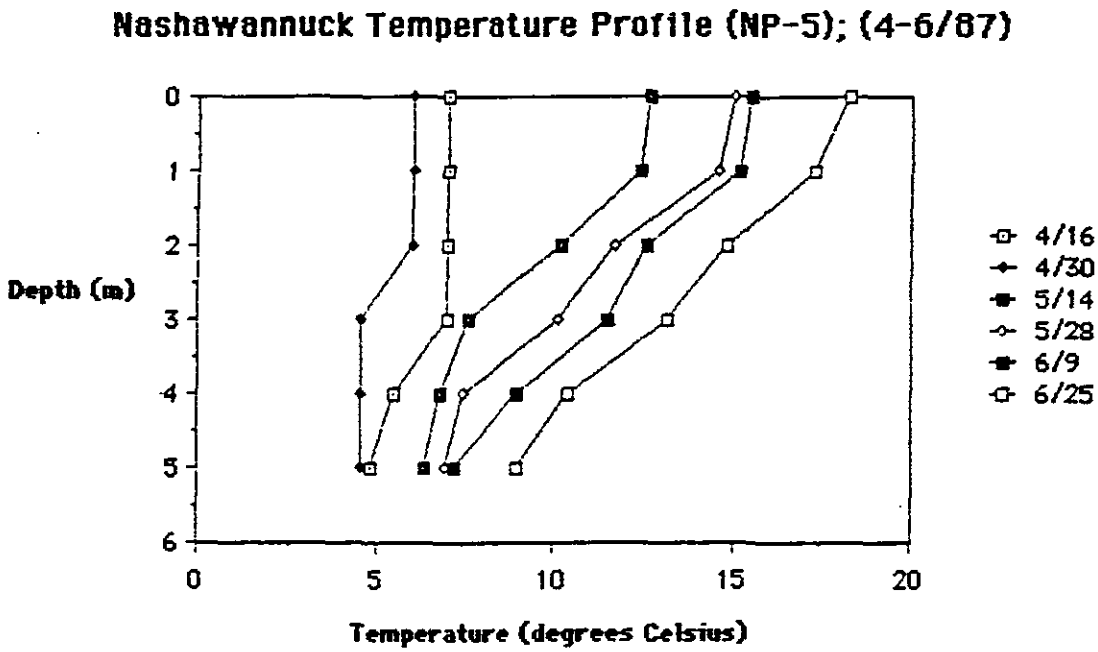


Figure 8a. Temperature and Dissolved Oxygen Depth Profiles; April-June 1987.



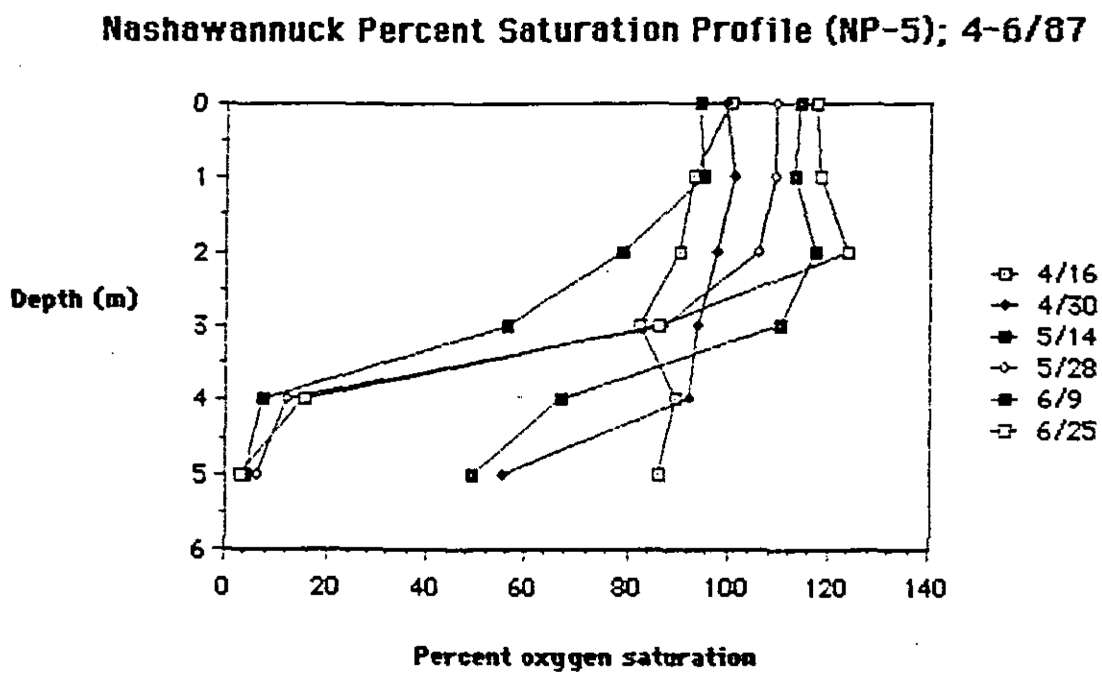
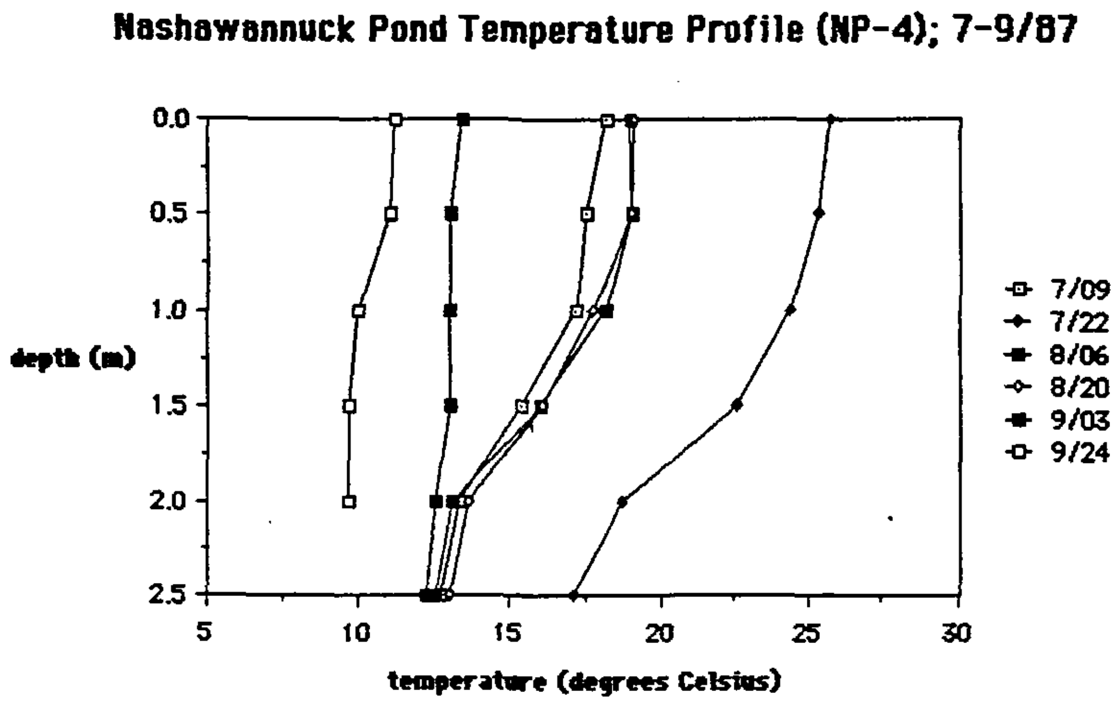


Figure 8b. Temperature and Dissolved Oxygen Depth Profiles; July-Sept 1987.



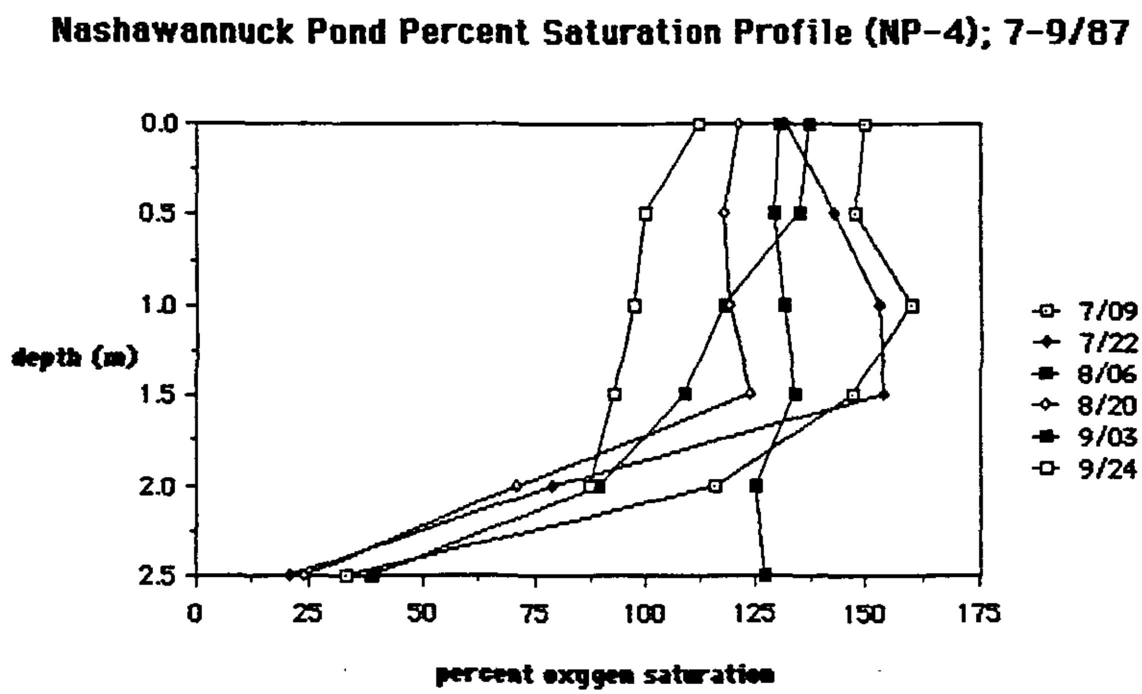
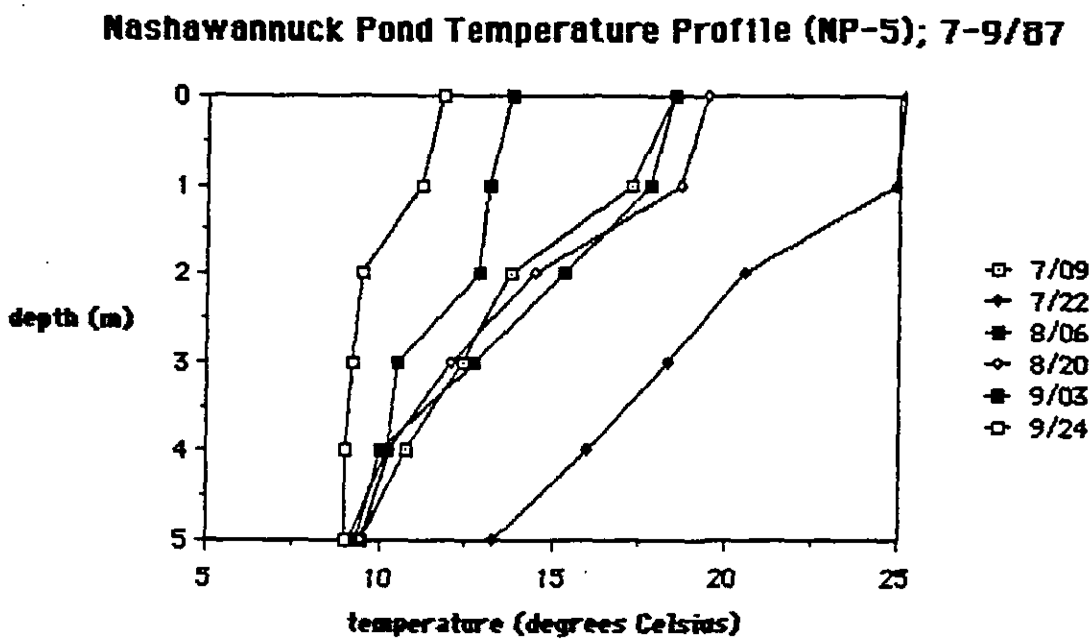


Figure 8b. Temperature and Dissolved Oxygen Depth Profiles; July-Sept 1987.



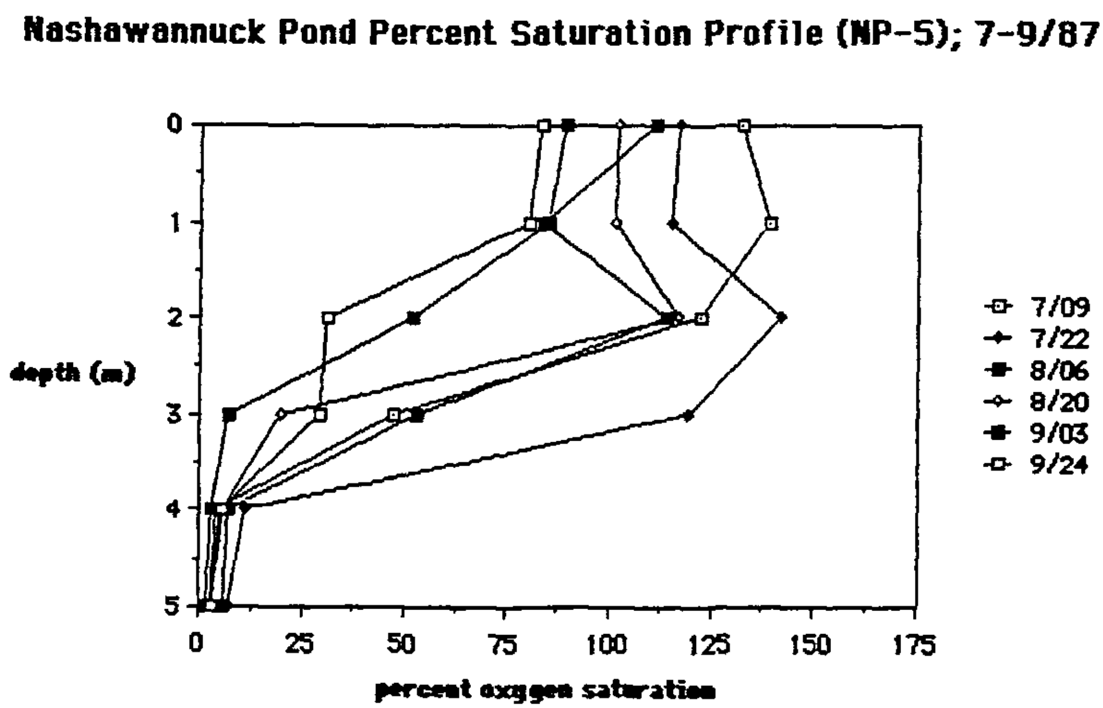
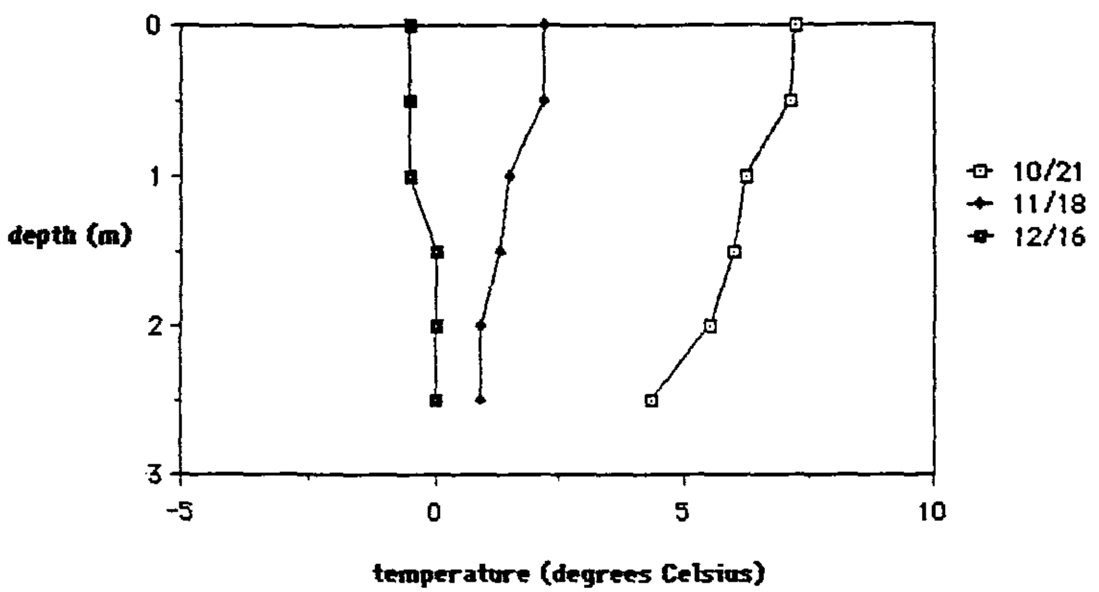


Figure 8c. Temperature and Dissolved Oxygen Depth Profiles; Oct-Dec 1987.

Nashawannuck Pond Temperature Profile (NP-4); 10-12/87



Nashawannuck Pond Percent Saturation Profile (NP-4); 10-12/87

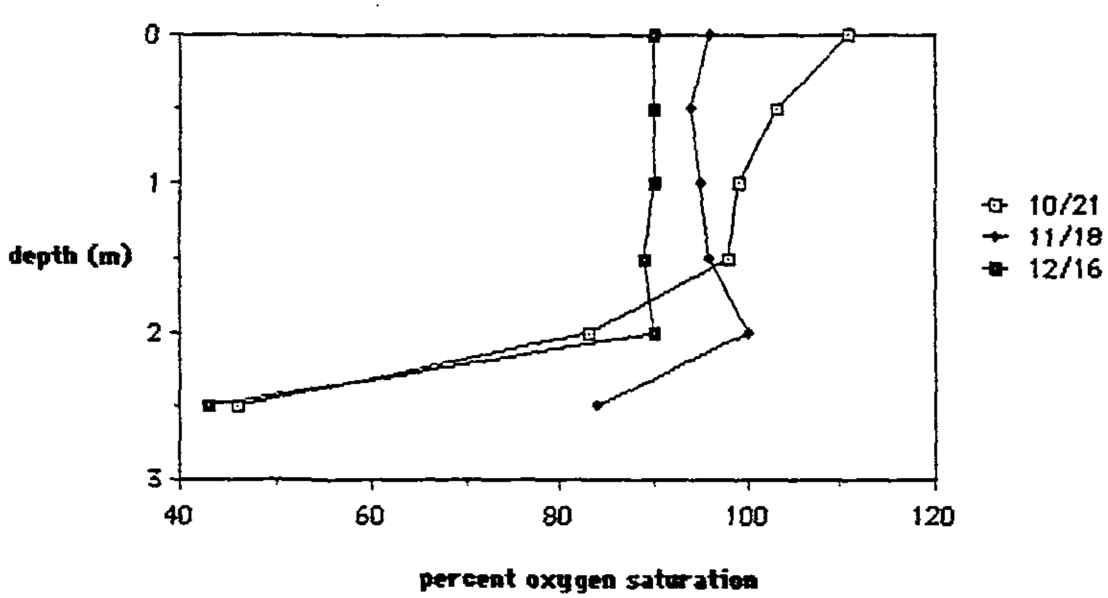
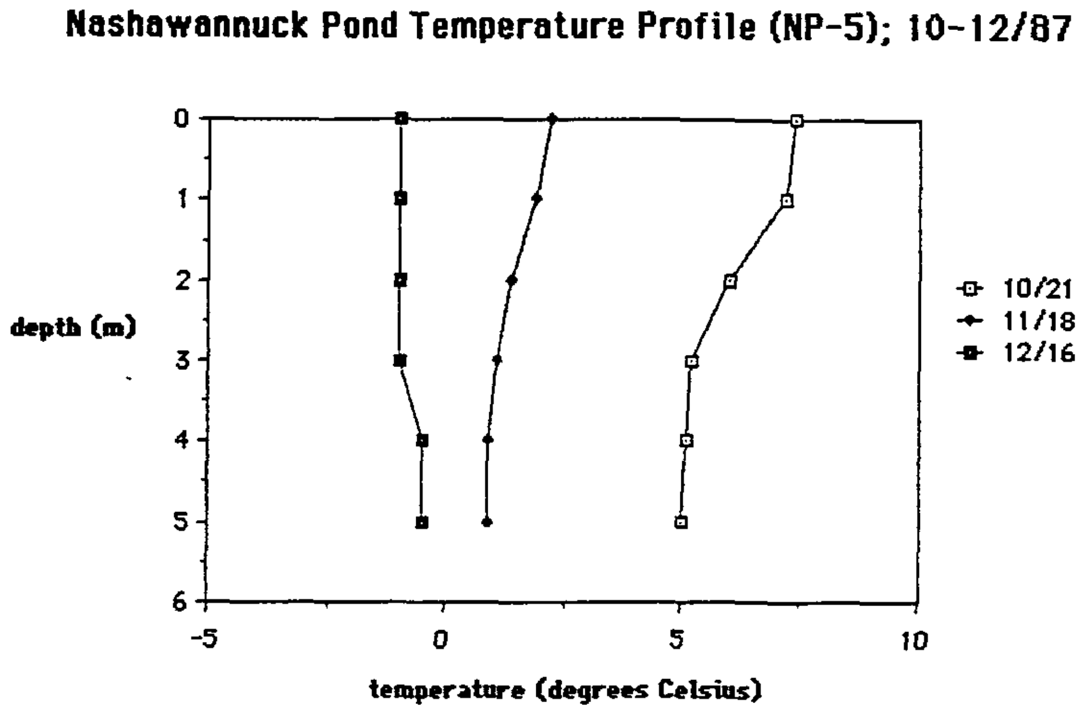


Figure 8c. Temperature and Dissolved Oxygen Depth Profiles; Oct-Dec 1987.



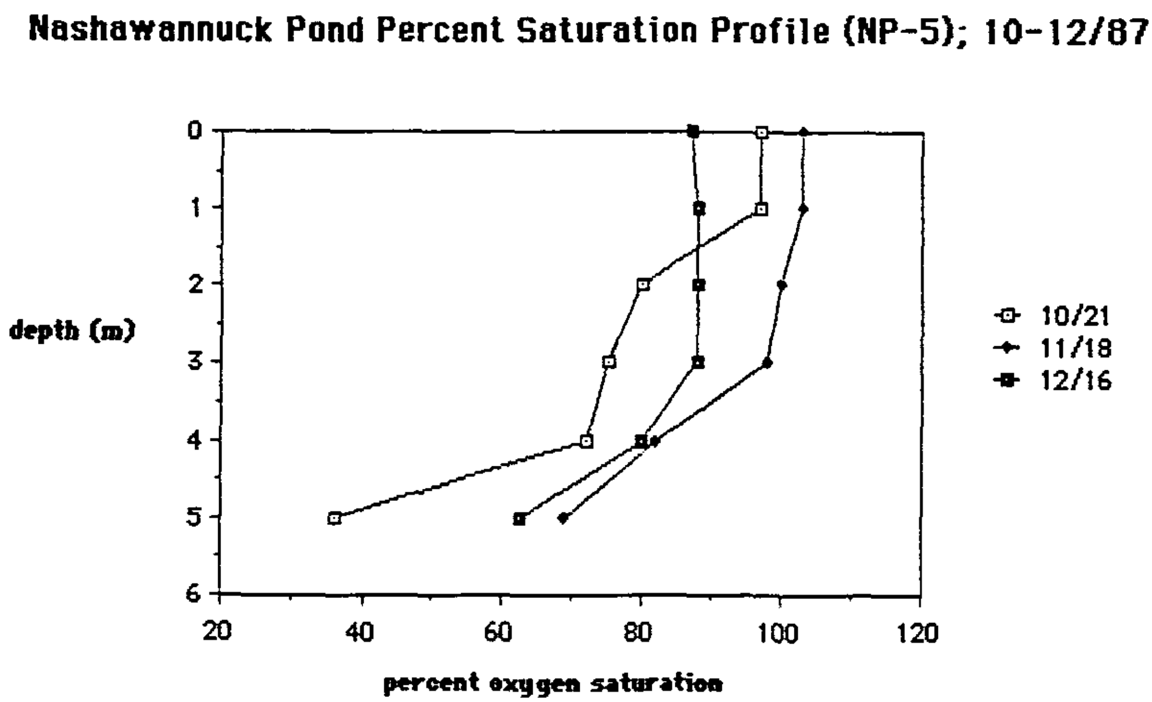
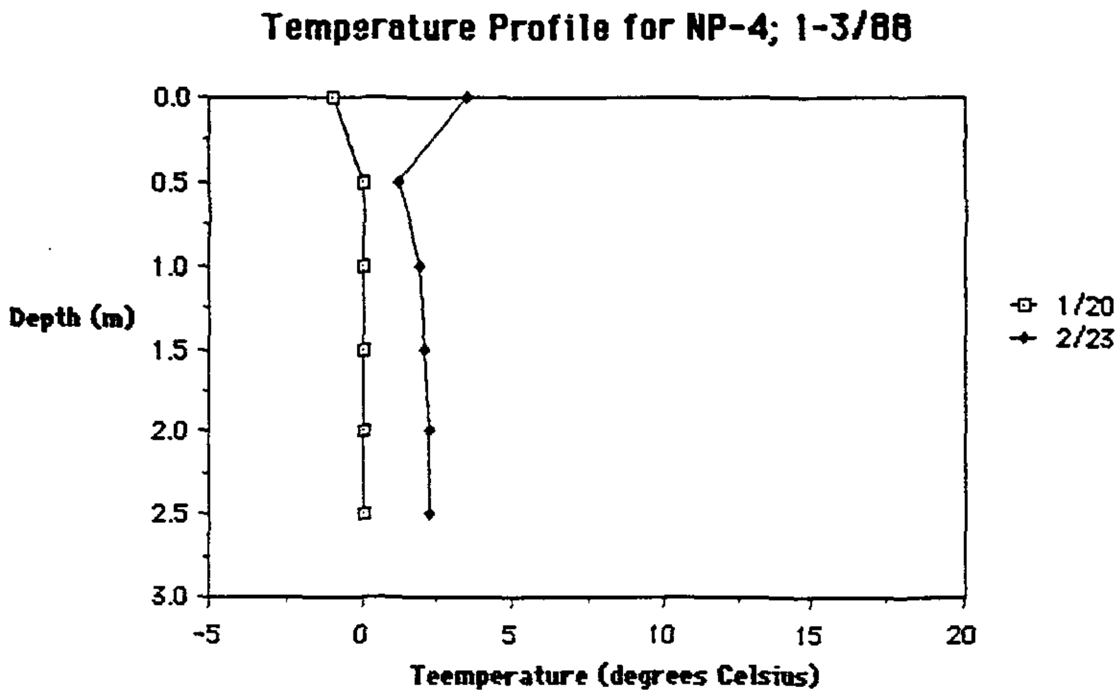


Figure 8d. Temperature and Dissolved Oxygen Depth Profiles; Jan-Mar 1988.



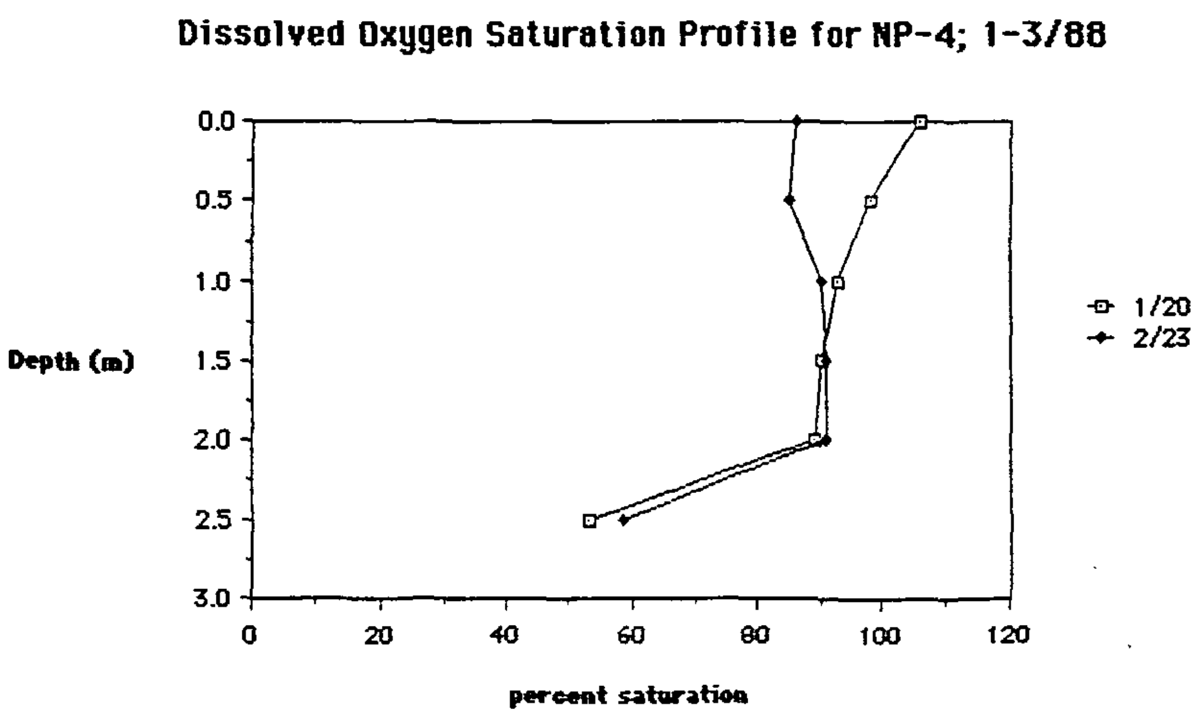
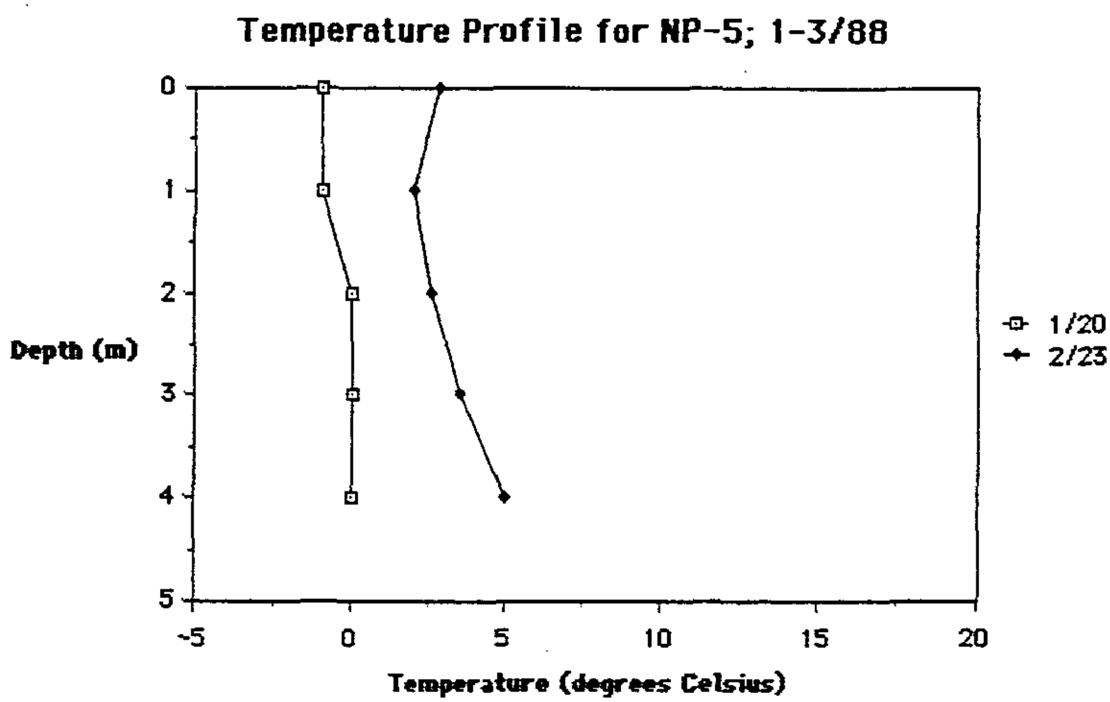
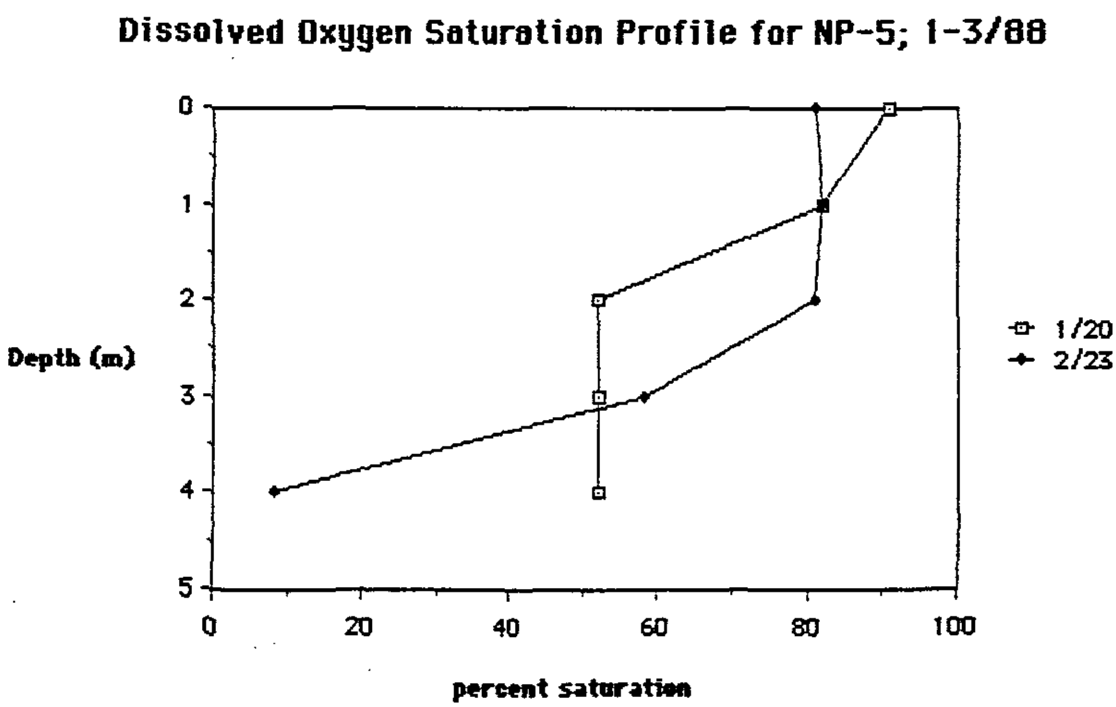


Figure 8d. Temperature and Dissolved Oxygen Depth Profiles; Jan-Mar 1988.





During late summer and early fall (July through September), the warming of the upper waters continued to climb, reaching a seasonal maxima in late July (Figure 8b). The water temperature does not go above 20^{o} C much during the summer, probably because of the groundwater contributions and shaded stream corridor for Broad Brook, the major source of water. The pond began to rapidly cool off in September, aided by higher than normal levels of precipitation (see Hydrologic Budget). The erosion of the summer thermocline was nearly complete by late September and isothermal conditions would denote the autumnal turnover.

Cooling of the pond waters continued in October through December (Figure 8c). The temperature profile remained close to isothermal throughout this period. Temperature values near freezing were recorded in the water column in December and January, but are likely unrealistically low due to some inaccuracy of the recording temperature probe. Ice cover returned by the time of the January sampling (7-9" thick). During this period there is a tendency towards inverse stratification as there is cooler water perched over warm water (Figure 8d). By the time of the March sampling the ice was in poor condition (preventing in-pond sampling), and spring inflows led to vernal turnover and completion of the yearly cycle.

Oxygen in the water column of Nashawannuck Pond displayed considerable seasonal variation, due to water temperature change and biotic activity (Figure 8a-d). The amount of oxygen which will dissolve in water is dependent on temperature, dissolved substances and atmospheric pressure. The relation of the actual oxygen level to the maximum possible concentration is called the percent saturation and reveals much about pond metabolism.

In early spring, the oxygen content in the water is roughly uniform from top to bottom (Figure 8a). As the season progresses, two changes occur in the oxygen profile. The first is the progressive decrease in oxygen levels in the bottom samples as thermal stratification takes place. Oxygen saturation values are below 20% by the end of June. The second trend is toward greater than 100% oxygen saturation (or super-saturation) seen in the upper waters or just below. This is caused by oxygen production arising from the intense photosynthetic activity taking place in the water column. At NP-4, the greatest summer oxygen levels were seen in the middle of the very dense macrophyte cover (Figure 8b). This mid-water or metalimnetic oxygen maxima was also observed at NP-5, at the top of the lower stratified layer. Density differences here produce stable water conditions. Accumulation of particulate matter and remineralization produces localized abundances of nutrients. The transmission of light to this depth is more than sufficient to sponsor plant growth. Subsequently, these conditions lead to an accumulation of active phytoplankton. Photosynthetic activity by these algae account for greater than expected levels of oxygen.

It should be noted that the annual mean percent saturation at NP-4 was greater than 100%. This is somewhat misleading as the production of oxygen in eutrophic conditions during the day is counterbalanced by respiratory uptake of oxygen and subsequent low levels during the night. Thus, significant swings in oxygen levels can be expected, depending on the time of day (a condition that can sometimes lead to summer fish kills). Since the sampling was generally done during the period of greatest photosynthesis, early to mid-day; it is not representative of the daily levels. It does indicate the important role that the biology of this highly productive pond has on the water chemistry; a role that is also observable in other chemical parameters such as pH and conductivity (see below).

During the fall, oxygen levels were a little below saturation; a situation due to the decomposition of organic material either produced or brought into the pond during the fall rains (Figure 8c). In the pond there were oxygen-poor conditions in the bottom waters of NP-5. During periods of ice cover in the winter, this oxygen debt became more severe due to decompositional activity and lack of contact with the atmosphere (Figure 8d). With ice-out and the vernal turnover, oxygen would be presumed to be well mixed throughout the water column, as is evident on April 16, 1987 (Figure 8a).

Other chemical parameters monitored on a routine basis included total suspended solids, turbidity, specific conductance, pH, total alkalinity and chloride (Table 2). Chlorophyll a and secchi disk transparency are discussed in the phytoplankton section and bacteria is considered separately.

Total suspended solids exhibited in-pond surface means of 2.5 to 7.3 mg/l, with the bottom samples containing higher totals (16 mg/l) of particulate matter from sinking and/or resuspension. The tributaries had means of 2.9 to 6.2 mg/l, indicating that they were also potential sources of particulate material.

Turbidity is related to the transparency of the water, which is influenced by the presence of dissolved organic materials and particulate matter, both organic (phytoplankton, detritis) and inorganic (silts and clays). Broad Brook had the least turbid waters (1.6 JTU); while White and Wilton Brook had less clarity (3.1-4.4 JTU). In the lake, turbidity was about 2 to 3 JTU on the surface, with highest values found at deeper waters.

Specific conductance (conductivity) is an indirect measure of the dissolved solids and chemical fertility of water. Low fertility is usually indicated by conductivity values less than

100 umhos/cm (USEPA, 1976). The conductivity values of the tributaries were consistent at 146 to 157 umhos/cm. From this index, Nashawannuck Pond would be considered to have moderate chemical concentrations, but the exact nature of these chemicals is not determined by this measurement. Of particular interest, there was a decrease in conductivity in the surface waters going from incoming water to the outlet. This would be expected if the biota were taking up nutrients from the waters as they pass by.

Total alkalinity provides a measure of the buffering capacity of Nashawannuck Pond. Mean values were very consistently in the range of 33 to 39 mg/l. Wilton Brook had slightly lower mean alkalinity at 25 mg/l. The amount of buffering capacity, the ability of the pond to withstand acidic or basic additions without pH change, would be considered good. The nature of the soils found in the watershed would make it difficult for "acid rain" to reduce pond pH down to unacceptable levels.

The pH of the tributary waters of Nashawannuck Pond was essentially circumneutral, that is, about the midpoint (7.0) of the pH scale. In the pond itself, there is a tendency towards more basic (>7.0) values. This is most pronounced in the midsummer readings at the surface (see Appendix D), caused by photosynthetic depletion of carbon dioxide and a shift in the bicarbonate : carbonate balance. These elevated pH values are typical of highly productive systems.

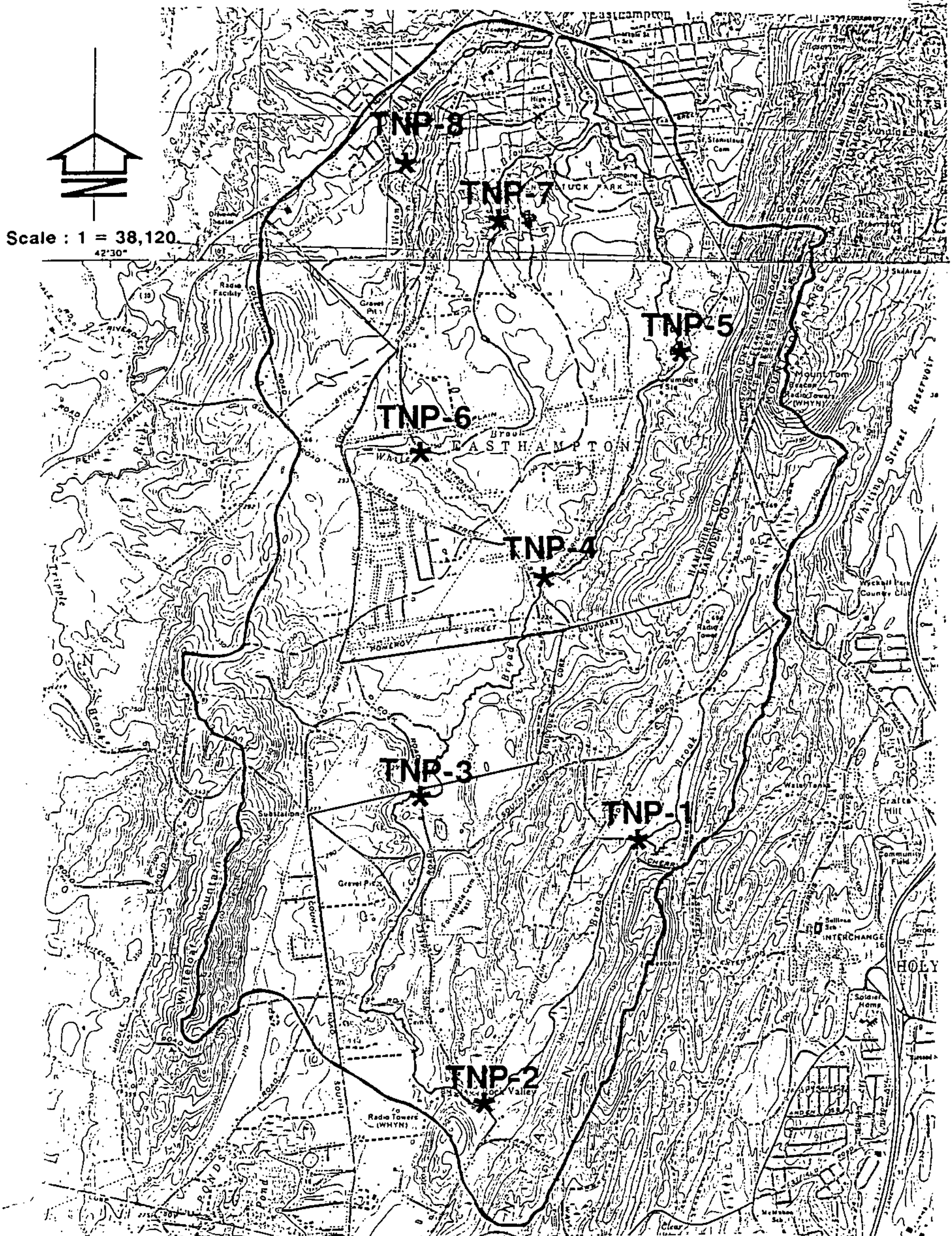
Chloride was measured in the Nashawannuck Pond system. The tributaries had annual means of about 21 mg/l; and the pond was slightly lower at between 18 to 19 mg/l. This is below the level expected under non-urbanized conditions (e.g., 25 mg/l). There is no real problem with chloride in these waters, but the influence of roadsalting is discernible in the elevated winter values.

Supplemental Water Quality Sampling

Routine water quality sampling was supplemented by sampling of the three main tributaries of Nashawannuck Pond. A watershed investigation and water quality sampling survey was conducted on July 22, 1987. The sampling sites are shown in Figure 9. Five sites were sampled along Broad Brook (TNP 1-5); two sites along White Brook (TNP 6-7) and one on Wilton Brook (TNP-8). Data from these samples are shown in Table 3. The sequence of sampling was upstream to downstream, hence TNP-1 is the uppermost station on Broad Brook.

The TNP-1 site was located in Holyoke off Cherry St. Extension just below a concrete dam. This stagnant (flow was

Figure 9. Tributary Sampling Sites in the Nashawannuck Pond Watershed.



Modified from Easthampton (1979) and Mount Tom (1972) U.S.G.S. quadrangle maps.

Table 3. Water Quality Data from Tributary Sampling.

TRIBUTARY SAMPLES IN THE NASHAWANNUCK POND SYSTEM 07/22/87

SAMPLE CODE* PARAMETER	TNP-1	TNP-2	TNP-3	TNP-4	TNP-5	TNP-6	TNP-7	TNP-8
PH (S.U.)	7.3	7.1	7.2	7.3	7.2	DRY	7.1	7.0
COND. (UMHOS/CM)	115	142	152	151	152		225	130
DISS. O2 (MG/L)	10.6	7.5	7.0	10.9	8.1		8.1	8.4
TEMPERATURE (C)	20.0	8.5	8.5	12.0	10.9		11.2	9.5
FLOW (CU.M/MIN)	.17	.68	1.41	1.67	3.91	0.00	.17	.66
FLOW (CFS)	.10	.40	.83	.98	2.30		.10	.39
TURBIDITY (NTU)	1.2	1.0	.4	.8	.8		2.5	3.4
TOT. ALK. (MG/L)	40	52	53	51	49		60	35
TSS (MG/L)	.4	.8	4.4	1.2	.4		2.4	.4
NH3-N (MG/L)	.05	.01	.01	.01	.01		.05	.04
NO3-N (MG/L)	.02	.63	.81	.96	1.10		4.90	.79
CHLORIDE (MG/L)	17	16	15	16	16		36	18
ORTHO-P (UG/L)	34	26	10	13	13		30	22
TOT-P (UG/L)	65	52	37	45	22		69	56
TKN (MG/L)	.85	.38	.33	.35	.37		.43	.39
F. COLI (N/100 ML)	200	64	300	400	200		1000	500
F. STRP (N/100 ML)	7	1000	600	700	600		1300	2000

* TNP-1 CHERRY STREET
TNP-2 ROCK VALLEY ROAD
TNP-3 COOK ROAD
TNP-4 WONDERLICH ROAD
TNP-5 HENDRICK ROAD
TNP-6 STRONG ROAD
TNP-7 WHITE BROOK; MIDDLE SCHOOL
TNP-8 SOUTH STREET

largely leakage from dam) impoundment was clearly eutrophic with blue-green algal blooms, duckweed, cattail and purple loosestrife. Upstream land use includes considerable agricultural and animal husbandry (Figure 5). Illegal dumping of old car tires was common in the stream valley below the dam. The next station (TNP-2) was established on Broad Brook at the Rock Valley Rd. crossing, the southernmost portion of the watershed. At this point, the stream corridor was well canopied and the bottom substrate rock and shale. Flow here was about 0.7 cu. m/min. and the water temperature was considerably cooler than at the impoundment.

The next tributary sampling site (TNP-3) was in the town of Southampton at the Cook Rd. crossing of an unnamed tributary from Whiteloaf Mountain (Figure 9). This was just downstream of a marshy wetland, bordered by agricultural lands. The amount of flow was measured at 1.4 cu. m/min. Continuing downstream on Broad Brook into the town of Easthampton, a sampling was made off Wonderlich Rd. This was made below a 6' bridge culvert, at a rocky sluiceway that goes into a small holding pond in a residential area.. The flow was about 1.7 cu. m/min. and the water appeared clear.

The final sampling station on Broad Brook was made off Hendrick Street at a bridge culvert (TNP-5), just below the pumping station. At this point the U-shaped stream bottom is gravelly with pockets of accumulated silt and sand. There is a forest and shrub wetland bordering the stream. The flow at this point was 3.9 cu. m/min. The reduced temperature and oxygen levels suggest that considerable groundwater enters the stream between TNP-4 and TNP-5, as it skirts the base of the Holyoke Range.

The water chemistry of Broad Brook changed over the upstream to downstream sequence. Going downstream, the following parameters increased: specific conductance, flow, and nitrate-nitrogen. In contrast , ammonia and phosphorus fractions decreased. Total alkalinity, pH, chloride, total kjeldahl-nitrogen and fecal bacteria were relatively uniform throughout the Broad Brook system. These results suggest that land use impacts Broad Brook at its headwaters and nearer the pond, but with some mitigation in between.

Water from the upper reaches of White (TNP-6, TNP-7) and Wilton Brook (TNP-8) were also sampled. The White Brook watershed south of Plain Street (Figure 5) has been altered through residential development there. The stream channel at the Strong St. crossing had no observable flow. Water was flowing (0.17 cu. m/min) near the access roads for the White Brook Middle School. Analyses of this water indicated very high nitrate and elevated phosphorus levels, high conductivity and high chloride levels. It should be noted that there are some active agricultural fields immediately upstream of this site.

Water from upper Wilton Brook was of slightly better quality than White Brook. This site (TNP-8) was located just upstream from a small pond with a flow of 0.66 cu. m/min. In general, water from the lowermost site on all three tributaries correlated very well to the averages found at the regular tributary sampling sites (i.e., NP-1:TNP-5; NP-2:TNP-7; NP-3:TNP-8).

Bacteria

Fecal coliform (FC) and fecal streptococci (FS) were assessed during this study (Table 2). 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 may be accompanied by pathogens, they are considered indicators of potential health hazard if present in substantial numbers. The FC values obtained for the pond during this study were usually below the Massachusetts standards for contact recreation, which are 200/100ml for multiple geometric means and 400/100 ml for single samples (or 10% of monthly samples). Still, all of the stations (except NP-4s) experienced at least one occasion of fecal counts greater that 400/100 ml. On an annual basis, the geometric means of in-pond stations were 14 and 23/100 ml. The tributaries were higher at 81-197/100 ml, with Broad Brook having the fewest counts.

Values for fecal streptococci were much higher than coliform counts, but there are no bathing standards for streptococci. Geometric means in the pond were 821 and 965/100 ml; the outlet was 1109/100 ml. The tributaries were even higher, with a range from 2153 to 4675/100 ml. Potential sources of bacteria in the latter stations could be wild animals. Higher values of FS were seen throughout the year, with spring months the time of least counts.

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 Schroeder, 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 some of the routine Nashawannuck Pond data from consideration. However, the tendency towards much greater FS counts in the same sample yield the conclusion that the human septage is not responsible for the observed counts.

Phytoplankton

Phytoplankton, or microscopic algae suspended in the water column, are an important component of aquatic food webs, but may also impart detectable color, odor, and taste to pond water as well as a reduction in water clarity. Phytoplankton biomass is often approximated by measuring the concentration of chlorophyll a, a pigment used in photosynthesis. It is the same pigment that makes grass and leaves green. Chlorophyll a usually represents 0.5 to 2% of 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 concentrations in Nashawannuck Pond ranged from 0.0 to 16.6 ug/l at station NP-4S, and from 0.5 to 19.3 ug/l at station NP-2S. The mean annual values were 4.3 and 7.8 ug/l, respectively. Based on equations which relate chlorophyll a concentration to total phosphorus concentrations, expected chlorophyll a values in the pond would range from 5.2 to 27.7 ug/l, with a mean value of 9.7 ug/l (Jones and Bachmann 1976, Oglesby and Schaffner 1978). For equations and calculations see Appendix D. These predicted values are greater than those observed in Nashawannuck Pond. A possible explanation for the observed lower values is that the rapid flow through of the system does not allow for complete utilization of the available phosphorus and conversion into algal biomass. There is also competition for available phosphorus with the dense macrophyte beds.

Chlorophyll a values are often considered indicators of the trophic state of a pond. Fitting a pond or reservoir into any classification system is a subjective process with no single parameter capable of fully "defining" the trophic status of a pond. However, chlorophyll a is among the more telling parameters. The mean and range of chlorophyll a values from stations NP-4S and NP-5S correspond to a mesotrophic or moderately fertilized condition (Wetzel 1983). However further comparison of this measure to other parameters, including total phosphorus and total plant biomass, (including macrophytes) and Secchi disk transparency indicates that a eutrophic classification is more appropriate.

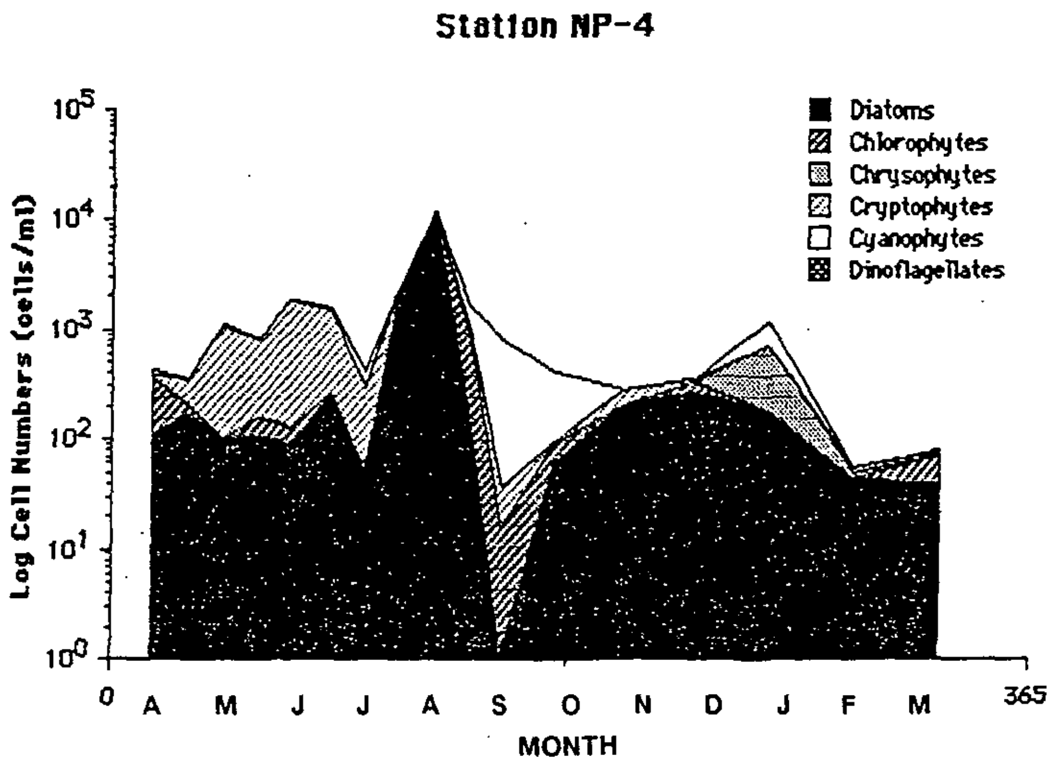
Chlorophyll and non-living suspended solids are important determinants of water clarity. Secchi disk transparency, a measure of water clarity, ranged from 1.2 to 2.5 m at NP-4S with a mean depth of 2.2 m, and 1.2 to 3.1 m at NP-5S, also with a mean of 2.2 m (Table 2). In case of NP-4S, the secchi disk usually touched the bottom sediments, preventing an accurate assessment of water clarity. As with chlorophyll a levels, these values were compared against predictive equations (see Appendix D). The predicted mean value for transparency, based on the observed mean chlorophyll values, was 3.7 m (Oglesby and Schaffner 1978, Vollenweider 1982). The nearness of the bottom probably prevented the full transparency from being accurately measured at NP-4. At NP-5, however, the bottom was never reached, and the lower than expected turbidity may be due to suspended silt and storm drainage runoff.

The nature of the phytoplankton community varied with time over the course of the study year and included members from six major algal divisions. The seasonal patterns of abundance as cell numbers is shown in Figure 10. The seasonal patterns and amount of algal biomass is shown in Figure 11. The actual algal species and biomass enumeration data is included in Appendix D.

The most numerous taxa were diatoms (Bacillariophyceae), cryptophytes (Cryptophyceae), green algae (Chlorophyceae), blue-green algae (Cyanophyta), and golden-brown algae (Chrysophyceae). Dinoflagellates (Pyrrophyta) were present, but only seasonally significant. The seasonal progression of dominants was diatoms and cryptophytes (spring to early summer), diatoms and blue-green algae (summer through fall), diatoms and chrysophytes (late fall) and flagellated forms during ice-cover. This pattern is somewhat dissimilar to many temperate ponds, due to the persistence of the diatom importance through the summer (Wetzel, 1983; Reynolds, 1980). However, the nature of the phytoplankton in any specific pond reflects the response of the plankton community to changing physical, chemical, and biotic factors which may be specific to that year and that waterbody. Some of the more numerous algal genera were: diatoms, Fragilaria, and Asterionella; chrysophytes, Chromulina; cryptophytes, Cryptomonas; chlorophytes, Scenedesmus, Eudorina; and the cyanophytes, Anabaena and Chroococcus.

Overall, the phytoplankton community structure and abundance are representative of a mesotrophic system. The limiting factors in Nashawannuck Pond are likely to be nutrients (phosphorus, during most times of the year) or rapid flushing and, secondarily, light (ice-cover in winter and turbidity in summer). Grazing by zooplankton may also subtly influence algal community structure through size-selective grazing.

Figure 10. Nashawannuck Pond Phytoplankton - Cell Numbers.



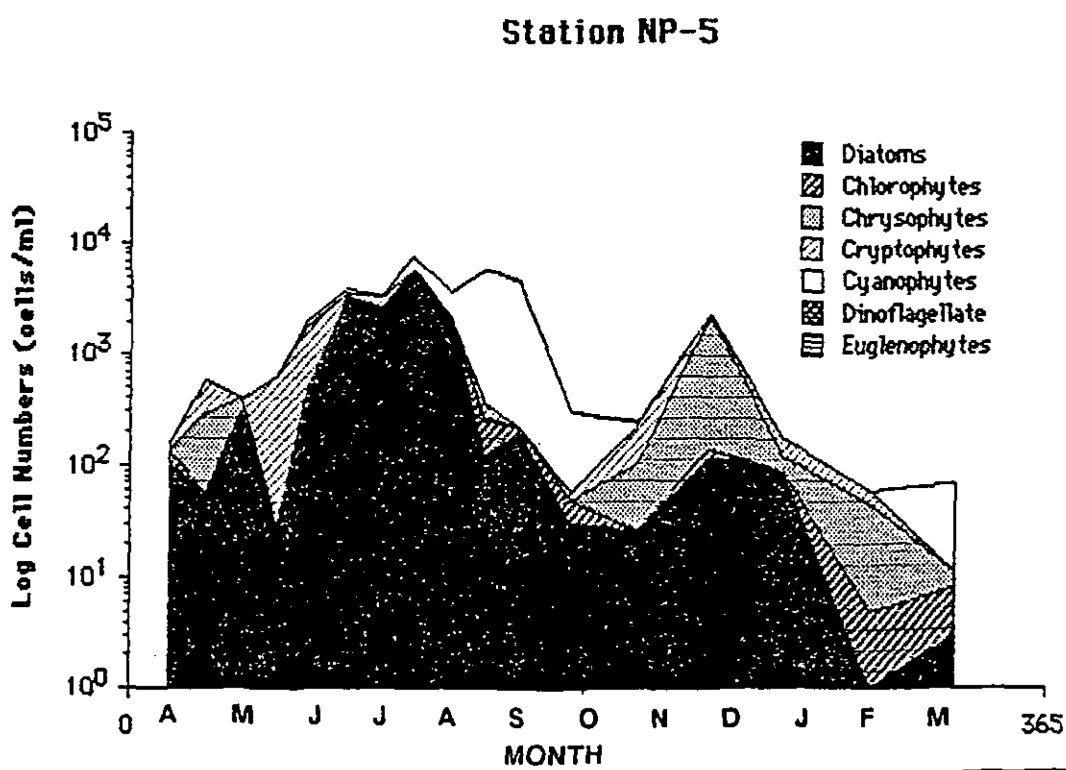
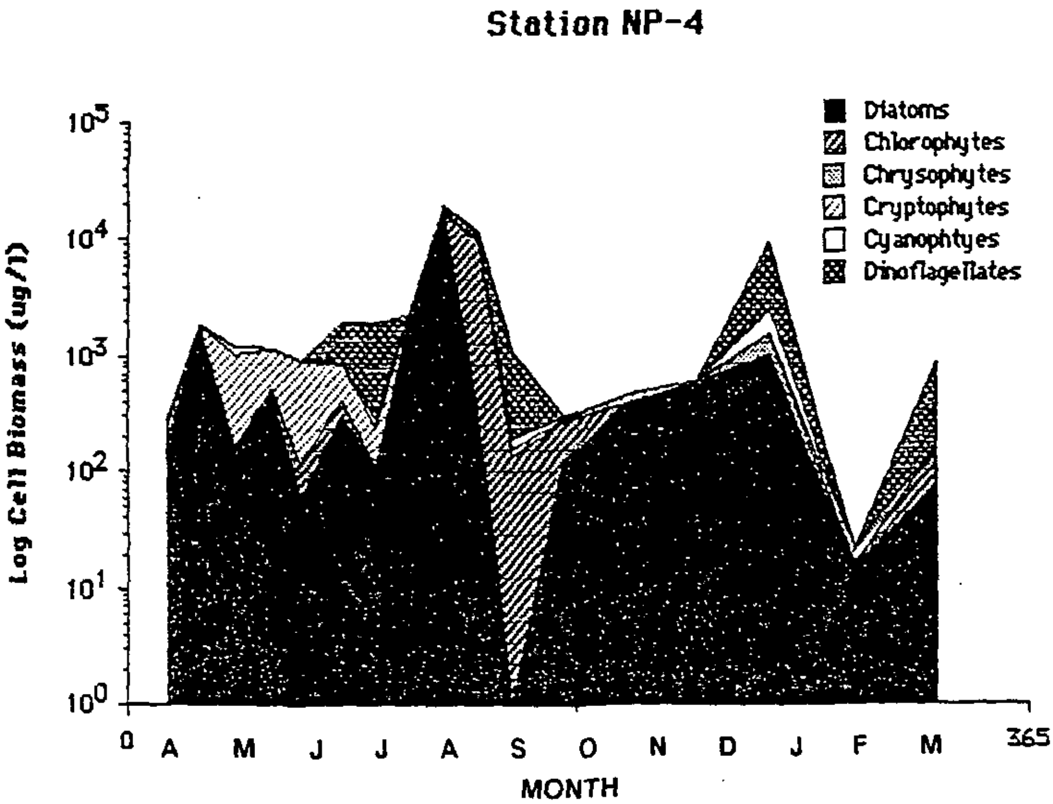
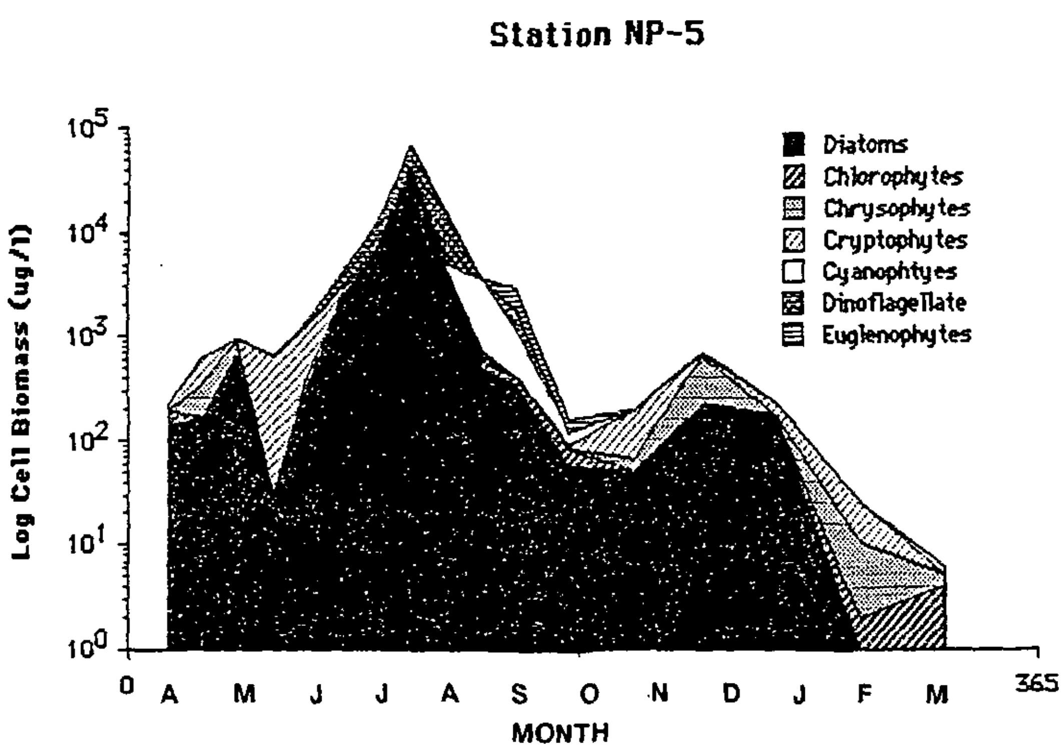


Figure 11. Nashawannuck Pond Phytoplankton - Cell Biomass.





Macrophytes

An extensive in-pond macrophyte (aquatic plant) survey was conducted on August 20, 1987. A team from BEC inspected the pond bottom from boat and limited SCUBA diving in the deepest sections. Macrophytes were identified and the density of their concentration was mapped.

The taxanomic composition of the macrophytes of Nashawannuck Pond is shown in Figure 12. A total of 20 submerged and wetland genera, along with unidentified aquatic grasses, were found in or on the shoreline of Nashawannuck Pond, or the wetlands associated with them. Identification was according to Fassett (1957). The in-pond macrophyte composition was dominated by two species, waterweed (Elodea canadensis) and coontail (Ceratophyllum demersum). A list of plant species found in the emergent wetlands at the base of each arm of the pond is also given in Figure 12.

The density of these plants is indicated in Figure 13. Macrophyte density was generally 75-100% coverage in the lower portions of the pond. Exceptions to this pattern were at the southern end of the Broad Brook arm and near the confluence of the White Brook arm with the rest of the lake. In the upper part of the pond, plant density begins to thin out as the depth increases past about 3m (10 ft). Near the dam, there were localized heavy macrophyte densities along the western littoral areas, but little plant life at the bottom of the basin.

Wetland species were confined to the general outline of the Nashawannuck Pond high water mark along the length of the lake. At the base of the two arms, there are two contiguous wetlands already noted (Figure 13). The wetland at the base of Broad Brook (#1) is the more complex and species-rich of the two, and would be expected to provide better animal habitat.

Zooplankton

Zooplankton are of interest because they represent the linkage between the bottom of the food base and higher trophic levels, namely planktiverous fish. Zooplankton were sampled twice during the year, at periods corresponding to spring (April) and fall (September). Examination of these surveys show that the zooplankton community of Nashawannuck Pond includes primarily copepods and cladocerans at low densities (see Appendix). The copepod genus Diaptomus was greatest in number and biomass. The cladoceran community included Bosmina, Ceriodaphnia, and Chydorus.

Figure 12. Distribution of Aquatic Macrophytes in Nashawannuck Pond.

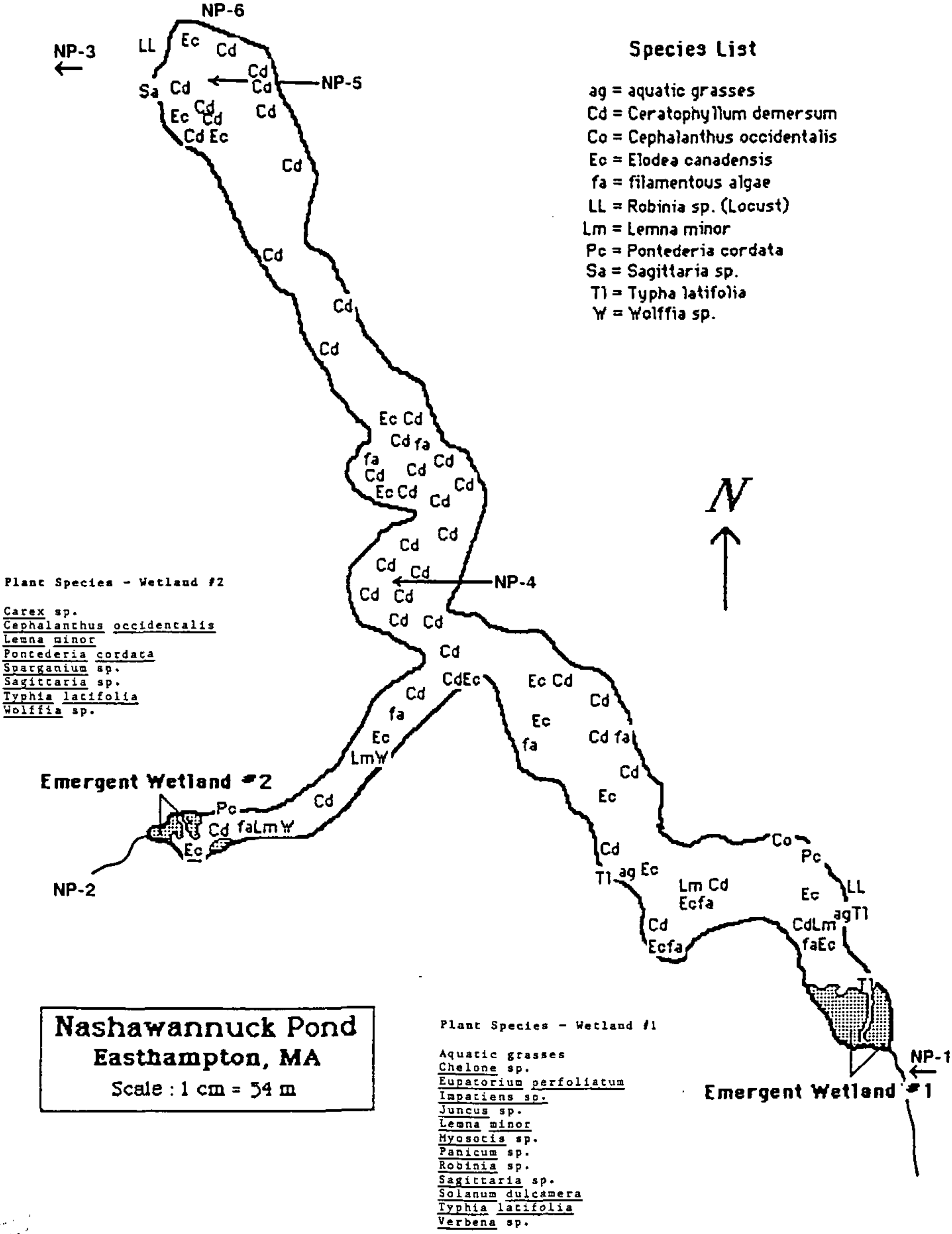
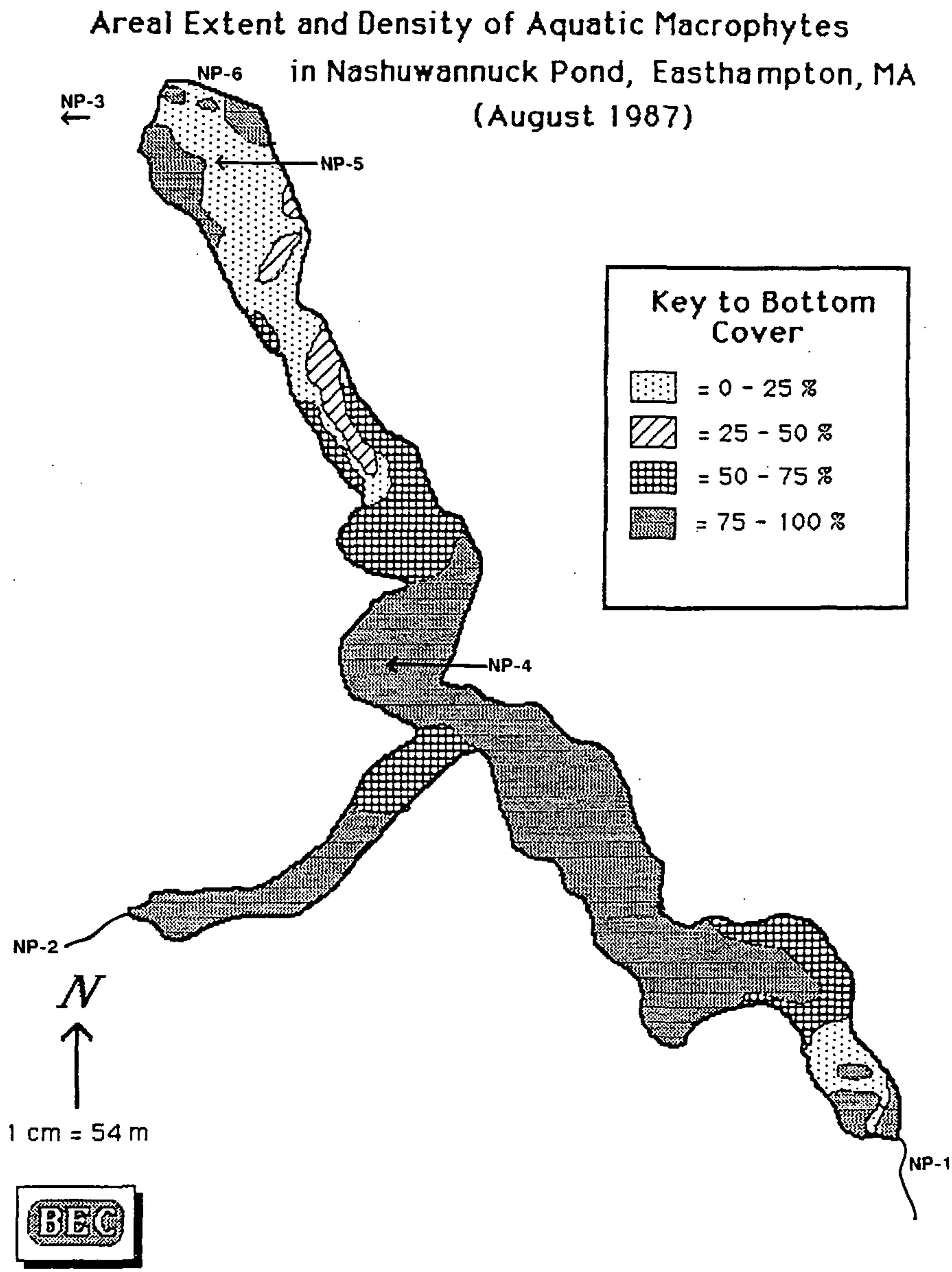


Figure 13. Benthic Cover by Aquatic Macrophytes in Nashawannuck Pond.



There is a slight increase in biomass from spring (7.2 ug/l) to fall (11.5 ug/l). The mean size is increased from 0.35 to 0.51 mm. Baystate's overall impression is that of a stunted zooplankton community that is impacted heavily by fish predation (Mills et al.,1987). This leads to the conclusion that the size of the zooplankton community is limited by fish grazing.

Macroinvertebrates

The invertebrates of Nashawannuck Pond were qualitatively sampled by dip net and visual observation. A number of surface dwelling insects were found including water striders (Gerridae) and velvet bugs (Mesoveliidae). Insects in the macrophytes included dragonfly nymphs (Anax, Libelludid), damselfly nymphs (Coenagrionidae), and mayflies (Baetidae, Ephemerellidae). Other invertebrate inhabitants included amphipods (Gammaridae), isopods, snails (Planorbidae), leeches (Erpobdellidae), oligachaetes (Oligochaeta) and crayfish (Cambaridae).

Fish

Records of the Massachusetts Division of Fisheries and Wildlife (MDFW) on Nashawannuck Pond go back to 1912. Fish mentioned in that report include bullheads, perch, pickerel and German carp (Cyprinus carpio). The presence of the carp was considered discouraging to stocking efforts (MDFW, 1912). Stocking and sampling reports of fish during the next 15 years include mention of smallmouth bass (Micropterus dolomieui, walleye (Stizostedion vitreum), yellow perch (Perca flavescens), largemouth bass (Micropterus salmoides), smelt (Osmerus mordax), brown bullhead (Ictalurus nebulosa), yellow bullhead (Ictalurus natalis), white perch (Morone americana), black crappie (Pomoxis nigromaculatus), longear sunfish (Lepomis megalotis) chain pickerel (Esox niger), and american eel (Anguilla rostrata).

Sampling was conducted again in July 1952, when the species list included: pumpkinseed (Lepomis gibbosus), chain pickerel, black bullhead, golden shiner (Notemigonus crysoleucus), black crappie and white sucker (Catostomus commersoni). Carp were seen, but not caught. The panfish and weedfish were found to be 96% of the combined sample weight (MDFW, 1956). The intense competition for food among the fish population was thought to be the chief limiting factor. The pond was recommended to be reclaimed by rotenone, with stocking for brown trout (Salmo trutta).

Chemical eradication was considered after replacement of the dam that was destroyed in August 1955. The chief consideration for not following through with this plan was the inability to

Table 4. Results of BEC Fish Survey in Nashawannuck Pond.

NASHAWANNUCK POND FISH SURVEY RESULTS

FISH SPECIES	COMMON NAME	# CAUGHT	% OF TOTAL #	MEAN LENGTH (MM)	GROWTH RATE
Salmo gairdneri	Rainbow Trout	2	5.7	285	(stocked)
Cyprinus carpio	Carp	1	2.8	620	--
Micropterus salmoides	Largemouth Bass	3	8.6	204	Avg.*
Pomoxis nigromaculatus	Black Crapple	3	8.6	193	Avg.*
Notemigonus crysoleucas	Golden Shiner	2	5.7	183	--
Catostomus commersoni	White Sucker	24	68.6	405	--
TOTAL	6 SPECIES	35	100		

Also known to be in the pond but not detected in this survey:

Chain Pickerel (Esox niger), Yellow Perch (Perca flavescens), Pumpkinseeds (Lepomis gibbosus), Bluegills (Lepomis macrochirus), Longear Sunfish (Lepomis megalotis), and Brown Bullheads (Ictalurus nebulosus).

* Average rating based on suggested mean growth rates (MDFW, 1984).

-- Mean growth rates not determined for non-game fish.

contain the effects of the rotenone due to the need to pass some water through the "mill" (unidentified) below the dam (MDFW, 1958). The Division of Fish and Wildlife stocked several thousand brook trout (Salvelinus fontinalis) in spring of 1959.

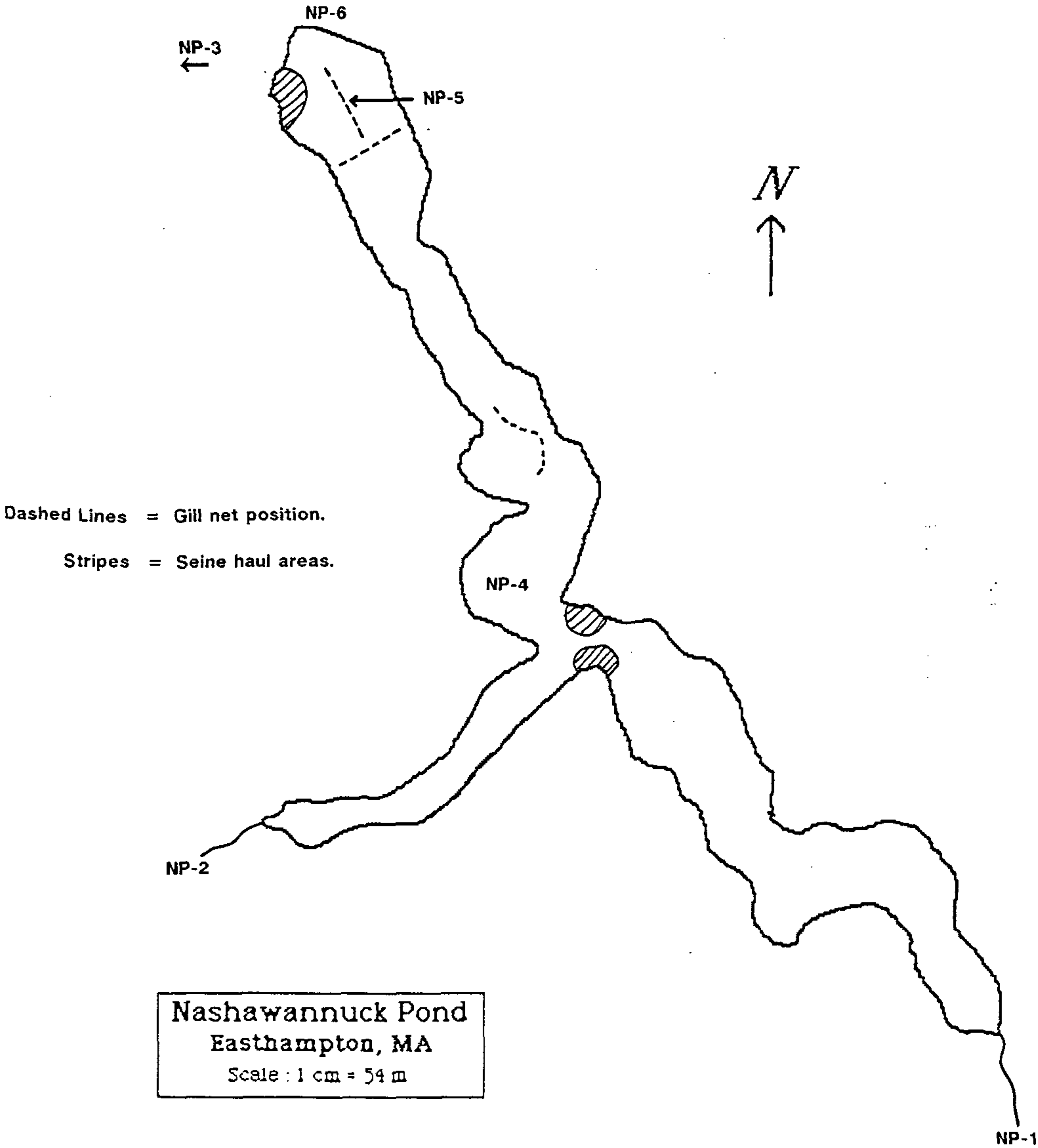
The fish population was most recently sampled by the MDFW in June 1979 using electrofishing and experimental gillnets. Of the 179 fish collected, twelve species were represented : largemouth bass, chain pickerel, yellow perch, white perch, bluegill (Lepomis macrochirus), pumpkinseed, brown bullheads, white sucker, golden shiner, black crappie, longear sunfish, and rainbow trout (Oncorhynchus mykiss).

Analysis of the gamefish sampled indicated that the bass had less than average growth for the young age classes and above average growth rates thereafter (MDFW, 1980). Chain pickerel had below average growth and condition factors. Pumpkinseed and bluegill had average growth rates but poor condition factors. Recommendations in the 1980 report include protective length limits for both largemouth bass and chain pickerel and stocking of 2,500 trout each year. The introduction of catfish was suggested.

BEC conducted a fishery survey on October 16, 1987. This consisted of setting three 100′ gill nets and hauling three shoreline seines. The location of these nets and hauls is shown on Figure 14. The BEC survey collected 35 fish including rainbow trout, carp, largemouth bass, black crappie, golden shiner, and white sucker. The numbers and average size of these specimens is shown on Table 4. The dominant species in terms of numbers and biomass was the white sucker, but this is probably due to the methods used. Growth rates of largemouth bass and black crappie were considered to be average.

Observations by BEC personnel during the study year indicate that fishing is a very popular activity. Ice fishing activity was very much in evidence during winter visits. Veteran Nashawannuck Pond fishermen indicated that rainbow trout were the favored game fish during the open water season.

Throughout the year, the most popular fishing mode was shoreline fishing on the western side of Nashawannuck Pond from the cemetery down through Nonotuck Park. Usually four or five fishermen could be observed at each of the major points of land during the spring and early summer. Shoreline fishing was diminished by the growth of weeds, but was still pursued even at the height of the weed growth.


NP-6
NP-3
NP-5
N
Dashed Lines = Gill net position.
Stripes = Seine haul areas.
NP-4
NP-2
Nashawannuck Pond
Easthampton, MA
Scale : 1 cm = 54 m
NP-1

Storm Water Assessment

The quality of storm water was estimated from a series of three storm drain samplings. These were conducted on 10/21/87, 5/24/88, and 6/30/88. The locations of the storm drains are shown on Figure 15 and the results given in Table 5. An additional storm sampling was conducted on 4/28/88 and is included in Table 5. In that the case, though, the first flush was not captured and it was not used for calculation of nutrient loading. It is included to indicate water quality following "washout" of the storm drain system. In general, our analyses indicates that poor quality water enters the pond, although there were differences between specific storm drains.

The initial storm sampling was on 10/21/87, during which composite samples were taken of the flowing storm drains going into the lake. The storm rainfall was 0.17" during a two hour period. A total of eight pipes were inspected during the storm event. The southernmost storm station (NPS-1), while emerging from a 6" clay pipe, seems to be mostly seepage (or tile drainage) rather than storm runoff. Examination of the most current storm drain map from the town of Easthampton indicates no flow directed towards it. On the other hand, NPS-2 drains an extensive network of storm catch basins along Route 141 (Holyoke St.) and Fairfield Ave., terminating in a concrete and stone headwall with a 18" concrete pipe. Some of the drainage on Holyoke St., north of Fairfield Ave. is actually directed into the Gaugh St. system, not as indicated on the town plans, In addition, drain NPS-3, off Water Lane, is not shown on the town map. This is a 12" corrugated metal pipe that seems to serve about four catch basins in the vicinity of Water St. and Water Lane.

Flow from Gaugh Street goes into NPS-4, a 12" PVC pipe that includes flow from Holyoke St. The NPS-4 system underwent repair and pipe reinstallation in early 1987. The storm drainage system to the north, on Orchard and Pine Streets does not flow into Nashawannuck Pond as indicated by the town map. A pipe connection exists to the pond, but BEC personnel discovered that no flow was getting through. The pipe itself appears clogged with debris. Where this water goes is not certain, but it is possible that flow is going into the lake via exfiltration. If the catch basins were overloaded it is possible that it would be routed into the NPS-4 drain.

Two other pipes entering the pond (NPS-5 and NPS-8) did not have flow under storm conditions on 10/21/87. Drain NPS-5 serves a single parking lot at the rear of some shops on Cottage St. and did have flow during the 5/24/88 storm. Drain NPS-8, near the northern end of Brookside Cemetery appeared collapsed. This may or may not ever have been a storm drain, as it may have been

Figure 15. Location of Storm Drains sampled on 10/21/87.

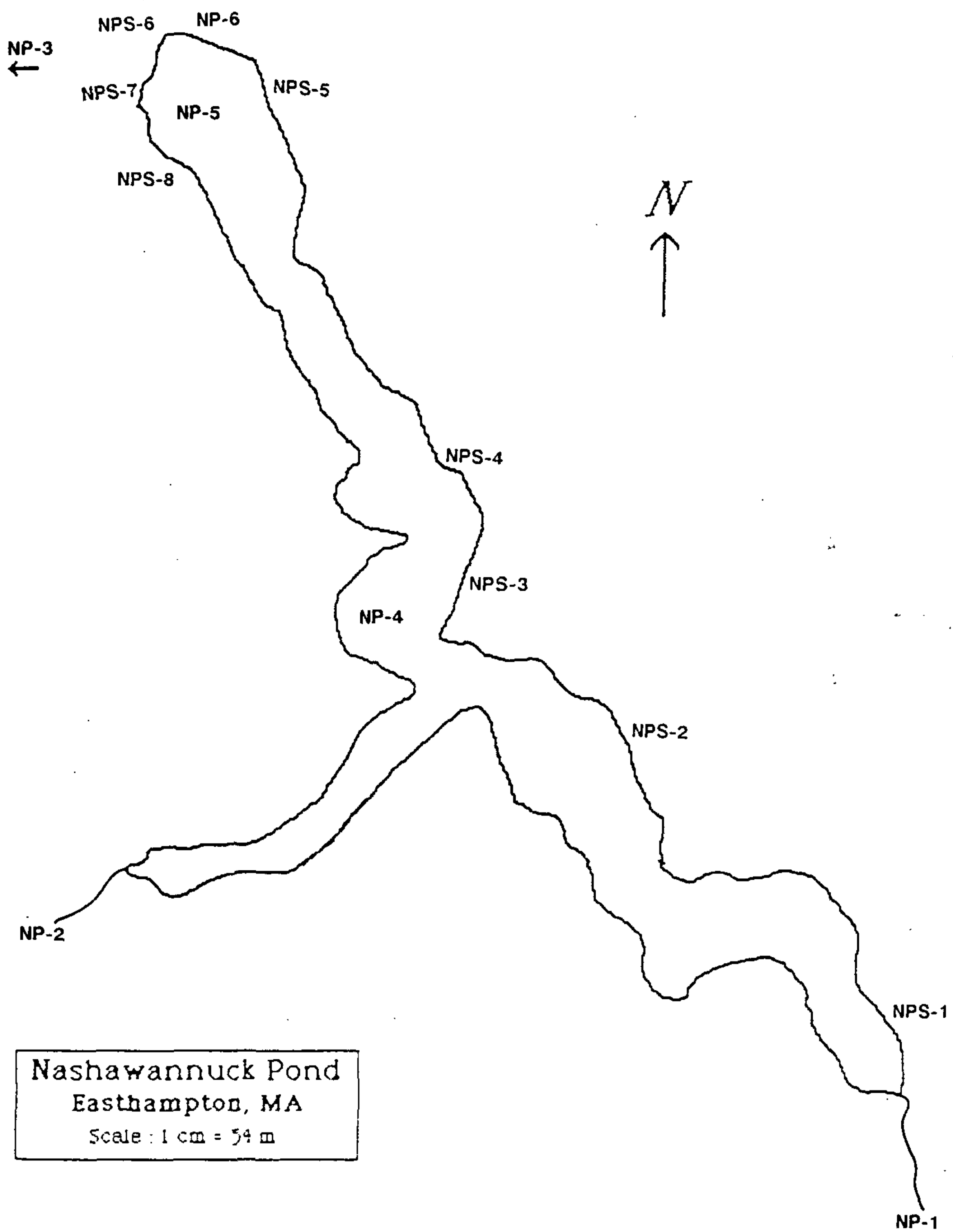


Table 5. Stormwater Water Quality Data.

NASHAWANNUCK POND STORM DATA 10/21/87 : COMPOSITE SAMPLES.

PARAMETER	UNITS	NPS-1	NPS-2	NPS-3	NPS-4	NPS-6	NPS-7
TALK	(mg/l)	12.4	4.4	10.2	5.6	23.1	1.7
TSS	(mg/l)	.4	12.8	79.2	25.0	407.8	11.0
AMM-N	(mg/l)	.1	.1	.1	.1	.1	.1
NITRATE-N	(mg/l)	2.30	.86	.12	1.00	.26	1.70
CHLORIDE	(mg/l)	40.1	11.8	13.5	8.4	12.8	12.2
ORTHO-P	(ug/l)	10	90	480	160	30	20
TOTAL P	(ug/l)	140	550	600	810	350	260
KNITRO	(mg/l)	.1	2.1	3.0	2.2	5.6	1.1
FEC.COLI	(#/100ml)	360	60000	100000	100000	5000	60000
FEC.STREP	(#/100ml)	100000	100000	60000	60000	100000	100000
COND	(umhos/cm)	225	102	123	109	158	110
FLOW	(cu.m/min)	.17	.46	.10	.16	.17	.16
TURB	(NTU)	2	22	12	21	82	18
Cd	(mg/l)	.02	.02	.02	.02	.02	.02
Cr	(mg/l)	.02	.02	.02	.02	.02	.02
Cu	(mg/l)	.02	.06	.05	.04	.09	.14
Fe	(mg/l)	.16	1.78	1.11	1.16	12.30	.81
Pb	(mg/l)	.10	.10	.20	.10	.22	.10
Mn	(mg/l)	.02	.15	.22	.17	.53	.09
Zn	(mg/l)	.02	.18	.19	.19	.44	.11
OIL & GREASE	(mg/l)	.2	2.4	12.4	2.2	7.0	2.6

NASHAWANNUCK POND STORM DATA 04/28/88 : COMPOSITE SAMPLES.

PARAMETER	UNITS	NPS-2	NPS-4
TALK	(mg/l)	3.0	1.0
TSS	(mg/l)	23.0	45.0
AMM-N	(mg/l)	.08	.12
NITRATE-N	(mg/l)	.07	.14
CHLORIDE	(mg/l)	3.1	3.1
ORTHO-P	(ug/l)	70	100
TOTAL P	(ug/l)	100	140
KNITRO	(mg/l)	1.2	1.7
FEC.COLI	(#/100ml)	210	250
FEC.STREP	(#/100ml)	4000	2000
COND	(umhos/cm)	18	14
FLOW	(cu.m/min)	.95	.42
TURB	(NTU)	29	35

Table 5. Stormwater Water Quality Data (continued).

NASHAWANNUCK POND STORM DATA 05/24/88 FOR NPS-2 : TIME SERIES.

PARAMETER	UNITS	"0"	"10"	"20"	"30"	"45"	"60"	"75"	"90"	"105"	"120"
TIME		12:20	12:30	12:40	12:50	13:05	13:20	13:35	13:50	14:05	14:20
FLOW	(cu.m/min)	.3	2.5	4.9	2.5	1.0	.3	.8	3.1	1.6	.6
AMM-N	(mg/l)	.04	.05	.32	.25	.30	.26	.32	.35	.25	.22
NITRATE-N	(mg/l)	1.05	.85	1.26	1.48	1.19	1.33	1.09	1.36	.58	1.0
KNITRO	(mg/l)	.5	4.1	2.3	1.4	1.0	1.8	2.3	2.0		1.4
ORTHO-P	(ug/l)	10	657	466	305	214	169	560	260	210	185
TOTAL P	(ug/l)	24	779	540	305	350	230	600	303	250	266
PH	(S.U.)	6.0	5.7	5.4	5.5	5.6	6.2	5.5	5.4	6.2	5.6
TALK	(mg/l)	18	6	3	2	3	6	3	2	13	3
TSS	(mg/l)	1	1100	360	146	66	31	424	187	60	44
TURB	(NTU)	9.0	140.0	82.0	44.0	22.0	15.0	90.0	39.0	19.0	14.0
COND	(umhos/cm)	168	93	35	28	32	42	50	31	25	27
CHLORIDE	(mg/l)	28.0	5.0	2.5	5.0	1.8	4.3	3.2	1.1	.5	.5
FEC.COLI	(#/100ml)	10	10		10		10		10		10
FEC.STREP	(#/100ml)										
FROM COMPOSITE:											
Cd	(mg/l)	.020									
Cr	(mg/l)	.030									
Cu	(mg/l)	.020									
Fe	(mg/l)	.97									
Pb	(mg/l)	.100									
Mn	(mg/l)	.040									
Zn	(mg/l)	.040									
OIL & GREASE	(mg/l)	.33									

NASHAWANNUCK POND STORM DATA 05/24/88 FOR NPS-4 : TIME SERIES.

PARAMETER	UNITS	"0"	"10"	"20"	"30"	"45"	"60"	"75"	"90"	"105"	"120"
TIME		12:15	12:25	12:35	12:45	13:00	13:15	13:30	13:45	14:00	14:15
FLOW	(cu.m/min)	.1	.3	1.4	.9	.4	.2	.2	.6	.4	.3
AMM-N	(mg/l)	.56	.19	.47	.28	.05	.32	.16	.24	.19	.05
NITRATE-N	(mg/l)	6.00	1.77	.65	.44	.60	.81	.77	.31	.22	.23
KNITRO	(mg/l)	.2	4.5	5.4	3.2	3.4	1.8	1.4	3.2		2.2
ORTHO-P	(ug/l)	10	226	921	552	259	205	150	388	240	248
TOTAL P	(ug/l)	27	660	1100	754	515	310	280	647	400	374
PH	(S.U.)	6.3	5.5	5.7	5.5	5.5	5.4	5.5	5.5	5.4	5.4
TALK	(mg/l)	10	6	6	6	4	4	4	4	3	4
TSS	(mg/l)	2	314	622	448	138	68	34	206	80	64
TURB	(NTU)	2.0	85.0	140.0	114.0	36.0	23.0	15.0	49.0	17.0	27.0
COND	(umhos/cm)	180	97	57	54	41	50	44	32	30	35
CHLORIDE	(mg/l)	30.0	9.4	3.2	6.9	2.5	6.9	3.2	.5	.7	2.5
FEC.COLI	(#/100ml)	10	10		10		10		10		10
FEC.STREP	(#/100ml)										
FROM COMPOSITE:											
Cd	(mg/l)	.020									
Cr	(mg/l)	.030									
Cu	(mg/l)	.020									
Fe	(mg/l)	2.21									
Pb	(mg/l)	.100									
Mn	(mg/l)	.070									
Zn	(mg/l)	.070									
OIL & GREASE	(mg/l)	.37									

Table 5. Stormwater Water Quality Data (continued).

NASHAWANNUCK POND STORM DATA 06/30/88 FOR NPS-2 : TIME SERIES.

PARAMETER	UNITS	"0"	"10"	"20"	"30"	"45"	"60"	"75"	"90"	"105"	"120"
TIME		14:30	14:40	14:50	15:00	15:15	15:30	15:45	16:00	16:15	16:30
FLOW	(cu.m/min)	2.6	2.6	3.1	3.4	3.2	2.6	1.7	1.5	1.2	.9
AMM-N	(mg/l)	.04	.05	.04	.05	.04	.06	.07	.09	.05	.04
NITRATE-N	(mg/l)	.07	.02	.02	.04	.01	.04	.04	.01	.04	.04
KNITRO	(mg/l)	1.5	1.5	6.5	4.5	3.0	2.0	2.0	1.5	1.5	1.5
ORTHO-P	(ug/l)	80	80	520	230	190	130	110	100	80	70
TOTAL P	(ug/l)	130	130	780	480	280	200	150	100	130	160
PH	(S.U.)	7.7	7.3	6.9	7.0	7.1	7.2	7.2	7.3	7.3	7.3
TALK	(mg/l)	28	24	23	20	22	26	28	29	30	26
TSS	(mg/l)	28	82	386	68	280	164	120	136	120	164
TURB	(NTU)	16.0	26.0	40.0	45.0	48.0	23.0	18.0	20.0	26.0	30.0
COND	(umhos/cm)	117	123	137	140	110	122	150	146	119	110
CHLORIDE	(mg/l)	25.5	14.3	15.3	11.7	10.7	15.3	19.4	20.4	21.9	22.5
FEC.COLI	(#/100ml)	250			5000		8000		100		200
FEC.STREP	(#/100ml)	5200			32000		22000		21000		17000

FROM COMPOSITE:		
Cd	(mg/l)	0.0
Cr	(mg/l)	0.0
Cu	(mg/l)	0.0
Fe	(mg/l)	0.0
Pb	(mg/l)	0.0
Mn	(mg/l)	0.0
Zn	(mg/l)	0.0
OIL & GREASE	(mg/l)	5.70

NASHAWANNUCK POND STORM DATA 06/30/88 FOR NPS-4 : TIME SERIES.

PARAMETER	UNITS	"0"	"10"	"20"	"30"	"45"
TIME		14:36	14:46	14:56	15:06	15:21
FLOW	(cu.m/min)	1.4	.9	.9	.4	.2
AMM-N	(mg/l)	.03	.04	.06	.09	.06
NITRATE-N	(mg/l)	.02	.03	.02	.03	.03
KNITRO	(mg/l)	4.5	2.0	2.0	4.0	4.0
ORTHO-P	(ug/l)	280	130	130	220	190
TOTAL P	(ug/l)	520	200	190	390	380
PH	(S.U.)	7.1	7.1	7.0	6.9	6.9
TALK	(mg/l)	16	18	14	12	15
TSS	(mg/l)	74	80	164	204	198
TURB	(NTU)	26.0	30.0	38.0	25.0	20.0
COND	(umhos/cm)	234	200	190	186	100
CHLORIDE	(mg/l)	6.1	4.6	4.1	4.1	5.1
FEC.COLI	(#/100ml)	20000			10000	
FEC.STREP	(#/100ml)	42000			146000	

FROM COMPOSITE:		
Cd	(mg/l)	0.000
Cr	(mg/l)	0.000
Cu	(mg/l)	0.000
Fe	(mg/l)	0.00
Pb	(mg/l)	0.000
Mn	(mg/l)	0.000
Zn	(mg/l)	0.000
OIL & GREASE	(mg/l)	3.60

associated with an old boathouse around that location. Neither drain is shown as receiving storm flow on the official town map.

The intersection of Union and Payson Streets, as well as a short distance up each street, drains into NPS-6 at the northwest corner of Nashawannuck Pond. This goes into a broken, 12" pipe entering at the waterline. Flow down Williston Street opposite the cemetery goes into NPS-7. This is a 15" pipe with a concrete headwall that flows onto a splash pad and overland into the pond.

Based on the flow patterns observed by BEC personnel during the October storm, the most important storm drain is NPS-2. In addition to the heavy storm flows, this drain flows during non-storm periods as well, presumably due to infiltration . The drains NPS-1, NPS-4, NPS-6 and NPS-7 all had about equal flow (0.16-0.17 cu. m/min.). Flow from NPS-1 was considered to be derived from outside the storm drain system and was thus dismissed from further consideration. The water from NPS-3 had a high oil and grease content, which seems linked to on-street parking and accompanying automobile maintenance. This was also evident in the contents of NPS-6, which also had the highest total suspended solids.

Storm water from the drains was very high in phosphorus, nitrates, suspended solids and organic nitrogen. The fecal coliform and streptococci values were all very high, as can be expected from flushing storm drains. Analyses for heavy metals indicated high values of cadmium, chromium, iron, lead and manganese. Two storm drains (NPS-2, NPS-4) were selected for further sampling. These two were selected in consultation with the state, based on nutrient loads, flow and location in consideration of potential restoration.

As noted above, a second storm sampling was conducted on 4/28/88 during an intense storm (Table 5). However the first flush was not captured and the sampling considered inadequate for assessment of the nutrient load imposed on the lake. A composite sample was assembled and analyzed, for information about the steady-state nutrient load under a long duration storm. Note the relatively low chloride and conductivity, indicating that the system was experiencing "washout" of materials and passing mostly rainwater.

A full scale time series sampling of NPS-2 and NPS-4 was conducted on 5/24/88. This storm passed a total of 0.44" during a two hour period, split nearly equally between two periods (12:15 - 13:05; 13:30 - 14:05). Consequently, the impact of the the "first flush" is seen twice at "10-20" minutes and "90" minutes in both drains. The total phosphorus content rose from 24 to 779 ug/l in 10 minutes for NPS-2, and 27 to 1100 in 20 minutes for NPS-4. Flow was maximal at the "20" minute sample for both stations, and may represent the time of concentration for the drain system. The second flow peak was achieved only 10 minutes after the second rain began, as the catch basins were already filled. The nitrogen load was more variable between systems. Nitrate was approximately independent of time of storm at NPS-2 and decreased with time at NPS-4. Ammonia increased with time at NPS-2 and somewhat decreased over time at NPS-4. Surprisingly, the bacteria found in this sampling was relatively low at 10/100ml.

The total suspended solids are also well coordinated with the timing of the first flush. At NPS-2, the water goes from 1 mg/l to 1100 mg/l in ten minutes, indicating transport of great amounts of particulate matter very rapidly in a storm event. This is also true for NPS-4 which went from 2 mg/l to 314 mg/l in ten minutes. The rapidity of this response, as well as the nutrients, indicates that the catch basins are probably not cleaned regularly and are filled with debris that is quickly transported into the pond. Inspection of individual catch basins by BEC personnel confirmed this.

A second time series of sampling for NPS-2 and NPS-4 was conducted on June 30, 1988. This was an 0.17" storm event which started about 1430 and was concluded by 1500. Flow was abbreviated in NPS-4, but persisted at NPS-2 over a two hour period. Some of the same phenomena observed during the first time series was seen here, including a flushing of the system in terms of phosphorus and particulate matter. Differences between the two samplings included bacterial counts, pH, alkalinity, ammonia and nitrate nitrogen. Some of these differences stem from the intensity and duration of the storms. The first storm had more intense rainfall and the surface runoff of this rain lowered pH and alkalinity values, as well as lowering bacterial counts. It also mobilized more nitrate and ammonia, which may be due to the seasonal application of lawn fertilizers. For whatever reason, there was much less of these nitrogenous forms in the subsequent storm sampling.

The total nutrient load to the lake was calculated based on flows and concentrations of total phosphorus and total nitrogen found in the storms of 10/21/87, 5/24/88 and 6/30/88. The amounts of nutrients were flow averaged to give the total amount entering the pond during that storm event. This amount was compared to the yearly amount of precipitation (122.5 cm for the study year). The yearly amount was corrected by a factor to account for the amount of rainfall that produces no runoff. Based on the frequency of low volume storm events documented by NOAA (1987,1988), approximately 10% of the volume of rainfall falling on the Nashawannuck watershed does not make it into the storm drain system. Assuming the nutrient load during the October storm is representative, a yearly total of 17.7 kg P/yr would be expected.

Analogous calculations were made for the May and June time series, with the additional correction. As only two storm drains were sampled, the amount of nutrients going into the system was adjusted for the other unsampled drains, based on the flow patterns seen in October. Using this method, additional estimates of 24.6 and 36.4 kg P/yr were produced. These three estimates were pooled and averaged to achieve the estimate of 26.2 kg P/yr. For all calculations regarding storm flow see the Appendix.

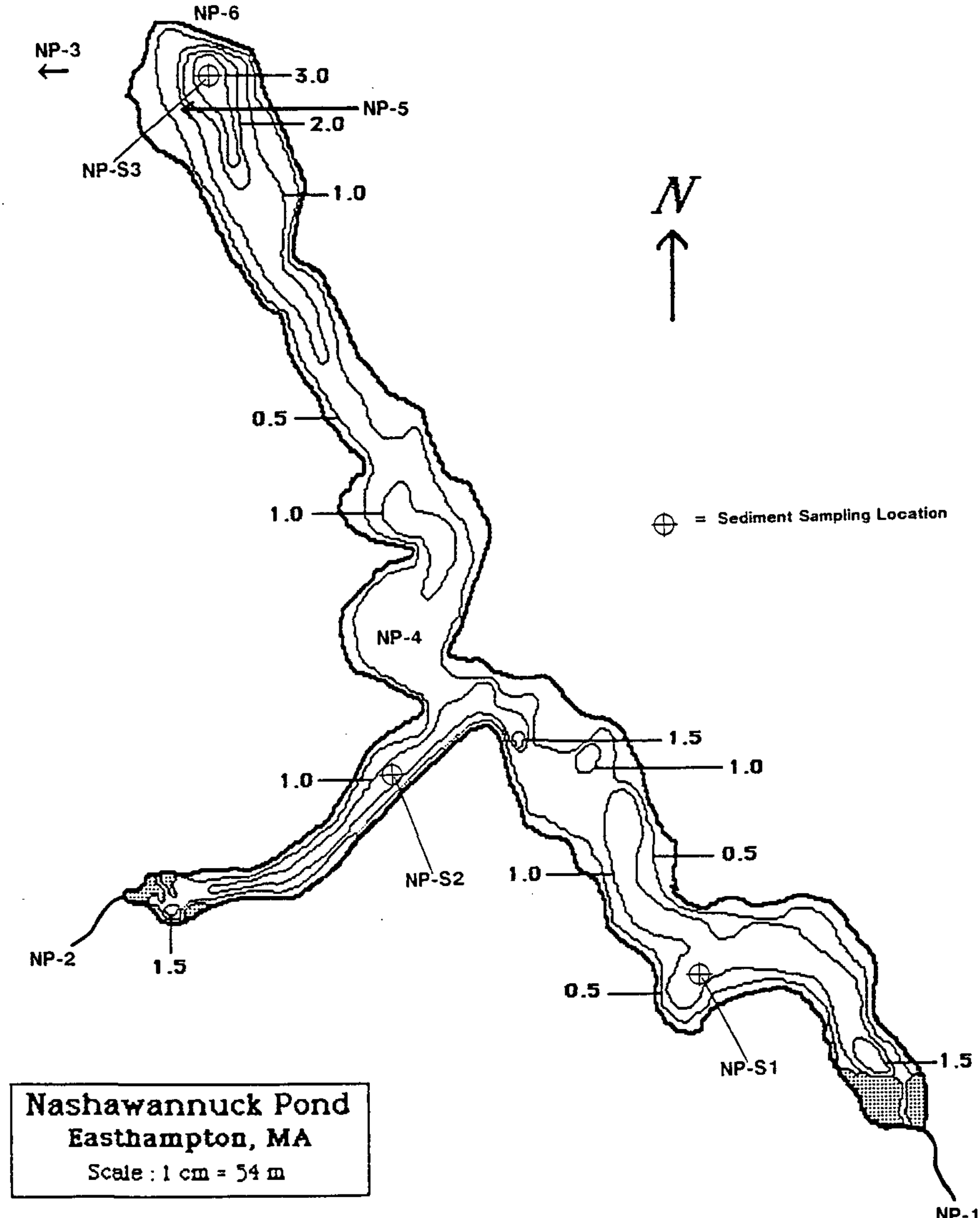
Seven heavy metals (Cd, Cr, Cu, Fe, Pb, Mn, Zn) were analyzed in the stormwater samples. Cadmium levels were less than 0.02 mg/l and chromium was less than 0.04 mg/l in all samples. Copper was at 0.15 mg/l or less and lead was at 0.10 mg/l or less. Lead content was generally below 0.20 mg/l, with one exception (0.22 mg/l). These levels exceed some of the standards or recommended limits set for Class A (public drinking) waters, but are fully consistent for the Class B water classification of Nashawannuck Pond. Other metals such as iron, manganese and zinc are not excessive for Class B receiving waters.

Sediment Analysis

The depth of the soft sediment in Nashawannuck Pond was mapped in August 1987. The sediment layer was measured by 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 16. The total amount of sediment in the pond was calculated at approximately 125,400 cu. m (164,300 CY). For calculations sheet see Appendix.

Sediment samples were taken from the pond at the three locations (positions indicated on Figure 16) via an Ekman benthic dredge. The areas sampled included both the Broad (NP-S1) and White Brook (NP-S2) arms and the deep hole near the northern end (NP-S3). The chemical characteristics of the samples are shown in Table 6. Note that zinc was inadvertently omitted from the list of heavy metals analyzed, but arsenic, nickel and vanadium were added to the list. Overall, the sediment properties were very similar between the two locations in the arms and they were better quality sediments than the outlet end. The heavy metal contents were compared to the USEPA (1977) flag limits for sediment contaminants and to the MDWPC (1979) criteria for sediments. The two arm samples (NP-S1, NP-S2) are Category One sediments under Massachusetts state criteria, while NP-S1 is classified as Type B sediment due to total volatile solids content. Sediment in the deepest basin (NP-S3) is Category Three sediments, based on lead content (>200 mg/l). Iron and manganese

Figure 16. Soft Sediment Depths in Nashawannuck Pond.



(Sediment contours given in meters).

TABLE 6

CHEMICAL CHARACTERISTICS OF NASHAWANNUCK POND SEDIMENTS.

(COLLECTED ON MAY 14, 1987)

Parameter	Value at: (mg/kg)	NP-S1	NP-S2	NP-S3
Arsenic		7.42	8.48	12.7
Cadmium		<4.84	<4.22	<5.49
Chromium		21.8	16.9	21.97
Copper		14.5	12.6	38.4
Iron		12,667	22,196	30,753
Lead		50.9	46.4	222.4
Manganese		167.1	360	318.5
Nickel		16.95	10.5	10.98
Vanadium		38.8	33.7	63.2
Nitrate-nitrogen		< 0.53	< 0.45	0.78
TKN		986	1,400	2,334
Phosphorus, Total		765	1136	2,223
Total Volatile Solids (%)		8.11	4.24	6.89
Oil and Grease		180.4	1,429	4,289

values were high and exceed USEPA flag limits for NP-S2 and NP-S3. Total Kjeldahl nitrogen and oil grease indicated that NP-S3 was moderately polluted under USEPA flag limits. Other values failed to exceed either Federal or State criteria.

The reason for the poorer quality sediments at NP-S3 is not definitively known, but the close proximity of Route 141 and the concentration of storm drainage at this location is suspect. Another contributing cause may be contaminants from adjacent Rubberthread Pond entering via the submerged connection. Industries that have discharged water with high metal content into this pond in the recent past include boiler cooling water from the J.P. Stevens plant and chemical waste from Tighe and Bond's analytical laboratories (DEQE acted on the latter early in 1988). According to fishery records, no attempt to chemically treat the pond has ever been made, other than spot poisoning with rotenone, performed during a fishery survey (MDFW, 1952).

Comparison with other studies

Nashawannuck Pond has been assessed for water quality in an informal sense by the observations and data reported in conjunction with the many Division of Fisheries and Wildlife reports (MDFW, 1912; 1952; 1958; 1980). The earliest (1912) reveals little about the condition of the pond, other than it was popular for boating and fishing. The August 1952 survey reported poor water transparency with a Secchi disk reading of 2 ft. The aquatic vegetation was reported as being scant to common, with species of Potomageton and Utricularia predominanting. Oxygen levels were greater than 5.0 mg/l throughout the water column. The 1958 report does not describe the pond, but mentions that Broad Brook was stocked with 3,000 brook trout and there was a commercial swimming pool on Wilton Brook [Note: this may be the same pool located downstream of tributary sampling station TNP-8]. The most recent fishery survey was conducted in June 1979 but did not include water quality information.

Nashawannuck Pond was surveyed by the Massachusetts Division of Water Pollution Control in August of 1978 (MDWPC, 1984). Four sampling stations were established, one each on the White and Broad Brook arms (comparable to NP-1, NP-2 in the BEC study), at the deep hole (NP-5), and at the outlet (NP-6). A temperature profile indicated that the pond was stratified at about 2 m with a Secchi disk transparency of 0.9 m (MDWPC, 1984). Oxygen decreased rapidly below 2.5 m and the bottom was anoxic. Specific conductance was fairly similar throughout at 160-170 umhos/cm. The outlet values were comparable with the in-pond surface sample.

Nitrogen values, particularly nitrate-nitrogen, were high in Broad Brook (1.0 mg/l); lower values (<0.4 mg/l) were recorded in the other tributaries and in-pond. Ammonia was fairly low throughout the whole system. Total kjeldahl nitrogen was not measured. Total phosphorus in the epilimnion was (90 ug/l) and increased with depth (the hypolimnion was 120 ug/l). This is probably due to the anoxic and reducing conditions found at the bottom. The recorded phosphorus levels indicated a well fertilized pond. It should be noted that silica was found at relatively high levels (7-11 mg/l) in the Nashawannuck Pond system.

Other chemical parameters were measured throughout the system; chloride ranged from 13 to 18 mg/l, hardness from 62 to 70 mg/l; and total alkalinity was 41 to 46 mg/l, increasing with depth. The pH values ranged from 7.0 on the bottom to 8.2 at the surface, indicating a highly productive system. Comparison of these values with the present study does not indicate any significant changes in these parameters.

The amount of chlorophyll found was 31 ug/l. The important identified phytoplankton species were Asterionella, Aphanizomenon, Chlorococcum, Mallomonas, Ceratium, and Trachelomonas (MDWPC, 1984). Fecal coliform were detected at low levels (10/100ml) in the pond, and at higher levels elsewhere.

The macrophyte survey conducted by the State identified 5 aquatic and wetland genera (MDWPC, 1984). The five genera were Elodea, Pontederia, Lemna, Cyperus, and Sagittaria. The pattern was very dense (75-100%) throughout both of the two arms and extending on both shorelines to the upper end of the pond. In the middle trough and at the deep basin, plant density decreased to sparse (0-25%).

Comparing these results with the BEC study conducted in August 1987; a greater diversity of macrophyte densities was found in the lower ends of the pond. A total of 20 species were identified in the BEC study, with general but not complete agreement with the previous survey. The important plant genera found in the BEC study were Elodea and Ceratophyllum. Differences in species dominance suggest a shift in plant composition, with coontail becoming more important. The greater number of plants found in the BEC survey is related to the greater attention given the stands of emergent wetland plants.

HYDROLOGIC BUDGET

The hydrology of Nashawannuck Pond is determined by runoff from the watershed, direct precipitation onto the lake and contributions from groundwater seepage. Losses from the lake occur through outlet flow and evaporation. The essential elements of the hydrologic budget are portrayed schematically in Figure 17. Note that there are no important consumptive withdrawals or significant outseepage.

Several different methods were used to estimate flow in the Nashawannuck Pond system. 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 the unit area. The yield coefficients of Sopper and Lull (1970) suggested a mean flow ranging from 17.6 to 26.4 cu.m/min.(10.4 - 15.5 cfs).

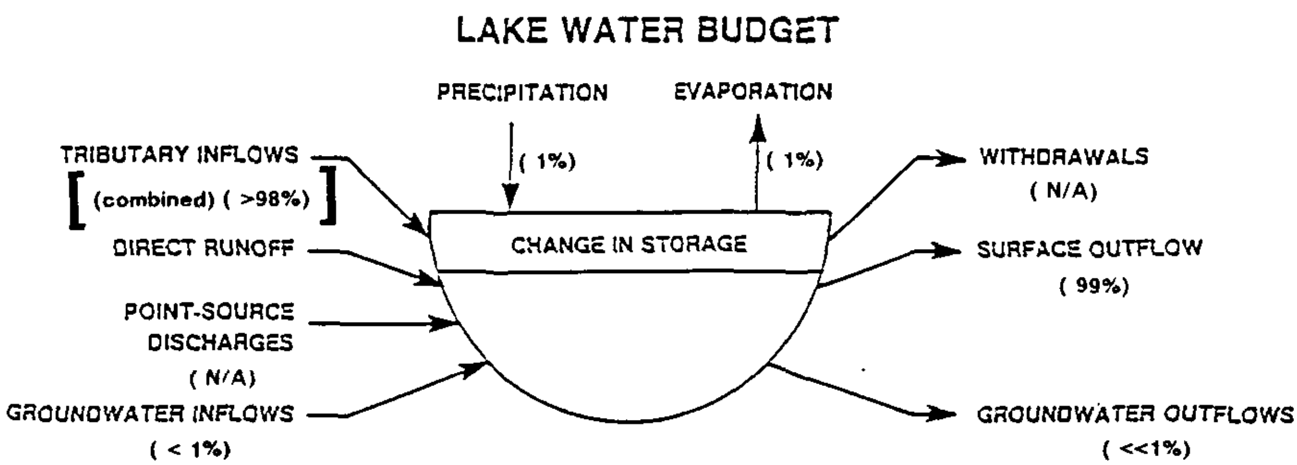
Runoff production in New England averages between 51-61 cm/yr or 20-24"/yr (Higgins and Colonell, 1971). Using these estimates the amount of runoff derived from the Nashawannuck Pond watershed (2,686.2 ha) can be calculated. If contributions from direct precipitation onto the pond and evaporative losses from same are included then flows of 26.1 - 31.2 cu.m/min. (15.4 - 18.4 cfs) are expected. Calculations and derivations of these flow ranges are given in Appendix D.

Several factors need to be taken into consideration when evaluating these estimates. The watershed is characterized by a combination of steep and flat relief (topography), a variety of land uses and a mosaic of soils. These site factors and direct observations do not suggest that either end of the range of surface flows is more likely. However, one consideration is the activity connected with the Hendrick Street well station. Given the use of this site as a pumping station, it is likely that some of the watershed recharge normally expected to go into Nashawannuck Pond is removed. This would tend to make these methods slightly overestimate the actual flows (see below).

Actual measurements of water inputs to Nashawannuck Pond included assessment of the flow in the three inlet brooks - Broad Brook, White Brook and Wilton Brook (Figure 1); determination of direct precipitation inputs, and estimate of groundwater seepage. Each of these inputs is considered below.

Nashawannuck Pond is the combined flowage of three permanent tributaries (Table 2). The time-weighted average flow of Broad Brook (NP-1) was 17.0 cu. m/min.(10 cfs). This accounted for about 73% of the total flow into Nashawannuck Pond over the study year. The second most important tributary was Wilton Brook (NP-3), which provided 4.4 cu. m/min (2.6 cfs) or 19% of the flows. White Brook added 1.6 cu. m/min or 7% of the flow to the lake.

Figure 17. Schematic Lake Hydrologic Budget.



Modified from : USEPA (1988).

Precipitation data reported to the National Oceanic and Atmospheric Administration (NOAA) is routinely tabulated and provided to requesting parties. Using NOAA precipitation data for the adjacent township of Holyoke, MA, precipitation of 122.5 cm (48.2") was measured for the period April 1987 to March 1988 (Table 7). Since the pond area is 12.7 ha, the average contribution of direct precipitation is estimated at 0.3 cu.m/min. (0.18 cfs). The total for the study year was slightly higher in comparison to long-term, thirty-year averages (NOAA, 1986) as shown in Figure 18. The months of April and September were particularly wet.

Groundwater was assessed by direct observation with seepage meters. Seepage was measured in meters placed around the periphery of the lake (Figure 19) following the procedure of Mitchell et al. (1988). Seepage was measured at six location for four hours on July 22, 1987. The groundwater influx measured was 0.112 cu. m/min (0.66 cfs). No seepage out of the lake was measured. The amount of seepage into the pond accounts for less than 1% of the hydrologic budget of Nashawannuck Pond. This lack of importance is probably due to the deep organic mucks in much of the lake and the slow passage of groundwater due to the confining layer in this area (see Geology and Soils section). For sample calculations and derivation of seepage totals see Appendix D.

The measured outflow as surface water over the dam at Holyoke Street averaged 23.2 cu. m/min. (13.6 cfs) This ranged from 58.0 cu. m/min during spring runoff (4/16/87) to no flow during a period when the bascule gate was raised slightly for the Annual Fishing Derby (5/28/87). Evaporation was calculated at 0.105 cu. m/min. (0.062 cfs) based on an average evaporative rate of 71.1 cm/yr. (Higgins and Colonell, 1971).

The total inputs and outputs of Nashawannuck Pond were exactly balanced at 23.4 cu. m/min (13.8 cfs); with a total volume of 12,300,000 cu. m/yr going through the system. This measured total is approximately the midpoint of the range of flows predicted empirically (17.6 - 31.2 cu. m/min.). The excellent agreement between inputs and outputs indicates that all other inputs and outputs are minor. A summary of the hydrologic inputs and outputs of Nashawannuck Pond for the study year is shown in Table 8.

Based on the average flow through the system in 1987-88 (23.4 cu. m/min.), the detention time for water in Nashawannuck Pond is 0.019 yr, or 7 days. Basically the water in the lake is exchanged or flushed 53 times a year, on average. For calculations of retention times see Appendix D.

TABLE 7

PRECIPITATION DATA FOR THE EASTHAMPTON, MA AREA.
(centimeters of precipitation as rain during 1987-88[1])

Month	Holyoke, MA
A	25.7
M	3.7
J	10.6
J	3.8
A	9.8
S	19.4
O	10.6
N	8.3
D	5.9
J	6.1
F	11.8
M	6.8
	Total =122.5 cm

1 - Source, NOAA, 1987,1988

Figure 18. Comparison of Study Year Precipitation to Thirty Year Average.

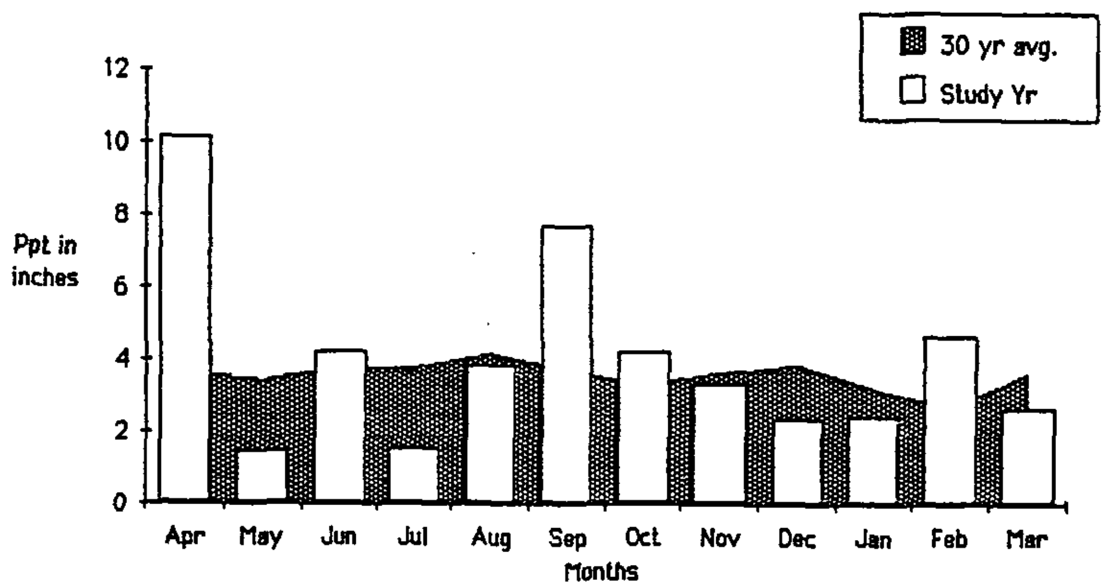


Figure 19. Location of Seepage Meters in Nashawannuck Pond.

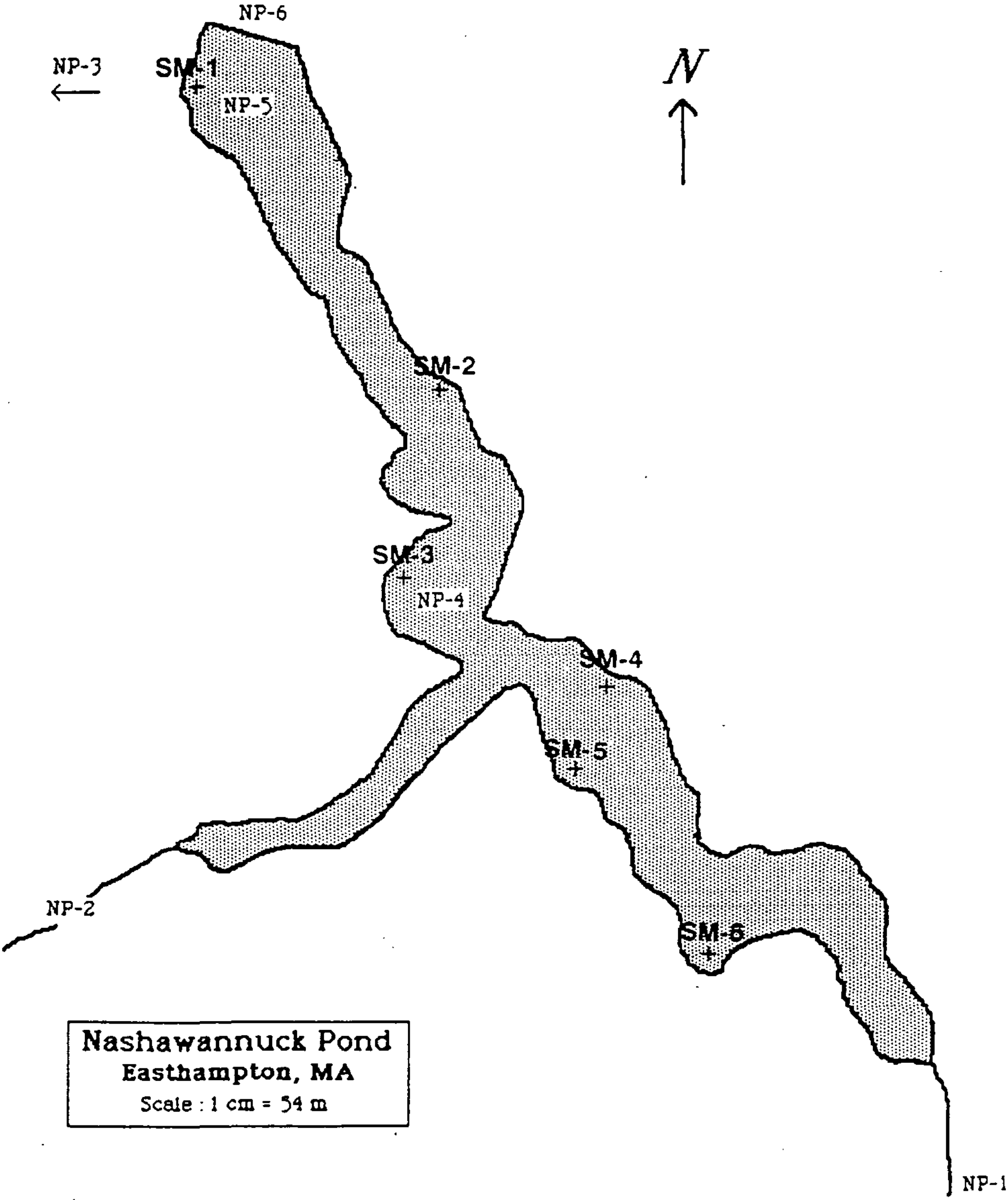


TABLE 8

HYDROLOGIC BUDGET FOR NASHAWANNUCK POND

Inputs	cu. m/min.	Volume (10^6 m^3/yr)	% of Total
Broad Brook (NP-1)	17.0	8.935	73
White Brook (NP-2)	1.6	0.841	7
Wilton Brook (NP-3)	4.4	2.313	19
Groundwater	0.1	0.053	< 1
Direct precipitation	0.3	0.158	1
Total Inflow :	23.4	12.300	100
Outputs			
Outlet (NP-6)	23.2	12.195	99
Evaporation	0.2	0.105	1
Total Outflow :	23.4	12.300	100
		Years	Days
Detention Time		0.019	7
Response Time		0.036-0.060	13-22

The response time, calculated according to Dillon and Rigler (1975) indicates how much detention time is needed for the potential impact of an episodic pollutant load to be completely realized. For Nashawannuck Pond, the response time ranges from 0.36 to 0.060 yr, or 13 to 22 days. These values are 2 to 3 times the detention time for Nashawannuck Pond. This suggests that during most of the year, the impact of a pollutant will not be felt by the system before it passes through. Pollutants will only have sufficient time to evoke a biological response when flows decrease to about 12 cu. m/min. For the study year this corresponds to the period of late July to late September. Note that this analysis pertains more to water blooms caused by phytoplankton. Aquatic macrophytes are not considered because of their rooted nature. Further, there is some variation associated with the pollutant response time, and it should not be strictly applied in a management content. However, it is clear that nutrients and other substances entering Nashawannuck Pond in the late summer experience sufficient residence time to have maximal impact on water quality of the system, augmenting the already vigorous growth of the rooted aquatic macrophytes.

NUTRIENT BUDGET

Phosphorus

Export coefficients for phosphorus can be used in conjunction with land use data to estimate the load generation in the Nashawannuck Pond watershed. The best of a wealth of literature values for areal phosphorus export have been summarized by Reckhow et al. (1980), and values can be selected from the range presented after evaluation of specific watershed traits such as vegetative features, soil types, and housing density.

Chosen export coefficients and corresponding justification are presented in Table 9. The coefficients, corresponding land areas and the results of their multiplication are given in Table 10. Based on this analysis 2207 kg of phosphorus are generated in the watershed each year. This does not mean that this amount will reach Nashawannuck Pond, as other mitigating factors such as distance are not considered. For example, phosphorus loads generated in the Broad Brook headwaters must travel greater than eight miles to reach Nashawannuck Pond.

In addition, not all of the generated phosphorus reaches a tributary stream; some of the load may remain associated with the soil or be detained by riparian vegetation. Of the portion that is washed into tributaries, there is potential for detention and/or sedimentation in wetlands or ponds (e.g., Rubberthread Pond) which are part of the stream systems. Along the path length, the phosphorus concentration of the water will be diminished through adsorption onto particles and subsequent sedimentation and biological uptake by the plant and bacterial communities. The usefulness of the watershed coefficient estimate is that it sets an upper limit to the potential amount of nutrient loading to the pond. It also allows identification of land uses and portions of the watershed which may contribute a disproportionate share of the phosphorus load that does arrive at the upper arms of the pond.

Since our interest is focused more on the amount of phosphorus which does impact the lake, another modeling approach is used. This approach uses empirical equations which rely on in-lake concentrations and hydrological parameters of the system to estimate the load to the lake. These empirical equations are derived from observations on a large number of lakes (Wetzel, 1983), and while widely accepted, are not specifically designed to mimick Nashawannuck Pond. Differences between the estimates are useful in identifying the importance of critical factors (concentration, flushing rate) which may be later useful in management applications.

TABLE 9

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

NUTRIENT SOURCE	EXPORT COEFFICIENT (KG/HA/YR) NITROGEN	PHOSPHORUS	SELECTION CRITERIA
LAND USE:			
Residential			
Light Density	12.50	1.51	Recently built, high lawn, low tree cover.
Medium Density	9.97	1.91	Older neighborhoods, more impervious area.
High Density	12.50	1.91	Cluster type apartment complexes.
Commercial	9.97	1.91	Mean value selected
Industrial	9.97	1.91	Combination of light and heavy industry.
Institutional	5.50	1.10	Median value selected.
Agricultural			
Pasturage	8.65	1.50	Includes fallow & active grazing.
Tilled Areas	16.09	1.50	Mean value selected.
Orchards	14.30	.91	Mixed agricultural designation.
Farm Buildings	680.50	21.30	Some fertilizer/manure storage.
Recreation/Park	8.65	1.50	Seasonally heavy use, spectator sports.
Open	5.19	.81	Abandoned fields, power easements, etc.
Forest	2.86	.24	Mean value selected.
Wetland	2.46	.21	Median value selected.
OTHER SOURCES:			
Atmospheric Deposition	11.88	.43	Approx. forested : agricul + residential.
Groundwater			Minimal impact on system due to muck.
Aquatic Birds	1.00	.20	Assumes density of 3 birds/ha/yr.
Internal Loading			Anoxic area at deep hole near dam

Note: Source of export coefficients is Reckhow et. al, 1980.

TABLE 10

NUTRIENT LOAD GENERATION BY SOURCES IN THE WATERSHED OF NASHAWANNUCK POND.

NUTRIENT SOURCE	ASSOCIATED AREA (HECTARES)	EXPORT COEFFICIENT (KG/HA/YR)		LOAD GENERATED (KG/YR)	
		NITROGEN	PHOSPHORUS	NITROGEN	PHOSPHORUS
LAND USE:					
Residential					
Light Density	350	12.50	1.51	4375	528
Medium Density	212	9.97	1.91	2114	405
High Density	8	12.50	1.91	100	15
Commercial	13	9.97	1.91	130	25
Industrial	13	9.97	1.91	130	25
Institutional	16	5.50	1.10	88	18
Agricultural					
Pasturage	153	8.65	1.50	1323	230
Tilled Areas	118	16.09	1.50	1899	177
Orchards	8	14.30	.91	114	7
Farm Buildings	8	680.50	21.30	5444	170
Recreation/Park	32	8.65	1.50	277	48
Open	191	5.19	.81	991	155
Forest	1513	2.86	.24	4327	363
Wetland	48	2.46	.21	118	10
OTHER SOURCES:					
Atmospheric Deposition	12.7	11.88	.43	151	5
Groundwater *				72	4
Waterfowl (kg/bird/yr)*				38	8
Internal Loading *				0	14
TOTAL				21691	2207

* Calculations for totals derived elsewhere.

A set of five equations was applied to the Nashawannuck Pond system (Table 11). Note that the concentration of phosphorus entering the system in tributaries (mean of NP-1,2,3 = 52.3 ug/l) is approximately equal to the concentration of phosphorus leaving (53 ug/l). This applies to the annual budget but may not be equal on a seasonal basis. Examples of this include uptake of nutrients by the biota during the growing season, with release by the plants upon senescence and decay in the fall and winter.

Appropriate values for corresponding variables and the calculated phosphorus loads are presented in Table 12. Loads ranged from 527 to 644 kg P/yr. One assumption of the models rarely approached in real lakes is that of complete and instantaneous mixing of the nutrient load throughout the lake. The unidirectional flow, sinuous morphometry, importance of storm drainage and short detention time of Nashawannuck Pond suggests that this lake is unlikely to be completely mixed, so that the models may be less appropriate. However it establishes an approximate range that can be compared to other estimates.

Vollenweider (1968) established loading criteria based on system morphology (mean depth) and hydrology (hydraulic detention time). Fitting data from Nashawannuck Pond and comparing it with tabulated values indicates that a phosphorus load of less than 117 kg/yr would be considered permissible under this scheme, while a load in excess of 232 kg/yr would be deemed critical. Loads below the permissible threshold should result in oligotrophic conditions, while those below the critical load lead to mesotrophic conditions in the pond. In fact, the mean predicted load (538 - 649 kg/yr) is far above the critical load, which indicates that eutrophic conditions are prevalent in Nashawannuck Pond. Needless to say this analysis is easily borne out by the weed-choked condition of the lake and summer surface algal blooms.

The most reliable approach involves direct measurement, although not all inputs are amenable to this approach. A combination of empirical data or export coefficients was therefore applied. The mass flow of total phosphorus past monitored stations was calculated based on flow volumes and sample concentrations (Table 13). Total phosphorus from Broad Brook (NP-1) was by far the greatest contribution, at 444 kg P for the study year; and accounted for greater than 64% of the total phosphorus entering Nashawannuck Pond. Wilton Brook accounted for 135 kg P or 20% of the total phosphorus inflows. White Brook was responsible for adding 55 kg P or 8% of the whole.

In addition to the surface water inputs of phosphorus, contributions from groundwater, benthic remineralization, storm runoff, atmospheric deposition and wildlife, principally

TABLE 11

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

Kirchner & Dillon, 1975 $TP=L(1-R)/Z(F)$ $L=TP(Z)(F)/(1-Rp)$	(K-D)	TP=Total P as ug/l in spring L=P load as mg $P/m^2/yr$
Vollenweider, 1975 $TP=L/(Z)(S+F)$ $L=TP(Z)(S+F)$	(V)	Z=mean depth as m F=flushing/yr
Chapra, 1975 $TP=L(1-R)/(Z)(F)$ $L=TP(Z)(F)/(1-R)$	(C)	Pin=Flow weighted average input concentration of phosphorus
Larsen & Mercier, 1975 $TP=L(1-R_{LM})/Z(F)$ $L=TP(Z)(F)/(1-R_{LM})$	(L-M)	Pout=Flow weighted average output concentration of phosphorus S=effluent TP/influent TP
Jones & Bachmann, 1976 $TP=0.84\ L/(Z)(0.65+F)$ $L=TP(Z)(0.65+F)/0.84$	(J-B)	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 defined = 13.2)
		$R_{LM}=1/1+(F^{.5})$

TABLE 12

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

Variable	Parameter Value
TP [ug/l]	50.0
Z [m]	1.6
F [yr^{-1}]	52.6
Pin (tributary composite:NP-1,2,3)	52.3
Pout (annual mean NP-6)	53.0
S=P out/P in	1.01
qs=Z(F) [m/yr]	84.2
R=(P in - P out)/P in	-.013
Rp=13.2/(13.2+qs)	0.14
$R_{LM}=1/(1+F^{.5})$	0.12
Predicted Load ($g/m^2/yr$) By Each Model	
K-D	4.89
V	4.29
C	4.15
L-M	4.79
J-B	5.07
Predicted Load (kg/yr) By Each Model	
K-D	618
V	545
C	527
L-M	608
J-B	644
Vollenweider Criteria	
Permissible Load	
$g/m^2/yr$	0.92
kg/yr	117
Critical Load	
$g/m^2/yr$	1.83
kg/yr	232

TABLE 13

NITROGEN AND PHOSPHORUS MASS FLOW IN THE NASHAWANNUCK POND SYSTEM

(for the period: April 1987 - March 1988*)

	MASS FLOW PAST GIVEN STATION (KG/YR)			
PARAMETER	NP-1	NP-2	NP-3	NP-6
Total Phosphorus	444	55	135	653
Orthophosphorus	133	23	40	227
Ammonia Nitrogen	294	36	187	616
Nitrate Nitrogen	9931	1692	2096	10134
Total Kjeldahl Nitrogen	1928	364	854	4204
Total Nitrogen	11859	2056	2950	14338

* all yearly totals are both time- and flow-weighted.

waterfowl, must be considered. A schematic of these contributions is given in Figure 20. Each of the relevant sources is evaluated below.

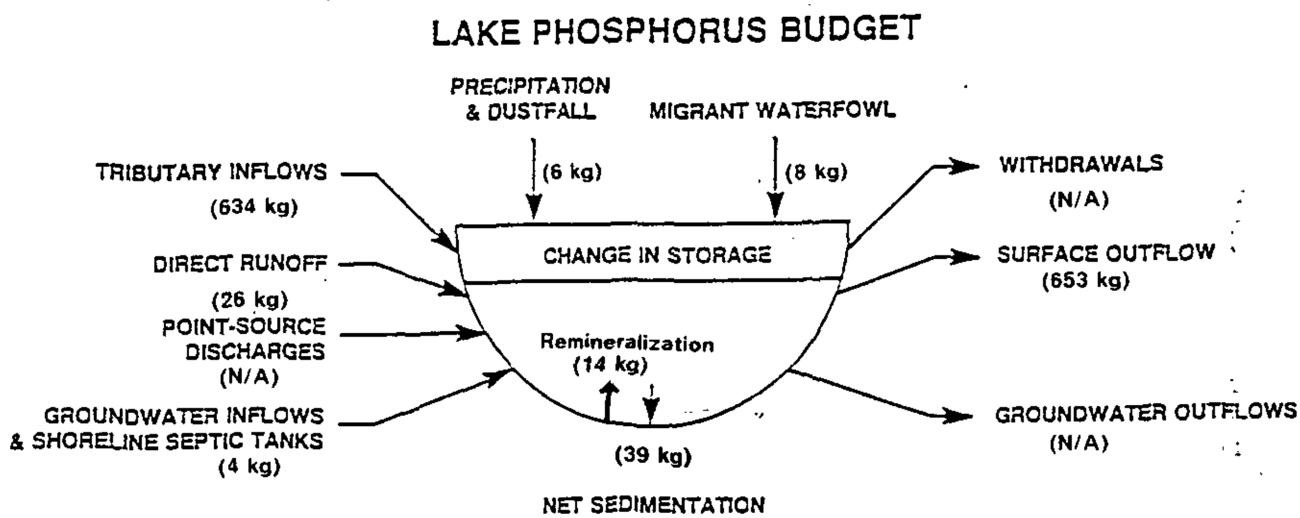
The amount of phosphorus entering via groundwater was not directly monitored, but can be estimated from available information. Phosphorus in the groundwater will be due to contemporary urban activities, such as lawn fertilization, that percolate down to the water table. Since the immediate vicinity around Nashawannuck Pond is serviced by sanitary sewers, contributions from on-site septic systems are not a factor. Phosphorus content in the groundwater was estimated using data from measurements at NPS-1 and seeps (the NP-7 samples) taken in Nonotuck Park. The NPS-1 station (originally misidentified as a storm drain) represents groundwater from the eastern, residential side of Nashawannuck Pond. Total phosphorus from this source ranged from 77 to 140 ug P/l, while the seeps from the Park sites were lower at 30 to 72 ug P/l. This difference is probably due to land use. A mean value of 80 ug P/l was used for groundwater phosphorus content. This value was multiplied by the groundwater flux of 0.112 cu. m/min (Table 8) to get the groundwater phosphorus loading total of 4.2 kg P/yr. This is a very small percent (0.6) of the total phosphorus budget.

The amount of phosphorus entering the water column via remineralization in the bottom sediments was calculated. Oxygen levels (Figure 8) in the bottom waters of the deep basin near the dam (NP-5b) were sufficiently low enough to produce the reducing conditions required for phosphorus release to the water column. The shallowness and lack of stratification did not allow phosphorus release from sediments to occur at the upstream site (NP-4). The amount of phosphorus realized from the benthic remineralization at NP-5b was estimated to be 14.3 kg/yr. For calculation of benthic remineralization see the Appendix D.

Stormwater inputs of phosphorus into Nashawannuck Pond were considered. The amount of phosphorus entering the lake from these sources was estimated at between 17.7 to 36.4 kg/yr. A mean value of 26.2 kg P/yr was assumed. This constitutes about 4% of the phosphorus load to the lake. Calculations of stormwater associated phosphorus is given in the Appendix D.

Using an atmospheric deposition value for phosphorus (0.43 kg P/ha) representative of a mixture of forested, agricultural and residential land use with some slight industrial (Reckhow et al., 1980), a direct load of 5.5 kg/yr is calculated. Wildlife inputs are harder to quantify, but a density of 3 bird equivalents per hectare of lake (a bird equivalent equals a year long residence by a waterfowl) is assumed since this lake is very popular as a winter feeding area for a flock of Canada geese (observed by BEC personnel). It addition, the secluded areas

Figure 20. Schematic Lake Phosphorus Budget.



Modified from : USEPA (1988).

associated with the wetlands on the Broad and White Brook arms of the pond are likely to harbor some wading birds. Given an average figure of 0.20 kg P/bird/yr; this density adds another 7.6 kg phosphorus altogether (Reckhow et al., 1980). For calculations of deposition and wildlife inputs see Appendix D.

A summary of the phosphorus inputs is shown in Table 14. The inputs contributed from all the various sources considered above account for a loading of 692 kg/yr. Comparing this value to the amount of phosphorus leaving the outlet (653 kg/yr), there is a discrepancy (39 kg); indicating that Nashawannuck Pond is a slight sink (<6% retention) for phosphorus. This disagrees slightly with the near balance of tributary and outlet concentrations (see above). Thus, it appears the system is removing some of the phosphorus inputs before it exits the lake. Wetland extensions and massive macrophyte beds in the upper part of the lake and settlement of particles from storm runoff are the most likely agents. The dense macrophyte cover may act as a living "biofilter" removing some of the phosphorus concentration in the water column and translocating it to the sediments, either through the roots or eventual decay. Phosphorus can also be removed through settlement of the nutrients associated with larger particles arriving through the storm drain system. Loss of fish through passage over the dam or being caught represents another, but much smaller, export of phosphorus.

The levels of phosphorus found in Nashawannuck Pond are important for the overall trophic level of the lake. Nashawannuck Pond has generally turbid water (less so at the upper station) with significant summer phytoplankton blooms. It would be clearly classified as a eutrophic lake based on its nutrient status, massive biological growths and bottom oxygen deficits. The nutrient limiting biological growth during most times of the year is phosphorus (nitrogen may be important during selected summer months). Although the pond is impacted by other pollutants, the reduction of phosphorus inputs is an important key to improvement of water quality in Nashawannuck Pond.

Nitrogen

Derivation of the nitrogen budget was approached in the same manner as the phosphorus budget. Lack of analogous equations for calculating nitrogen loads from in-lake concentrations precluded the use of that method. Export coefficients and resulting loads are given in Table 9 and 10. Mass flow of the three nitrogen forms and total nitrogen past monitored stations are presented in Table 13. A breakdown of the total nitrogen loadings by the source is shown in Figure 14.

From export coefficients it is estimated that 21,690 kg of nitrogen are generated in the Nashawannuck Pond watershed each

TABLE 14

NUTRIENT LOADS TO NASHAWANNUCK 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
Broad Brook (NP-1)	444	64.2	11859	68.4
White Brook (NP-2)	55	7.9	2056	11.9
Wilton Brook (NP-3)	135	19.5	2950	17.0
Storm Runoff	26	3.8	221	1.3
Benthic Remineralization	14	2.0	0	0.0
Bird Inputs (Direct Input)	8	1.1	38	0.2
Atmospheric Deposition (Direct Input)	6	0.9	151	0.8
Groundwater	4	0.6	72	0.4
Total	**692**	**100.0**	**17,347**	**100.0**

year. The fraction of this load reaching the pond is largely dependent on the form of nitrogen generated; nitrates move rapidly through groundwater while organic nitrogen (TKN - ammonia nitrogen) is more dependent on surface flow. Nitrates are the most important form of nitrogen in the system. Sources of nitrates are effluent from septic systems, agricultural and domestic fertilization, stormwater drainage and animal wastes. These are likely to arrive in Nashawannuck Pond through watershed land use (see breakdown of land use categories - Figure 6). Agricultural fertilizer and animal wastes are likely to be important in the Broad Brook and White Brook watersheds. Septic systems and domestic fertilization are applicable to these watersheds also, due to the residential developments at the southern end of Easthampton. Storm drainage from street surfaces can enter Nashawannuck Pond directly, or through the tributary loadings.

Totaling the contributions of the tributaries, with the addition of groundwater, storm runoff, atmospheric deposition, and wildlife inputs, the total nitrogen load to Nashawannuck Pond was 17,347 kg/yr (Table 14). This range is comparable (± 20%)to the amount of predicted nitrogen generated by the watershed. The measured output of total nitrogen (NP-6) was lower at 14,338 kg/yr. Thus, the lake apparently retains a portion of the nitrogen going through the system (21%). However, unlike phosphorus which has no atmospheric form, nitrogen can be lost to the system by bacterial metabolism and production of nitrogen gas (denitrification). So the actual amount accumulated by Nashawannuck Pond cannot be estimated confidently.

On an annual basis, the magnitude of the nitrogen load suggests that phosphorus will be in relatively shorter supply for plant growth in Nashawannuck Pond. During selected summer months, nitrogen limitation may occur. However, the duration of this limitation is likely to be on the order of a few weeks. Therefore, phosphorus would be the logical target of lake management actions. This does not mean that nitrogen should be ignored. The tendency of nitrogen sources to be linked to other pollutants suggests that an overall management should address nitrogen inputs. It is unlikely, however, that control of nitrogen alone (if possible) would yield any detectable benefits in Nashawannuck Pond.

DIAGNOSTIC SUMMARY

Nashawannuck Pond in Easthampton, MA is situated in a large watershed which extends into the neighboring towns of Southampton and Holyoke. Land use in the watershed is mostly forested with agricultural and residential applications also important. The watershed largely determines the nature of Nashawannuck Pond due to its hydrologic and nutrient contributions. The effect of urban Easthampton is manifested also, in the form of stormwater drainage, but impacts the pond to a lesser degree than do watershed non-point sources.

Nashawannuck Pond is an impoundment formed by the damming of flow from three tributary streams. The major tributary is Broad Brook, which provides 73% of the water in the pond on an annual basis. Wilton Brook and White Brook contribute 19% and 7%, respectively. Groundwater and direct precipitation account for the remainder. Total flow through the system was measured at 23.4 cu. m/min. Flow through the system results in a rapid flushing, with a mean hydraulic retention time of just 7 days.

On an annual basis, phosphorus is in relatively shorter supply than nitrogen in Nashawannuck Pond. Phosphorus enters the pond mainly through the tributaries : Broad Brook, 64 %; Wilton Brook, 20%; and White Brook 8%. Other sources including stormwater, benthic remineralization, aquatic wildlife, atmospheric deposition, and groundwater account for the remaining 5%. The total phosphorus load to Nashawannuck Pond is estimated at 692 kilograms per year. Nitrogen loadings are approximately 25 times greater, but phosphorus still remains the element which controls water quality.

The overall nutrient status of Nashawannuck Pond would be considered eutrophic, based on its chemical and biological characteristics. There are pronounced summer and winter hypolimnetic oxygen deficits, and these anoxic conditions may present stress to fish life there, particularly stocked trout which gravitate to these colder waters in summer. The water transparency is quite low during the summer months. Late summer phytoplankton blooms are are unsightly and a problem for water quality.

Growths of aquatic macrophytes are extensive with very high densities and biomass accumulations occurring in the southern two-thirds of the pond. The extent of this growth interferes with surface recreation and shoreline fishing by mid-summer. The fishery, while productive, is overpopulated with less desirable pan and rough fish, which are more adapted to existing in the pond's eutrophic conditions. Presently, fishing is the most popular activity on the pond.

Nashawannuck Pond provides an accessible water resource for Easthampton. The phosphorus load entering the pond is well above a desirable level, and factors within the watershed make it difficult to manage water quality. However, good watershed practices and reduction of the nutrient inputs to Nashawannuck are essential for any management plan that hopes to restore appreciable recreational function to the pond.

PART II.
FEASIBILITY ASSESSMENT

EVALUATION OF MANAGEMENT OPTIONS

Available Techniques

The number of techniques available for pond and watershed management is not limitless (Table 15). However, the potential combination of these techniques and level of their application do result in a great number of possible management approaches. Each pond must be considered a unique system, thus an effective restoration and management program must be tailored to a specific waterbody (Wagner and Oglesby, 1984).

Improvement to conditions in Nashawannuck Pond will be linked to control of nutrient inputs to the pond. Since this can be done in many ways, there exists many potential pond management options that need to be evaluated. The pond and watershed characteristics of Nashawannuck Pond and nature of problems there immediately eliminate some alternatives from further consideration, however. These easily rejected alternatives are considered below.

Biocidal chemicals and dyes are inappropriate here. Biocides are considered by BEC to be an ecologically unsound management tool in all but a very restricted class of applications. Recent literature on pond management does not even consider biocides as management tools (e.g., Cooke et al., 1986). The rapid flushing rate of Nashawannuck Pond, as well as the potential for downstream effects, eliminate it as a possible candidate.

Dilution and flushing are also not viable solutions for Nashawannuck Pond. The pond's eutrophication problems would be slightly lessened from quicker movement of its waters, particularly in the summer. However, other sources of good quality water are not easily diverted or obtainable for such a scheme, and in most times of the year the flushing rate is already rapid enough. Further, most of the problems in Nashawannuck Pond are due to rooted macrophytes that would not be significantly affected by more rapid passage of water. This solution is simply not useful for Nashawannuck Pond.

Hypolimnetic aeration or destratification is the mechanical introduction of oxygen or warmer waters into the bottom layers in an attempt to increase the oxygen level of those waters. While Nashawannuck Pond does have oxygen poor waters in the deep basin; this constitutes a small portion of the total pond volume. The amount of anoxic phosphorus remineralization that oxygenation would prevent is a small proportion of the total phosphorus budget (see Nutrient Budget section). The costs associated with either this option would be high due to the need for sophisticated aeration technology. Since passive hypolimnetic

TABLE 15

LAKE RESTORATION AND MANAGEMENT OPTIONS

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

TABLE 15 (continued)

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

withdrawal is possible at very low costs to the town, aeration is not recommended.

Nutrient inactivation could be used to help prevent remobilization of phosphorus from the bottom sediments. The technique relies on the use of aluminum salts to induce phosphorus precipitation from the water column or binding (inactivation) in the sediments. This technique may require repetitive applications to be effective. This treatment is most successful for ponds in which the flushing rate is relatively slow and the tributary nutrient inputs have been much reduced such that recycling of nutrients from phosphorus-rich sediments is a major part of the nutrient budget (Cooke et al., 1986). This is clearly not the case in Nashawannuck Pond, where tributaries bring in large amounts of nutrients and the flushing rate is rapid. It would provide little relief from the eutrophication problems in the pond.

One relatively inexpensive technique to allow some measure of relief from nuisance aquatic plants would be the deployment of bottom barriers. A bottom barrier consists of a layer of synthetic material that is laid directly over the bottom and weeds. It effectively compresses and shades aquatic macrophytes such as to suppress their growth. The screen is positioned in shallow water by hand, but a diver may be necessary for application to deeper waters. It must be weighted (e.g., cinder blocks) or staked down. A major advantage of these screens is that they are reusable. They can be retrieved from the water, washed, dried and stored for use in succeeding years. With proper care, five to ten seasons of use can be expected in lakes with low turbidity and suspended solids. Successful applications are the creation of channels or cleared beach areas, but rarely as a practical whole-pond management tool. In Nashawannuck Pond, sedimentation from upstream sources, high spring inflows, the depth and morphometry of the areas to be treated and the large size of the areas to be treated are factors which would increase the cost and decrease the longevity of the benthic barriers. Given the costs ($11-12,000/ac) associated with this short-term management plan and lack of effect on overall trophic state, this technique does not provide much permanent benefit and is not recommended.

Macrophyte harvesting refers to the direct mechanical removal of nuisance aquatic vegetation to permit the desired use of the water or littoral area. Basic types of harvesting include mowing, tillage, and suction and diver-operated dredging and hydraulic washing equipment (Cook et al., 1986). The conventional (and least costly) method used is the cutting and harvesting of the summer growth of macrophytes. More recently a more selective method referred to as hydro-raking has been utilized.

Briefly, harvesting has the advantages of immediate removal of the nuisance plants and the nutrients they contain, which are subject to release upon plant senescence, as well as direct targeting of problem areas with little hazard to other biota. The harvesting activities do not preclude concurrent pond use in other areas and are usually acceptable to local pond ordinances. Further, the operating costs are less expensive than many other forms of physical control.

The disadvantages of harvesting need to be considered as well. These include the labor and energy to remove the cut vegetation from the pond. Effective harvesting is usually delayed until the nuisance plant biomass is maximal and carbohydrate storage in the roots has already peaked (producing the following year's growth). A high cost can be associated with mobilization (just getting machine to and from the pond), and there are operational costs and delays connected with machinery breakdown. Obstacles in the water may prevent conventional harvesting in those areas, and only a relatively small area can be treated by an individual machine. The depth of harvesting is limited to about 5 ft below the surface. Conventional harvesting is effective at removing present vegetation but does little to affect the roots and seed beds which are the source of future problems.

In Nashawannuck Pond, the scope of the macrophyte problem, its location in relatively deep water and the narrow operating dimensions of the affected areas are factors that limit the effectiveness. Together with the very large biomass involved, the temporary nature of the improved conditions and the requirement for annual operation and maintenance costs, these factors make harvesting unattractive, both technically and economically.

Biomanipulation is an attempt to influence pond conditions through the removal or introduction of more favorable species. It is a new and still largely experimental technique, and not without risk to the ecosystem (Wagner, 1985). The nature of conditions at Nashawannuck Pond do not make it a particularly good candidate for improvements following biotic manipulations. Replacement of the nuisance macrophytes with more desirable types is uncertain and a loss of their functional utility may result. One of the types of macrophytes (Elodea) is often a preferred plant when in it's low growth form. While long range improvement in Nashawannuck Pond might be aimed at improving the recreational fishery, the basic conditions under which Nashawannuck Pond exists would not be changed by biotic introductions. Biomanipulation attempts are therefore not recommended at this stage.

Often the most effective pond management options are those which are applicable to a pond's watershed and not directly to the pond. This is also the case in Nashawannuck Pond, particularly in light of the large watershed area. Of course, not all watershed options make sense for the Nashawannuck Pond system. Considering these watershed options (Table 15), it is apparent that most but not all of these management techniques would be appropriate for Nashawannuck Pond.

Development of a sanitary sewer in the Nashawannuck Pond watershed is not needed due to the availability of sewer lines in most of the area. Septic systems that are in the watershed are sufficiently distant that their direct influence on Nashawannuck Pond is slight. Still, the maintenance or improvement of on-site disposal systems is encouraged and addressed in the context of a watershed non-point reduction program (see below).

Restriction of motorboat activity on Nashawannuck Pond is a moot point since such activity is forbidden by the town. The desirability or probability for opening the pond up to such activity in the future is negligible.

Thus, the following techniques are eliminated from further consideration: biocides, hypolimnetic aeration, nutrient inactivation, dilution and flushing, plant harvesting, bottom barriers, biomanipulation, building of sanitary sewers, and restriction of motorboat activity. A critical examination of the remaining techniques is given below.

Evaluation of Viable Techniques

The techniques considered at this stage are ones that are appropriate for improving conditions in Nashawannuck Pond. These techniques include dredging, water level control, hypolimnetic withdrawal, land use planning, stormwater treatment/diversion, detention basins, agricultural best management practices, bank stabilization, increased street sweeping, and behavorial modifications. Whenever possible, it is preferable to spend dollars to reduce or remove factors leading to pond degradation rather than merely treat pond conditions in isolation.

Dredging is an effective means to reduce macrophyte infestation by removal of existing plants and organic sediment layers and help limit future growth by increasing depth. The importance of the additional depth is in the reduction of light penetrance to the bottom dwelling plants; limiting or severely reducing their growth. By fundamentally changing the pond's morphometry, dredging provides a restoration that is relatively long lasting. The increased storage capacity affects hydraulic and physical relationships such as flooding and thermal stratification. This alters nutrient loading, budgets and recycling within the waterbody, with accompanying changes in the trophic levels of the biota.

In Nashawannuck Pond, dredging would provide a long-lasting solution to the macrophyte problem and open up large areas of the pond to increased recreation. Dredging of sediments to a hard bottom provides a very effective means of eliminating the existing macrophyte beds and severely limiting regrowth. The existence of gates on the dam which allow a very complete drawdown make conventional excavation techniques applicable. Overall, dredging provides the single most powerful restoration technique, as well as the most costly. Despite the large costs associated with dredging, this technique will provide the most immediate and long-lasting benefits.

The dam at Cottage St. allows the winter drawdown of Nashawannuck Pond for macrophyte control. A drop in water level would expose the sediments containing areas of high macrophyte density, making them vunerable to the combined effects of freezing and dessication. Due to the morphometry of Nashawannuck Pond, the amount of littoral zone exposed per foot of dropped water level is not extensive. However, exposing even a small area would have some positive benefit, and since there is no real expenses connected with this option, it is a recommended option.

In a similar sense, use of the dam structure to release oxygen-poor bottom water in the summer or late winter is an economical technique. This hypolimnetic release would induce more oxygen into the bottom waters by mixing, thus providing better conditions for fish and prevention of the anoxic remineralization of phosphorus. Although this benthic remineralization is but a small fraction of the total phosphorus budget, its prevention is nonetheless positive and done without real expense. It is recommended for the continued management of Nashawannuck Pond.

Since the majority of the nutrients are derived in the watershed, especially the Broad Brook sub-drainage basin, it makes sense to reduce these inputs at the source rather than remove them or their by-products in the pond proper. The medium of this reduction is a watershed level non-point source reduction program. Under this heading come such related issues as zoning, agricultural best management practices and aquifer protection. Zoning and land use planning is often a very effective way to guide and control the extent and density of development in a watershed. In the case of Nashawannuck Pond, this is particularly true, since considerable change in land use (often agricultural to residential) is expected in the next few years. Alternatively, land that is kept in agriculture should utilize best management practices. The influence of land use on the quality of water percolating down into recharge zones of the major regional aquifer makes this a related issue. Thus, watershed control is jointly concerned with mitigating existing nutrient loadings to the pond and reduction/prevention of future loadings by coordinating planning of future development in Easthampton.

Stormwater manangement refers to either treatment or diversion of flows into Nashawannuck Pond from the storm drain system. The negative impacts of storm water pollutants on water quality of the receiving water body is well documented (USEPA, 1988). In Nashawannuck Pond, the impact of storm drainage accounts for about 4% of the total phosphorus budget. Reducing this loading improves the water quality and eliminates potentially harmful discharges to the pond. Elimination or reduction of flow from selected storm drains would lead to localized improvements in water quality.

An educational program aimed at the Easthampton abutters and users of Nashawannuck Pond is needed. Information in this program concerns the elements of good "urban housekeeping" (USEPA, 1988); regarding use and misuse of storm drains, restrictions on lawn fertilization, protection of shoreline integrity, disposal of organic material in waterways, storage of materials near ponds, and similar topics. The purpose of such a program is two-fold : to eliminate some of the practices that lead to unsightly conditions in the pond and to provide awareness and pride of the people of Easthampton in Nashawannuck Pond.

The use of a detention basin to increase the time available for sedimentation and purification is practical in this watershed. These basins act to decrease sediment transport and increase nutrient removal in inflowing waters to Nashawannuck Pond. Two good locations exist for these detention basins at the entrances of Broad and White Brooks. Installation of low gabion weirs at these points is both economical and merited in terms of nutrient removal.

There are several sites along the shoreline of Nashawannuck Pond which are heavily eroded or show signs of future failure (e.g., undercut banks, collapsing trees). These problems are exacerbated by overuse and abuse by fishermen using Nashawannuck Pond. As these banks slump, eroded sediment falls into Nashawannuck Pond. Further problems are due to compacted soils caused by vehicular traffic. Bank stabilization is required to check present erosion, prevent future erosion, and to provide a usable and scenic access point to the pond.

Thus, after reviewing viable techniques and in light of the characteristics of the system, the recommended in-pond management techniques are water level control, hypolimnetic release, and dredging. At the watershed level the preferred options include: a non-point source reduction program, installation of gabion weirs, stormwater system improvements, bank stabilization and behavioral modifications of abutters.

WATER LEVEL DRAWDOWN

Elements and Anticipated Impact of Drawdown

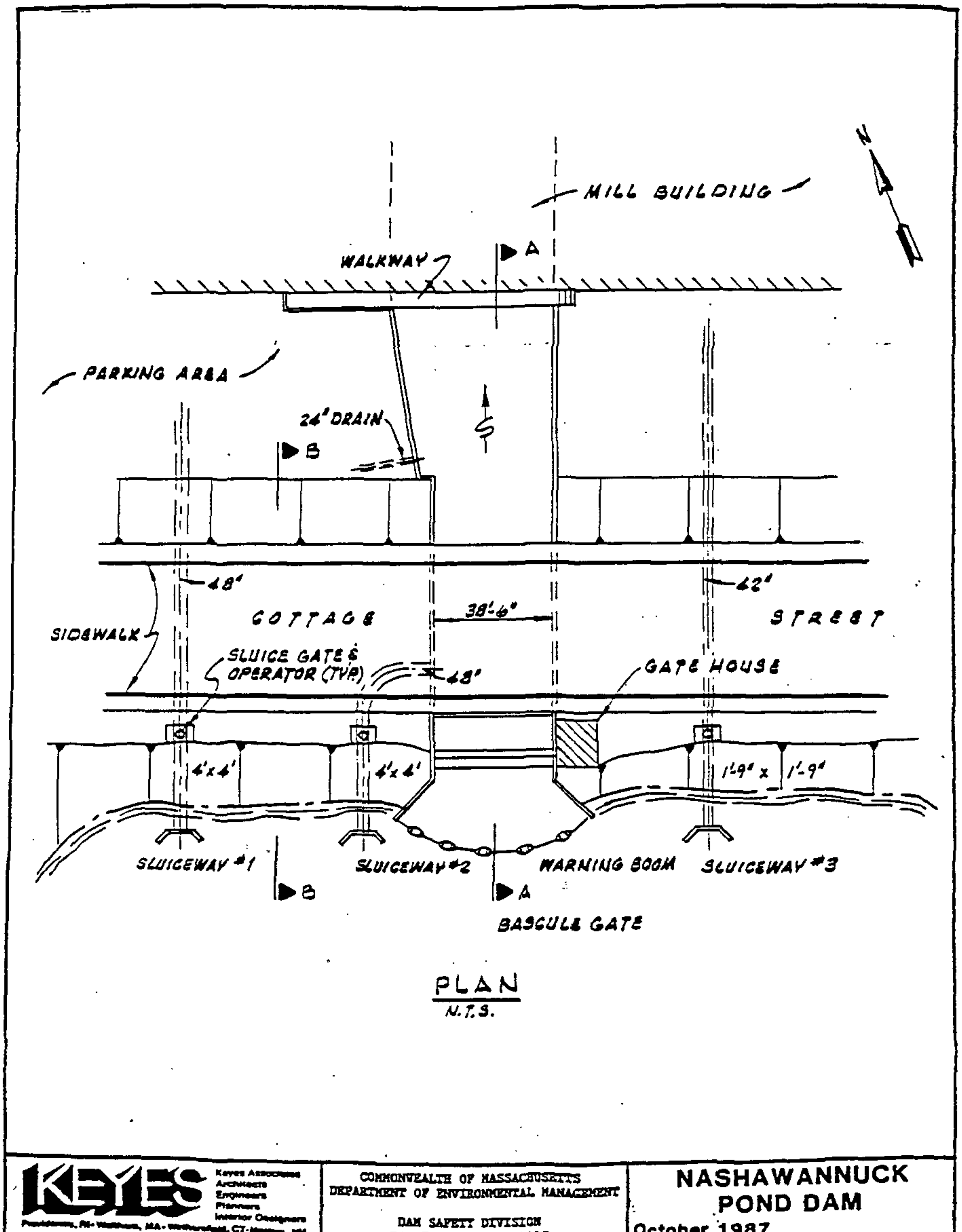
The dam and outlet structure at Nashawannuck Pond allows the winter drawdown for control of macrophytes. The drop in water level will expose the sediments containing areas of high macrophyte density, making them vulnerable to the combined effects of freezing and dessication. Not all macrophytes are negatively affected by a winter drawdown. However, one of the major nuisance species in Nashawannuck Pond, Ceratophyllum has been shown to usually decrease in abundance following a winter drawdown (Cooke et al., 1986). The response of the other major macrophyte species, Elodea, has been more variable. Thus, it seems worthwhile to explore this possibility with an experimental drawdown and evaluate the results before implementing other control measures.

The Nashawannuck Pond Dam is an earthen roadway embankment approximately 300 feet long with associated bridgework (MA DEM, 1987). This structure was built in 1956 after a hurricane destroyed the existing dam in August 1955. Cottage Street, a four-lane major town thoroughfare (also Rt. 141) crosses the top of the dam. In the center of the dam is a 38.5 ft concrete spillway discharging over a drawbridge-type or bascule gate into a concrete raceway which flows under Cottage St. and through mill buildings to Lower Millpond. The bascule gate is hydraulically operated, with control from the adjacent gate house (MA DEM, 1987). There are three gated sluiceways extending through the embankment. Two convey water to the mill structures downstream, while the central sluiceway is the reservoir drain which discharges into the concrete raceway. All the gates are reportedly operable (MA DEM, 1987). A general plan, taken from the Dam Safety Inspection Report of 1987 is shown in Figure 21.

There are six potential problems associated with conducting a drawdown of Nashawannuck Pond. These are the sustainability of the drawdown, the impact on abutting wells, the impact on the fish, the impact on the neighboring wetlands, impact on industrial uses and the refilling of the pond in the spring. The drawdown would require a discharge of 26.6 cu. m/min on average during fall through winter (October-March), and there is little doubt that the bascule gate can outlet all the combined inflows during this period. According to MA DFW notes, the water level was last reportedly dropped in the 1960's.

Use of the bascule gate is the recommended means to conduct the winter drawdown. The gate has a maximum elevations of 153.2 ft (above SL), and can be lowered to 146 ft, with an vertical extent of drawdown of 2.2 m (7.2 ft). A vertical drawdown of 1.5 m (Figure 4) would expose about 50% of the pond bottom and the

Figure 21. General Plan of Nashawannuck Pond Dam.



peripheral macrophyte beds. With a 2.0 m drawdown about 59% of the bottom would be exposed, including most of the southern arms, save middle channels where the streamflows of Broad and White Brooks would tend.

The second potential problem involves the impact of the drawdown on shallow wells in the vicinity of the pond. This does not seem to be much of a problem because all of the abutting residences are on town water. There is a town well adjacent to the Broad Brook arm in Nonotuck Park. However, this well is quite deep and hydrologically isolated from Nashawannuck Pond by intervening clay layers (IEP, 1988).

The third problem is impact to the fishery of Nashawannuck Pond. The decreased area and depth of the remaining standing water make the possibility of oxygen depletion under the ice a possibility. This could lead to a winter fishkill and reduced numbers in the spring. Currently, the fish community at Nashawannuck Pond does not present a particularly desirable one, as it is dominated with forage fish. Improvement of the fishery through the reduction of macrophytes is likely to outweigh the adverse effects of the drawdown. However, the frequency of using a winter drawdown as a lake management technique should take this factor into account.

The effect of the drawdown on the wetlands needs to be considered. The area affected by the drawdown would include wetlands marking the entry points of two of the major tributaries into the lake. Most of these wetlands should be kept well supplied with water by streamflow, although some dessication of marginal wetlands can be expected. During an experimental drawdown, the effects on these areas can be ascertained. If more water depth is required, there are two places where gabion weirs are recommended to be installed. These gabion weirs, (described fully elsewhere) act to increase depth in the wetland areas, decrease tributary sediment and nutrient loading. The two locations are in Nashawannuck Pond at a constriction of the southern Broad Brook arm and at the Nonotuck Park entrance road culvert.

The effect of the drawdown on the water supply of downstream users needs to be considered. The top elevations of the gates of the two sluiceways (#1,#3) which take water into the mill buildings are 144′ and 146.4′, respectively (MA DEM, 1987). Therefore, drawing down the pond to the minimal bascule gate elevation of 146′ would interfere with the performance of sluiceway #3. It is thus recommended that the bascule gate be brought down to no further than an elevation of 148′. This minimum level would allow a pond drawdown of 1.5 m (5 ft) while still assuring the water supply for sluiceway #3. There would be

0.5 m (1.6 ft) of water above the top of the gate valve to allow for wave and ice action.

The last problem connected with a winter drawdown is the required assurance that once drained, the lake can be refilled. As Nashawannuck Pond is an impoundment, refilling to a full pool simply becomes a matter of raising the gate and allowing tributary inputs to accumulate. The very rapid flushing time of Nashawannuck Pond (e.g., 7 days) during high flow events, such as those found during the spring, indicate that a refilling period of less than two weeks can be expected if all inflows are retained. Both the drawdown and the refilling are recommended to be stretched out over a one to two week period, so that downstream flows are moderated.

A more precise estimate of drawdown and refill periods may be required for permit considerations and actual operation of the drawdown. This analysis of the hydrologic characteristics of the Nashawannuck watershed could include estimates of: the calendar periods for drawdown and refill, the 25 year average flows in the receiving stream, the 7Q10 of the receiving stream and an analysis of the impacts of the drawdown and refill on the receiving stream. Some monitoring of the actual flows should be proposed.

This information would be used to calculate the periods most likely to ameliorate any negative effects of the drawdown and refill on downstream resources. Realistically, no significant impacts are expected on biological resources due to their nature. The actual receiving stream that would be most impacted is the wide concrete sluiceway that goes under the mill complex. This sluiceway currently supports no biota except attached algae. Approximately 400 ft beyond Nashawannuck Pond, the flow enters a channelized section. This canal runs for another 800 ft before it enters Lower Millpond. The water level of Millpond is determined by the spillway elevation of its dam. In other words, the receiving stream of Nashawannuck Pond is approximately 1,200 ft long, 1/3 of which is unlikely to support much biota under the best of conditions. While some of the calculations suggested above may be require to satisfy permit determination, the impact of this action on the receiving stream is likely to be negligible, due to its already heavily impacted state.

At the opposite end, the drawdown should not significantly impact the upstream movement of fish into the streams to spawn since streamflow will be normal throughout the filling period. A date for the complete refill should be agreed upon in consultation with the regional Division and Wildlife fisheries manager. In any event, the timing of the return of full pool size should be such that maximum depths are obtaining in time for spring stocking of trout.

The anticipated impact of the winter drawdown is a reduction in the littoral nuisance macrophytes in 50% of the area of Nashawannuck Pond. This program will not significantly change the nutrient budget of the pond. Some increased turbidity downstream may result from streamflow carving through drawdown sediments due to resuspension of fine silts and clays. However, significant transport of sediment is not likely due to the standing pool that will exist near the dam.

Costs, Permits and Summary

The projected costs of a winter drawdown are minimal, as the actual operation appears to require only a daily adjustment of the bascule gate. An operation which is well within the duties of current municipal employees. The determination of the best possible period for drawdown and refill should be made following analysis of hydrologic factors. This analysis should produce a specific drawdown protocol (list of instructions) for town employees regarding the dates and corresponding elevations of the bascule gate. A cost of $1,000 is allotted for this purpose, but it may be reduced if the town engineering staff is able to produce this information.

Apart from generic review by state programs (Natural Heritage Program, Historical Commission, and MEPA unit) of information generated in this study; contact is necessary with the Division of Fisheries and Wildlife and the Easthampton Conservation Commission. The latter may require a Notice of Intent under the Massachusetts Wetlands Protection Act with an Order of Conditions. The addresses of these agencies are given in the Permits table later in this section.

A winter drawdown of Nashawannuck Pond appears worthwhile, as the potential benefits are great and risks can be minimized. If successful in controlling macrophyte growth and improving boat access, winter drawdowns could be used as a management tool as needed, say at two to three year intervals. Monitoring of macrophyte cover and density would be needed to determine regrowth rates and the appropriate spacing of drawdowns, but this does not represent a major expense. A winter drawdown would be recommended for the additional benefit of supplying needed information required if dry dredging were to be implemented.

HYPOLIMNETIC RELEASE

Elements of Anticipated Impact of Bottom Water Release Program

One consequence of the eutrophic nature of Nashawannuck Pond is the pronounced oxygen deficit occuring in the deep northern basin during summer and winter months. This oxygen depletion of the bottom waters or hypolimnion is progressive over the period of stratification (Figure 8). Waters at or below about 3.5 m or elevation 142′ are the most seriously impacted. Two results of this lowered oxygen is loss of fish habitat for coldwater fish (e.g., trout), and the potential for anoxic remineralization of phosphorus. Calculation of the latter provides an estimate of 14.3 kg of total phosphorus per year derived from this source (Table 14).

Selective removal of bottom water would provide a means to induce replacement and mixing with the more oxygen-laden upper waters. One relatively easy way to accomplish this is allowing water from Nashawannuck Pond to exit from a lower elevation drain than by spilling over the bascule gate.

In the existing dam structure, the invert elevations and operational characteristics of sluiceway #2 (Figure 21) make it the best choice for removal of water. It has the lowest elevation, does not supply water for a downstream industrial application, and the discharge point is well known. The gate opening has an invert of 137′ and a 4′ height; producing a opening from 137′ to 141′ (MA DEM, 1987). This is precisely the right elevation to drain bottom water (<141′). The gate opening can be manually operated to produce varied size openings to adjust the flow more specifically. Additionally, all the sluiceways are protected by trashracks, and are in good operating conditions (MA DEM, 1987).

The amount of water that needs to be removed from the hypolimnion is not too great. Approximately 19,050 cu. m of water are affected by the oxygen deficit (see Appendix for details). If this released over a normal municipal workweek of 104 hours (8:30 AM Monday to 4:30 Friday), then the required flows are 3.1 cu. m/min, (1.8 cfs). This is a little less than 1/2 of the minimal flows recorded over the bascule gate during the study year summer (6.8 cu. m/min), so a combination of under and overflow could be used. The location of the discharge for sluiceway #2 is right below the highway bridge. This, coupled with the rapid aeration in the raceway, dilution with spillway water and the proximity of industrial buildings suggest that any odors connected with the hypolimnetic release will be minor and not located near sensitive receptors (e.g., hospitals). Further, this same raceway receives storm drainage and the underside of the highway bridge is the preferred roost for a considerable pigeon population, so ambient odors are already present.

The anticipated impact of this program would be the effective reduction of anoxic remineralization of phosphorus from the sediments in the deep basin. If conducted successfully this procedure would greatly limit anoxic conditions to all but the bottommost water and would remove an estimated 2% of the phosphorus budget.

Costs, Permits and Summary

As with the winter drawdown, the operation will only require activities within the proscribed duties of municipal employees. There will initially be some testing required to establish at what elevation the gate needs to be raised to allow these flows. It is unlikely to be more than 2", given a four foot width. If the minimal flow is greater than 3.1 cu. m/min., a shorter time period of release is needed. Using a Monday to Friday schedule, bottom waters can be periodically released during the summer and late winter. During the summer, "ventings" might be initially scheduled at roughly three week intervals. Monitoring of dissolved oxygen in bottom waters can then establish whether more frequent intervals should be used. In the winter, the higher watershed flows would allow for almost continuous release, if sufficiently low flows are possible with the gate. A cost of $500 is allotted for the purposes of determining the best timing and amount of release, as well as monitoring the oxygen level on a periodic basis.

Permits requirements are relatively straightforward. Aside from the generic state review process for any project (Natural Heritage, Historical, MEPA), there is need only for review by the MA DFW, Easthampton Conservation Commission, and MA DWPC. As the dam operation will still be essentially "run-of-river", no problems are anticipated. Due to the low flow and natural origin of the water, a requirement for a DWPC Water Quality Certificate is unlikely.

WATERSHED MANAGEMENT

Elements of Program

The most important source of nutrients to Nashawannuck Pond is from the Broad Brook sub-drainage basin, where they are derived from a variety of land uses. Reduction of these largely non-point sources has the greatest potential for improving the water quality and trophic status of Nashawannuck Pond. The White and Wilton Brook sub-drainage basins also contribute to the pond, but neither has the size or flow of the Broad Brook basin. Considering the relative size of the nutrient inputs and the location of the tributary inlets, the priority for clean-up should be the Broad Brook watershed followed by the White and Wilton Brook watersheds.

Addressing these non-point sources is a complex issue, containing both technical and strategic solutions. The technical approach combines elements of nutrient and sediment control, under what is broadly termed "Best Management Practices" or BMP's. A partial listing of these BMP's is given in Table 16 (MDWPC, 1988). These BMP's are an effective way to mitigate or eliminate nutrient/sediment loadings. Information and supervision for implementing these BMP's typically comes from the local Conservation Commission, town engineer or sanitarian, regional SCS or USDA staff. A strategic approach attempts to protect water quality through careful planning and decision-making about present and future land use in the watershed. The tools in this case are zoning ordinances, establishment of environmental setbacks and development options and other examples shown in Table 17. The personnel connected with making these decisions are the local Planning Boards, Zoning Board of Appeals, Board of Selectmen, Conservation Commission, the town planner, parks and recreation department and citizens groups (e.g., nature conservancy groups). Influencing local technical and strategic decisions are regional issues which transcend political boundaries. Aquifer and lake watershed management and protection are two examples of these issues. Regional planning agencies (e.g. Lower Pioneer Valley Planning Commission), aquifer or lake districts, and intermunicipal councils are likely groups to provide coordination at this scale.

Several lake management options for Nashawannuck Pond involve some sort of change in the watershed, often concerning modification of existing land uses or practices. These include agricultural and residential best management practices, land use controls, and changes in watershed resident practices. These are by no means independent entities, as all interact with each other. They are addressed below on an individual basis, but the means to promote all is best achieved by packaging this information in a single source.

Table 16. Best Management Practises Categories.

BEST MANAGEMENT PRACTICE CATEGORIES

1. Animal Waste Management
   a. Waste Storage Pond
   b. Waste Storage Structure
   c. Waste Treatment Lagoon
   d. Streambank Fencing

2. Pasture Management
   a. Prevent Overgrazing
   b. Pasture Planting
   c. Windbreak

3. Conservation Tillage
   a. No-Till
   b. Ridge-Till
   c. Strip-Till
   d. Mulch-Till
   e. Reduced-Till

4. Cover Cropping
   a. Off Season Planting
   b. Rotate crops with Sod

5. Contour Farming
   a. Contour Strip Cropping System

6. Nutrient Management
   a. Application Rate Control
   b. Eliminate Fall Applications
   c. Soil and Manure Testing
   d. Animal Waste Storage

7. Pest Management
   a. Use Less Persistent/Volatile Pesticides
   b. Application Timing/Method Control
   c. Use of Resistant Crop Varieties

8. Filter Strips
   a. Grass
   b. Forested

9. Grassed Waterways

10. Diversions & Terraces

11. Rehabilitate System
   a. Septic Systems
   b. Sewer Lines
   c. Upgrade Runoff Controls

12. Extended Detention Ponds

13. Wet Pond/Marsh

14. Infiltration Trench/Basin
   a. Dry Wells

15. Porous Pavement

19. Oil/Grit Separators

20. Stormwater In-Line Storage

21. Grade Stabilization
   a. Streambank Stabilization

22. Dredging

23. Tight Tank Bylaw
   a. Septage Receiving Facilities

24. Physical/Chemical Treatment
   a. Package Treatment Plants
   b. Capping
   c. Incineration
   d. Filtration

25. Education
   a. Septic System
   b. Lawn Care
   c. Boat Septage Handling
   d. Waterfowl

Source : MDWPC (1988).

Table 17. Zoning and Developmental Options (USEPA, 1988).

TOPIC	DEFINITION
Zoning	The regulation of building types, densities, and uses permitted in districts established by law.
Special Permits/ Special Exceptions/Conditional Use Permits	*Administrative permits for uses that are generally compatible with a* particular use zone, but that are permitted only if certain specified standards and conditions are met.
Variances	Administrative permits for uses that are generally compatible with a particular use zone, but that are permitted only if certain specified standards and condition are met.
Floating Zones	Use zones established in the text of a zoning ordinance, but not mapped until a developer proposes and the legislative body adopts such a zone for a particular site.
Conditional Zoning	An arrangement whereby a jurisdiction extracts promises to limit the future use of land, dedicate property, or meet any other conditions. The arrangement is either stated in general terms in the zoning ordinance or imposed on a case-by-case basis by the legislative or administrative body, prior to considering a request for a rezoning.
Contract Zoning	An arrangement whereby a jurisdiction agrees to rezone specified land parcels subject to the landowner's execution of restrictive covenants or other restrictions to dedicate property or meet other conditions stated in the zoning ordinance or imposed by the legislative or administrative body.
Cyclical Rezoning	The periodic, concurrent consideration of all pending rezoning applications, generally as part of an ongoing rezoning program, focusing upon one district at a time.
Comprehensive Plan Consistency Requirement	Provisions that require all zoning actions, and all other government actions authorizing development, to be consistent with an independently adopted comprehensive plan.
Zoning Referendum	Ratification of legislatively approved land use changes by popular vote, before such changes become law.
Prohibitory Zoning	The exclusion of all multifamily, mobile, modular, industrialized, prefabricated, or other "undesirable" housing types from an entire jurisdiction, or from most of the jurisdiction.
Agricultural Zoning/Large Lot Zoning/Open Space Zoning	The establishment of "permanent" zones with large (that is multiacre) minimum lot sizes and/or a prohibition against all nonagricultural development (with the exception of single-family residences and, possibly selected other uses).
Phased Zoning/ Holding Zones/ Short-Term Service Area	The division of an area into (1) temporary holding zones closed to most nonagricultural uses and/or with large minimum lot sizes, and (2) service areas provided with urban services and open for development in the near term (for example 5 years).
Performance Zoning/Performance Standards	An arrangement whereby all or selected uses are permitted in a district if they are in compliance with stated performance standards, that is, if they meet stated community and environmental criteria on pollution, hazards, public service demands, etc.
Flexible Zoning/ Cluster Zoning/ Density Zoning	Freedom from minimum lot size, width, and yardage regulations, enabling a developer to distribute dwelling units over individual lots in any manner the developer desires, provided (usually) that the overall density of the entire subdivision remains constant.

Table 17. Zoning and Developmental Options - continued (USEPA, 1988).

TOPIC	DEFINITION
Planned Unit Development (PUD)	A conditional use or floating zone regulated through specific design standards and performance criteria, rather than through the traditional lot-by-lot approach of conventional subdivision and zoning controls.
Subdivision Regulations	Procedures for regulating the division of one parcel of land into two or more parcels—usually including a site plan review, exactions, and the application of aesthetic, bulk, and public facility design standards.
Minimum Lot Size	The prohibition of development on lots below a minimum size.
Minimum Lot Size Per Dwelling Lot	A limitation on the maximum number of dwelling units permitted on a lot, based on the land area of that lot (usually applied to multifamily housing).
Minimum Lot Size Per Room	A limitation on the maximum number of rooms (or bedrooms) permitted on a lot, based on the land area of that lot (usually applied to multifamily housing).
Setback, Frontage, and Yard Regulations	The prohibition of development on lots without minimum front, rear, or side yards or below a minimum width.
Minimum Floor Area	The prohibition of development below a minimum building size.
Height Restriction	The prohibition of development above a maximum height.
Floor Area Ratio (FAR)	The maximum square footage of total floor area permitted for each square foot of land area.
Land Use Intensity Rating	Regulations that limit the maximum amount of permitted floor space and require a minimum amount of open space (excluding parking areas) and recreation space, and a minimum number of parking spaces (total and spaces reserved for residents only).
Adequate Public Facilities Ordinance	The withholding of development permission whenever adequate public facilities and services, and defined by ordinance, are lacking, unless the facilities and services are supplied by the developer.
Permit Allocation System	The periodic allocation of a restricted (maximum) number of building permits or other development permits first to individual districts within a jurisdiction and then to particular development proposals.
Facility Allocation System	The periodic allocation of existing capacity in public facilities, especially in sewer and water lines and arterial roads, to areas where development is desired while avoiding areas where development is not desired.
Development Moratorium/ Interim Development Controls	A temporary restriction of development through the denial of building permits, rezonings, water and sewer connections, or other development permits until planning is completed and permanent controls and incentives are adopted, or until the capacity of critically overburdened public facilities is expanded.
Special Protection Districts/ Critical Areas/ Environmentally Sensitive Areas	Areas of local, regional, or State-wide importance—critical environmental areas (for example, wetlands, shorelands with steep slopes); areas with high potential for natural disaster (for example, floodplains and earthquake zones); and areas of social importance (for example, historical, archaeological, and institutional districts)—protected by a special development review and approval process, sometimes involving State-approved regulations.

Adoption of Best Management Practices

A best management practice (BMP) is defined as "a practice or combination of practices that has been determined by the Massachusetts DEQE to be the most effective and practicable means of preventing or reducing the amount of pollution generated by non-point sources to a level compatible with water quality goals" (Massachusetts River Basin Planning Program, 1984).

In a survey of agricultural water quality in Massachusetts, the Broad Brook watershed was ranked as a "high priority" watershed (as was the Manhan River) due to the relatively high proportion of phosphorus in the surface water that was linked to agricultural practices (MRBPP, 1984). The average added total phosphorus in water resources was estimated at 31 ug/l due to erosion and 11 ug/l due to livestock and poultry manure. The estimated sum of 42 ug/l total phosphorus introduced into Easthampton water resources is probably an overestimate for the Broad Brook due to the type of agriculture and possible decrease in active acres (estimate was based on 1980. Nonetheless, the current total undoubtedly constitutes an appreciable portion of the current (1987-88) average of 50 ug/l total phosphorus in Broad Brook. Tributary water quality from the diagnostic study also suggests that agricultural practices in the Holyoke portion of the Broad Brook watershed export large nutrient totals.

The application of agricultural best management practices (BMP's) is highly desirable but can provide an economic burden to the farmer that is not easily borne and may, in fact, lead to a less desirable state of affairs for the watershed (overdevelopment). Currently, there are a diversity of programs, but limited money available for implementation, and the economic status of many farms preclude intensive individual action. Further, the economic pressure and monetary incentives to sell farmland for residential developments that exist in Easthampton Southampton, and Holyoke do not encourage adoption of additional costs on the area's remaining farmers.

At this time, a less stringent approach is suggested; that of gradual education and adoption of BMP's through propagation of information on alternative farming methods which are both economically beneficial to the small farmer and represent good stewardship of the land. These practices are also beneficial in reducing the effects of cultural eutrophication and sedimentation in Nashawannuck Pond. Information on BMP'S and watershed erosion protection is available from the United States Soil Conservation Service (SCS), whose nearest field office is in Hadley, Mass., the Cooperative Extension Service, University of Massachusetts, Amherst, and the New England Small Farms Institute, Belchertown. A description of the more relevant BMP's is listed in the Appendix (USEPA, 1988).

Another fertile area for adoption of BMP's is with regard to residential development in both the White and Broad Brook watersheds. Treatment of septage and storm drainage are two important factors determining water quality. Sanitary sewers are preferable to on-site wastewater management ("septic") systems. If the latter are used, their proper care and maintenance is important for the minimization of pollutant loading to the groundwater. A variety of educational materials regarding septic systems is available (see Appendix A for a partial listing).

The careful management of stormwater runoff is getting increasing attention with the growing awareness of the need to manage not only for flood protection, but for water quality, as well (Schueler, 1987). There are many alternatives to simply routing runoff from impervious surfaces to the nearest watercourse. These include use of : filter strips, grassed swales, detention ponds (both dry and wet), infiltration trenches and leaching basins. Selection of the most appropriate BMP is always dependent on site-specific characteristics such as the amount of storm flow, distance from wetland resources, depth and nature of the soils, proximity to aquifer recharge zones, and maintenance considerations. A matrix illustrating some of the factors used in the screening the appropriateness of BMP's is shown in Figure 22.

Land Use Controls

Protection of lake water quality through zoning ordinances involves possible changes of local regulations intended to provide for more comprehensive protection of Nashawannuck Pond. Easthampton and Holyoke should potentially designate sensitive areas for either re-zoning, protection from development, or accompanying strict orders of conditions for development. Southampton's portion of the watershed area of Nashawannuck is relatively slight, so action there is desirable but less imperative.

The town of Easthampton recently underwent a study looking into possible revisions of the master plan (LandUse, 1987). The zoning by-laws were judged well organized and logical, but not especially conducive to creative development options (Table 17) or protection of agriculture. The existing zoning classifications for the Nashawannuck Pond watershed in Easthampton are shown in Figure 23. In the Broad Brook and White Brook watersheds the major types of zoning are varying residential (R-10,R-15,R-35), although agriculture is important in the R-35 zones. In the Wilton Brook watershed, business and industrial zoning are also present.

Recognition and management of the watershed and sub-drainage basins is necessary to improve or protect tributary water

Figure 22. Common Restriction on Best Management Practices (Schueler, 1987).

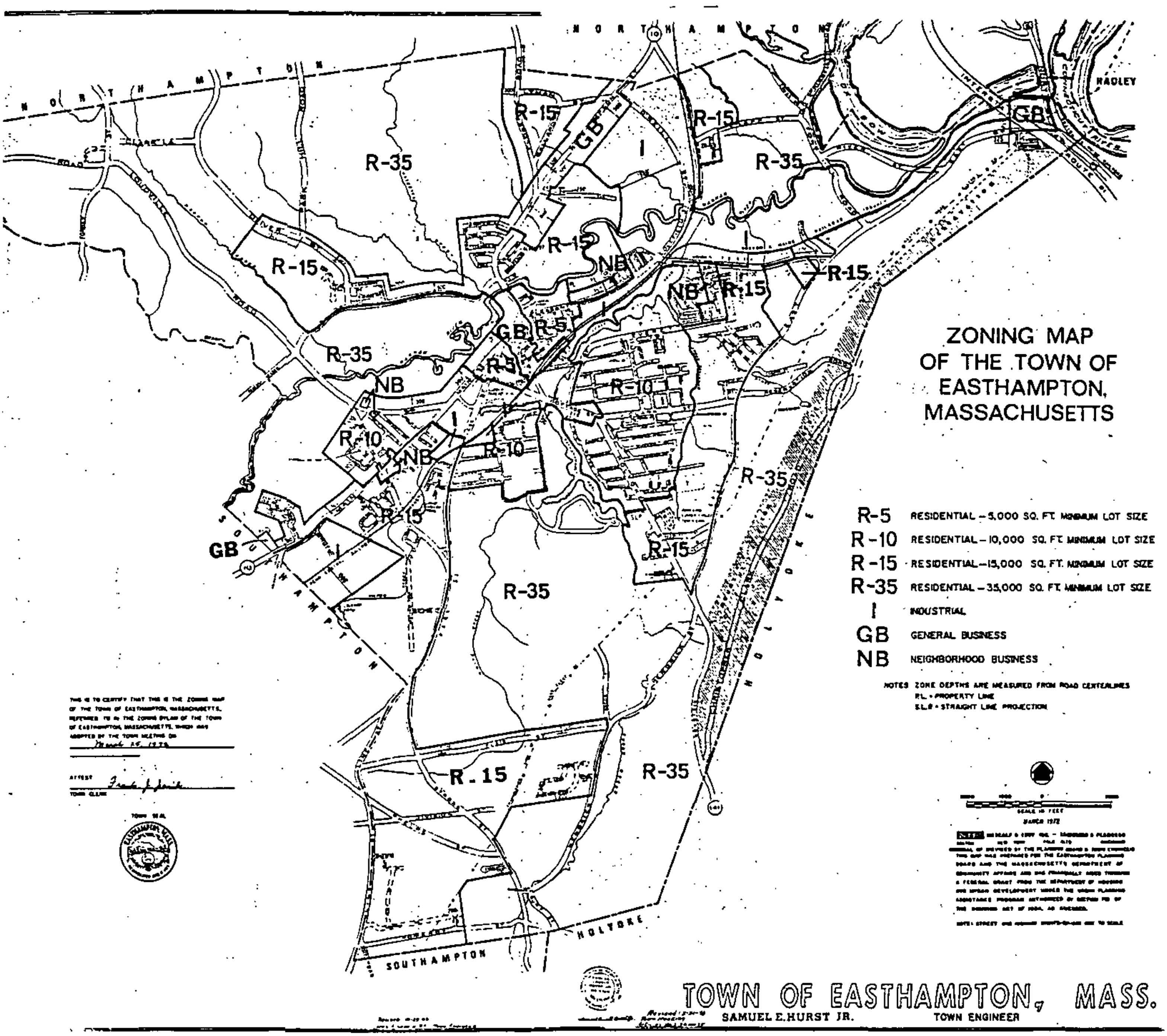
BMP	SLOPE	HIGH WATER TABLE	CLOSE TO BEDROCK	PROXIMITY TO FOUNDATIONS	SPACE CONSUMPTION	MAXIMUM DEPTH	RESTRICTED LAND USES	HIGH SEDIMENT INPUT	THERMAL IMPACTS
EXTENDED DETENTION POND	●	●	◑	●	○	●	●	◑	●
WET POND	●	●	◑	●	○	○	●	◑	○
INFILTRATION TRENCH	○	○	○	○	●	○	●	○	●
INFILTRATION BASIN	◑	○	○	◑	◑	○	●	○	●
POROUS PAVEMENT	○	○	○	○	○	○	○	○	●
WATER QUALITY INLET	●	●	○	○	●	○	○	○	●
GRASSED SWALE	○	○	◑	◑	●	●	○	○	●
FILTER STRIP	◑	◑	◑	◑	●	●	◑	○	●

○ MAY PRECLUDE THE USE OF A BMP

◑ CAN BE OVERCOME w/ CAREFUL SITE DESIGN

● GENERALLY NOT A RESTRICTION

Figure 23. Zoning Map of Easthampton.



quality. Each sub-drainage basin should be evaluated to see whether potential threats to the well being of Nashawannuck Pond water quality exist. Existing threats should be eliminated or mitigated. This has been done to some extent in the course of the aquifer land acquisition study recently completed (IEP, 1988). What is most needed is that the agent of future change, i.e., the planning boards, take into consideration the implications and effect that zoning changes have on water quality. The rationale behind any resulting restrictions is that where water quality is concerned , it is much more cost effective to extend regulatory protection now than pay for a costly clean-up program (or repetition of such) later.

The acquisition of open space land and "greenbelts" along the major tributary streams to Nashawannuck Pond is part of the recommendations of the master plan revision study (LandUse, 1987). In addition to providing recreational space, these areas reduce nutrient and sediment loadings to Nashawannuck Pond, and are consistent with other town goals (e.g., aquifer protection). The Conservation Commission and Pascommuck Trust could provide the expertise and means of selecting and preserving environmental sensitive areas. Grants for acquiring conservation or open space land are available through the Federal Land and Water Conservation Fund (EOEA, Federal Pass Through) or the Massachusetts Self-Help Program (M.G.L. Chap. 132).

For the Broad Brook watershed, another useful program is the Division of Fisheries and Wildlife 's Riverways Program, better known as "Adopt-a-Stream". This program aids in the protection of natural stream corridors through assistance in public education and technical expertise. Given the intermunicipal meanderings of Broad Brook, this program may act as the nucleus to a citizen's coalition group. Broad Brook is particularly important due to the location of the Hendrick St. well field along it stream corridor. White and Wilton Brooks are less amenable for this program due to their shorter length and less frequent use by abutters. Information about this program is included in the Appendix.

Acquisition of land for agricultural preservation is another important land use decision in the Nashawannuck watershed. Land can be retained for agricultural purposes through several programs including the Agricultural Preservation Restrictions Act (M.G.L. Chap. 780), the Farmland Tax Assessment Act (M.G.L. Chap. 61A), and the Massachusetts Farm and Land Conservation Lands Trust. At the local level, creation of agricultural preservation districts or enablement of transfer of development rights are ways that agriculture and its life style can be preserved within a town. These decisions are related to the town's perception of its image and future cultural inheritance.

With regard to agricultural preservation and water quality in Nashawannuck Pond, no recommendation can be easily made. In the long term, agricultural land use usually has a greater potential for export of nutrients and sediment that residential land use. This does not mean that a well-managed farm will inevitably export more nutrients and sediment than a large residential sub-division. The reverse may be true, particularly during construction of the latter. However, as the disturbed land is revegetated and stabilized, loadings from residential areas decline, while agriculture provides an annual disturbance of the land and application of fertilizers, herbicides, and pesticides. If best management practices are judiciously applied, thought, both types of land use can be made compatible with good water quality.

Regional Issues

The Easthampton aquifer provides a good example of a regional issue. This aquifer, the major source of drinking water in Easthampton, stretches from Southampton to Northampton (IEP, 1988). Major recharge zones for the strata serving the town wells have been identified in the Nashawannuck Pond watershed. Proposed residential development in these identified recharge zones incur additional constraints which must be considered when evaluating their impact. Since the aquifer and Nashawannuck Pond watershed have much overlap, protection of water quality, whether of groundwater or surface origin, has a double benefit.

Adoption of BMP's within the aquifer area needs to be addressed. A proposed aquifer basin council (pers. comm., P. Klejna) seems like a promising approach to this problem. If appropriate, purchase of open space plots in the aquifer recharge zone could be funded by the Massachusetts Aquifer Land Acquisition Program (M.G.L. Chap. 286).

A proposed state program for the reduction of non-point sources has much promise for the Nashawannuck Pond watershed. Funding ($50 million) is being sought for the Massachusetts Nonpoint Source Program. The proposed program is analagous to the Massachusetts Clean Lakes Program; with the effort and monies being spent on the watershed lands rather than the lakes of the Commonwealth. Passage of this proposed legislation is uncertain at present. If and when these monies are made available, the Nashawannuck Pond watershed should make a good candidate due to the importance of non-point sources to the lake's nutrient budget, the large, intermunicipal size of the watershed, the status as a "high priority" watershed for reduction of agricultural inputs, and the popularity and visibility of the pond as a recreational resource. It should be emphasized that this is a future option, which is at least two or more years away from realization.

Cost and Summary

All the programs identified above are interrelated, though obviously at different scales of public awareness. At the individual level, the desire, however intangible, is to instill a sense of responsibility for the water leaving one's property, be it in a stream, a curb gutter or a septic waste. At the town level, the balance between controlled development and protection of the towns natural resources must be maintained. Intermunicipal or regional education is necessary to reinforce the notion that the events in any part of a watershed, however distant, will affect the water down below (Dunne and Leopold, 1978).

The amount of money recommended for this option ($30,000) is obviously inadequate to directly clean up such a large watershed. What this money is slated for is to provide educational materials and the establishment of watershed councils to implement and coordinate efforts at reducing sediment and nutrient loadings into any water resource. Development of an educational program for presentation at town meetings or to educate local officials is merited. Printing costs would be picked up by the program. Distribution of educational materials can be handled through the town. Local conservation commissions, planning boards, and/or recreation departments seem likely candidates to serve as clearinghouses for such information. Contact with other towns should be made through like agencies. Promotion of Broad Brook for the "Adopt-a-stream" program is recommended.

The amount of phosphorus reduction that can be expected from this option is difficult to precisely predict. Watersheds such as Broad or White Brook would benefit from watershed management and agricultural BMP's. Better septic system performance would reduce some of the direct and diffuse loadings to White Brook. Overall, an estimated range of between 10 and 20% of the phosphorus would be eliminated. The actual amount of phosphorus reduction realized will be a function of the intensity at which local officials pursue implementation of BMP's in existing and future regulated activities.

The potential for greater actions and phosphorus reduction is linked to the town receiving funding for a Nonpoint Source Program. This option will be viable only at some future date. However, the organization and infrastructure which would oversee implementation of a reduction program is latent in the intermunicipal aquifer planning council.

INSTALLATION OF GABION WEIRS

Elements of the Program

The wetlands at the base of the two southern tributary arms (Broad and White Brooks) act as sediment and nutrient sinks. Increasing the detention time of water in these areas is an effective, low cost means of removing particulate pollutants and controlling increases in downstream bank erosion (Schueler, 1987). Settling is the primary pollutant removal mechanism associated with extended detention. Reduction of the dissolved fraction of pollutants is mediated via biological uptake by wetlands plants.

Establishment of greater detention is accomplished by installation of gabion weirs. These are rectangular cages made of hexagonal woven steel wire mesh laced together and filled with stone. Resistance to the elements is provided by zinc coating; with additional PVC put on for further protection. They are initially pervious and pass ambient flows. Filter fabric is placed over the gabions for faster closing of voids. In addition the filter fabric will not allow passage of silty soil, so will it will collect behind the gabions.

The location of the two proposed gabion weirs is shown in Figure 24. The gabion weir on the White Brook watershed is located just west of twin 48" culverts which carry flow under the Nonotuck Park entry roadway. The intention is to create a 1 ft pool behind the weir, with flow passed through notches located at the approximate location of the existing stream channels. Details of the proposed weir scheme are shown in Figure 25. The existing wetland behind the culverts would shift from largely forest and shrub vegetation to largely emergent grasses and reeds. More importantly, the existing channels that carry the water would expand and merge into a more continuous sheet of water. The more extensive the water-sediment interface and contact time, the greater particle/nutrient removal is enhanced.

By creating a shallow pool behind the weir, additional sedimentation and purification of the waters of White Brook is possible. This may be of greater significance in the future, particularly since residential development in the White Brook drainage is likely in the next few years. Further, this detention area can also serve as the destination for storm drainage off roads in Nonotuck Park. Funding is currently being sought to repair the park infrastructure, and this detention area makes a much more appropriate location for the stormwater than the alternative - routing into Nashawannuck Pond.

The other weir is located on the Broad Brook arm of Nashawannuck Pond, approximately 75′ north of the edge of the

Figure 24. Location of In-Pond Restoration Options.

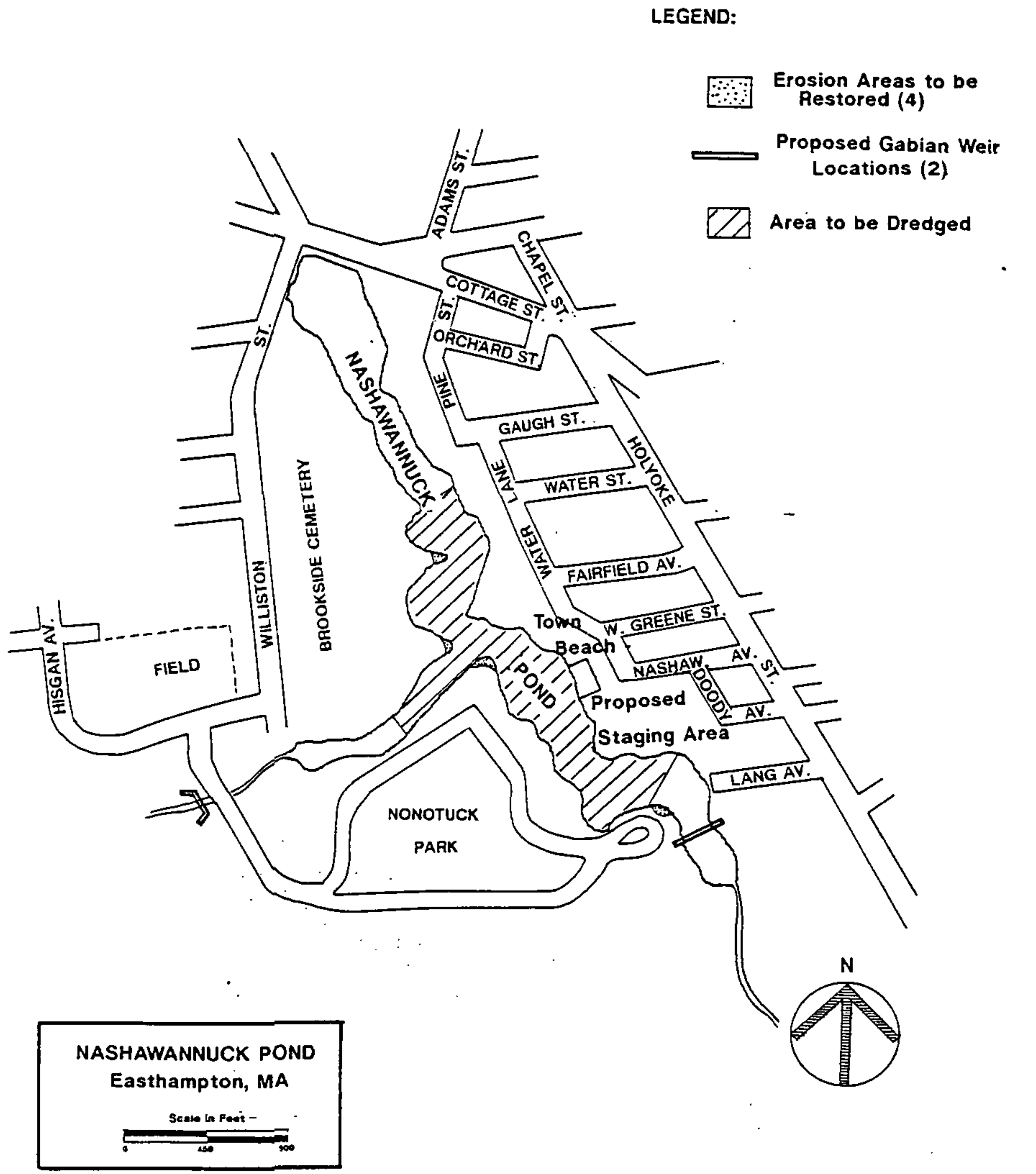
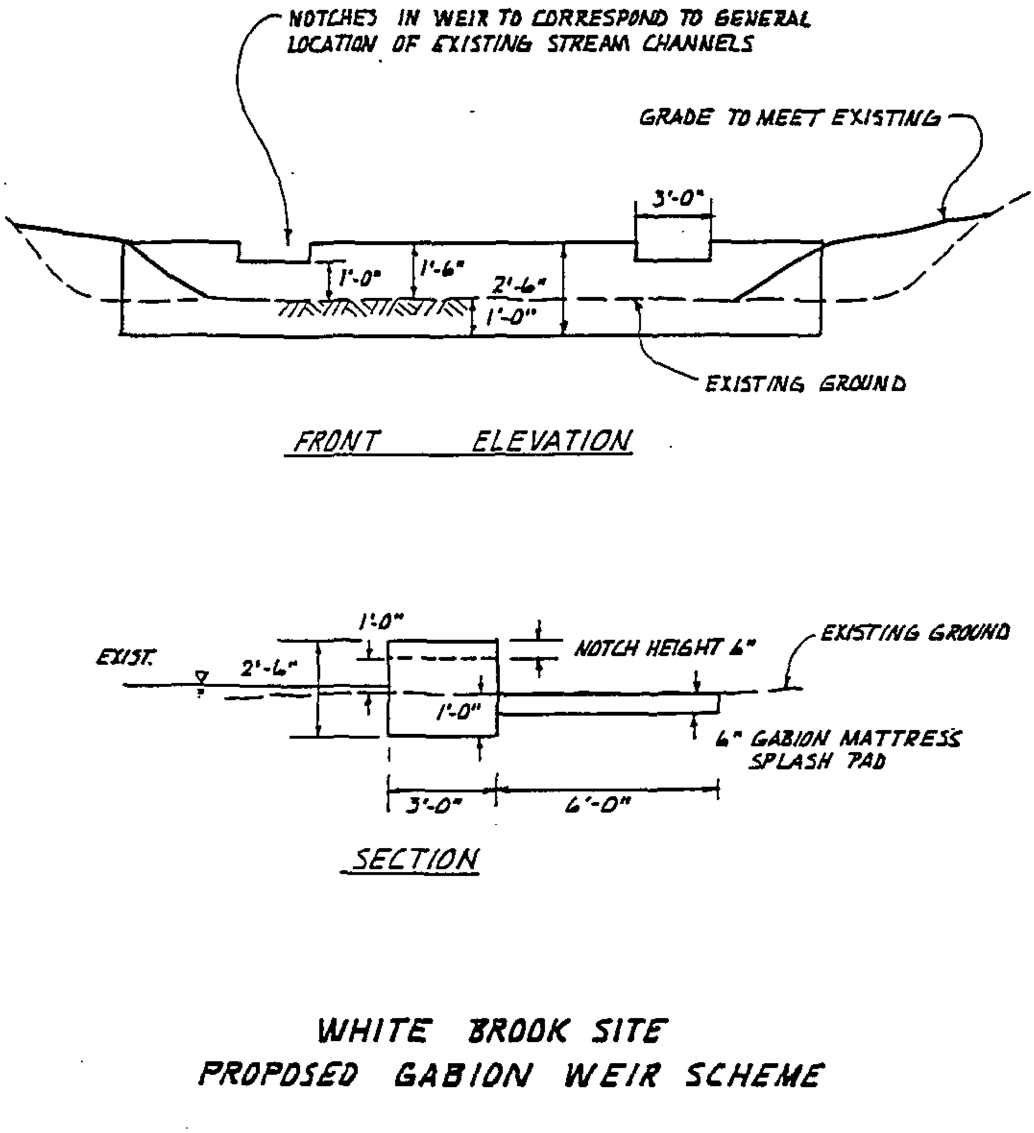


Figure 25. Proposed Weir for White Brook.



existing emergent wetland. This structure will be placed in the bed of the lake on a gabion mattress. The top edge of the structure will extrude from 0 to 6" from normal lake levels. There is a splashpad for use during drawdown situations. Extremely low flows would be directed through a central notch. The bottom elevation of the notch is set at the normal pool elevation or 153.2′ (above MSL). A sketch of the proposed structure is given in Figure 26.

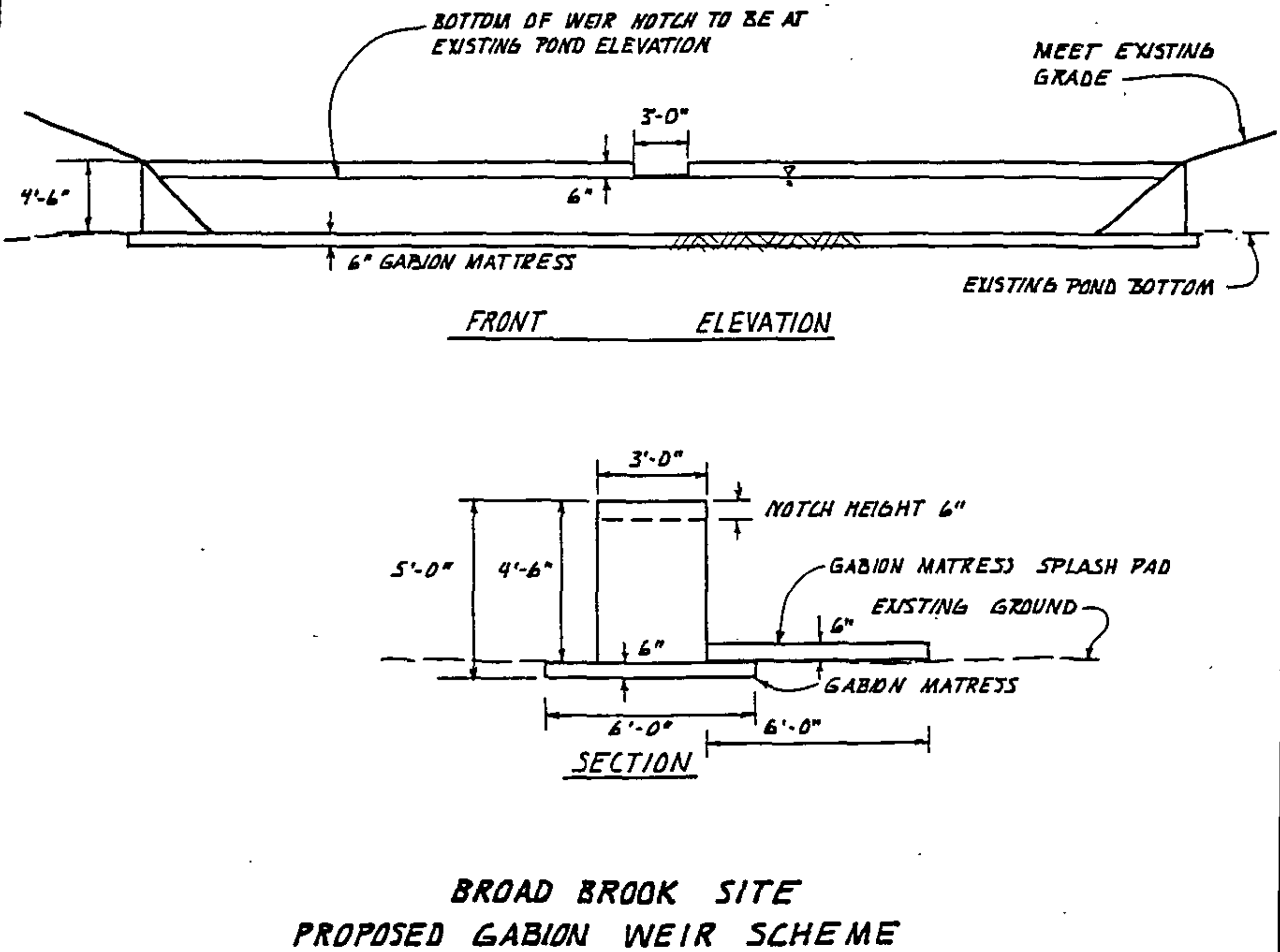
The usefulness of this proposed gabion weir is twofold. During normal flows it enhances nutrient and sediment removal for Broad Brook, the most important tributary. During times of pond drawdown, whether for periodic passive macrophyte control, such as a winter drawdown, or for an extended period of time, as when sediment excavation is underway, the gabion weir would maintain the level of water in the wetland area just to the south. This maintenance of the water level would preserve the integrity of this good quality wetland. Note that the gabion is easily overtopped by storm events (due to the small pool storage), and there would be no adverse effects due to flooding.

Anticipated Impacts of the Gabion Weirs

The amount of nutrients removed by the gabion weir options is a function of the removal efficiencies of both the ponded area and the wetlands. Both areas serve to remove particulate and dissolved fractions of phosphorus and nitrogen. Recent work with stormwater treatment by a combined wet pond - wetland system has reported removal efficiences of total phosphorus from 22 to 43%, and for total nitrogen, 15 to 36% (Martin, 1988). [The differences were related to the weighting of the storm events]. Alternatively, estimates of nutrient and sediment removal in wet ponds are well documented (Schueler, 1987). These efficiencies can approach 95% but are generally a mostly a function of basin size (i.e., flow detention time).

The White Brook weir will create a ponded area where presently a marginal red maple swamp exists. Development of a more extensive wetland with reeds and cattails will greatly increase the efficiency of pollutant removal. Given a storage space of 1 to 1.5 ft (Figure 25), a estimated pool of 2.5 acre-ft would result. The annual flow is 1.6 cu. m/min (0.95 cfs), resulting in a mean detention time of about 32 hours. This period would greatly increase in the summer time (June - August) when flows average about 0.38 cu. m/min (0.22 cfs). Even though higher efficiencies are possible, expected reduction of total phosphorus is conservatively estimated at 30%; with reduction of total nitrogen estimated at 25%. Since the annual total phosphorus load of White Brook is 55 kg P/yr; the amount of reduction is estimated at 17 kg P /yr. The amount of total nitrogen removed from White Brook would be 514 kg TN.

Figure 26. Proposed Weir for Broad Brook.



The weir on the Broad Brook arm will create a smaller pool, since the amount of storage possible is only 0.5 ft. An estimated two acres behind the weir produces a pool storage of 1.0 acre-ft. Due to the high flows of Broad Brook of 17 cu. m/min. (10 cfs), detention time is only slightly greater than one hour on a annual basis. Even summer flows would exit the pool in about two hours. The amount of reduction in nutrient loading would be estimated as low, at 10% removal efficiency. This would largely be associated with particle settling. Reduction of the dissolved nutrient fraction by plant uptake would also be functioning, but this removal is already existing and is not created by the installation of the gabion weir. Therefore an estimated 44 kg of total phosphorus and 1,186 kg total nitrogen would be removed by this option.

The combined nutrient reduction by this option is 61 kg P or 9% of the total phosphorus budget and 1,700 kg TN or 10% of the total nitrogen budget. It should be noted that a major reduction in the tractive or bedload transport of large particles in Broad Brook can be expected.

The impact of the gabion weirs to the fisheries of Nashawannuck Pond must be considered. The impact on the put-and-take trout fishery will be negligible as the fish will tend to the deeper basin at the northern end. During a drawdown, the gabions would act as barriers to migrating fish, must notably white sucker. These fish would tend to congregate below the gabion outlets, and be more susceptible to harvesting. However, negative impacts to this species (reduction or demise) may prove beneficial to the overall fish population (pers. comm. - R. Madore; see Appendix C).

Cost, Permits and Summary

The amount of money required for the installation of the gabion weirs at the two proposed locations is $52,000 (Table 18). The White Brook weir is the less expensive of the two at $14,000. The more lengthy Broad Brook weir is priced at $38,000.

Permitting requirements are fairly extensive for this option (see Table 26). There are the generic requirements for State aid (Title to Project site, Intergovernmental Agreement, Fair Housing, Commission against Discrimination, and Wage Rate Compliance) and usual state review (MEPA, Natural Heritage, Historical, Fisheries). In addition, a Section 404 permit from the Army Corps of Engineers; a Waterways Permit (Chap. 91) from the Division of Wetlands and Waterways, and a Notice of Intent filed with the Easthampton Conservation Commission.

Overall, the gabion weirs provide dual protection for the lake water quality during normal flow and for the wetlands during periods of drawdown. They act to mitigate present pollution and provide additional protection and options for future development in their watershed (e.g. White Brook). Further, if the bulk excavation of sediments is done in Nashawannuck Pond, these weirs would act to reduce sedimentation and prolong the benefacial effects of this dredging action.

TABLE 18

COSTS ASSOCIATED WITH GABION WEIR REPLACEMENT

Item or Task	Estimate Cost	Maximum Percent Reimbursable Under Clean Lakes Program
White Brook		
1. Engineering and survey	5,000	
2. Three (3) 12' x 2.5' weirs at $100/LF	3,600	
3. Installation of stone fill 10 CY @ $150/CY	1,500	
4. Excavation 50 CY @ $5/CY	250	
5. Repair of present erosion	1,000	
6. Grading and restoration 10 CY @ $5/CY	50	
7. Construction of access road	1,000	
8. Filter fabric	300	
9. Ten percent contigency	1,300	
Subtotal	$14,000	75
Broad Brook		
1. Engineering and survey	7,500	
2. Seventeen (17) 12' weirs at $100/LF	20,000	
3. Installatin of stone fill 20 CY @ $150/CY	3,000	
4. Grading and restoration 100 CY @ $5/CY	500	
5. Construction of access road	2,500	
6. Filter fabric	1,000	
7. Ten percent contingency	3,500	
Subtotal	$38,000	75
PROJECT TOTAL	**$52,000**	**75**

DREDGING

Introduction

Dredging in Nashawannuck Pond would involve the removal of significant amounts of organic hydrosoil in the central area. Dredging is an effective means to reduce macrophyte infestation by removal of existing plants and organic sediment layers and help limit future growth by increasing depth. The importance of the additional depth is in the reduction of light penetration to the bottom dwelling plants; limiting or severely reducing their growth. Reduction in the amount of surface cover is also seen, as the plants have to grow taller to reach the surface. Often species replacement also occurs such that successful plants are shorter and of a non-nuisance type (e.g. Nitella, Najas).

By fundamentally changing the lake's morphometry, dredging provides a restoration that is relatively long lasting. The increased storage capacity affects hydraulic and physical relationships such as flooding and thermal stratification. This alters nutrient loading, budgets and recycling within the waterbody, with accompanying changes in the trophic levels of the biota. As many of these changes tend to reduce the effects of eutrophication, an overall improvement in the lake's water quality is predictable.

The anticipated effective "lifetime" of improvement achieved through dredging is always an unique estimate due to the individual nature of lakes, but is heavily influenced by the rate and amount of sedimentation. Sedimentation rates in the dredged area will be determined by a combination of factors including: the amount of erosion in the watershed, the migration of in-lake sediments, and major storm events (e.g., hurricane of 1955). It can be anticipated that erosional rates in Easthampton will decrease over the heavy loadings of the past that created two emergent wetlands. Construction intensity is likely to be more distant in nature and better managed than in the past, due to the more stringent sediment controls now currently required. For sediments that do enter the tributaries, the combination of the existing wetlands and gabion weirs provide potential settling areas. Widespread migration of the in-lake sediments will be prevented by the extensive macrophyte beds in place in the upper arms. Rerouting of storm drainage would also reduce some of the sediment load. If watershed erosion controls are strictly adhered to, the effective lifetime of the dredging should exceed at least 20 years and quite possible be effective for much longer.

Dredging is often the most cost-intensive lake restoration method, but can be less expensive if done with conventional excavating equipment under drawdown conditions (dry dredging). Alternatively, dredging can be conducted with water present (hydraulic dredging). Since Nashawannuck Pond is an artificial impoundment, dredging can be done in either way. The cost effectiveness of each of these methods depends upon the physical and chemical characteristics of the organic bottom materials to be removed and the availability of disposal areas for dredged materials. Thus, design and siting of the basin should also be figured in the cost. Hydraulic dredging requires temporary storage and disposal of the dredged materials in a basin adjacent to the lake. Treatment of the water removed during the dredging process is also often required prior to its re-entry into the lake. Such a discharge may require a NPDES permit for operation. Dry dredging or excavation can present less difficulties with regard to dewatering, but still requires a temporary site for drying of the dredged material before its final disposal.

Bottom sediment core sampling in Nashawannuck Pond has shown the benthic materials to consist primarily of organic muck and sand overlaying clay. As shown in Figure 16, the depth of soft sediments in the lake range from approximately 0.5 to greater than 3.0 meters. The location of the sediment sampling stations are also shown on Figure 16.

The area to be dredged is located in the central portion of the pond, adjacent to Nonotuck Park and preferred recreational areas. The total material to be removed in this manner will be approximately 55,300 cu. m (72,300 CY). This estimate is based on removal of soft sediment to a hard bottom, in this case a clay layer. The areas to be dredged are indicated on Figure 24.

Using conventional equipment, the lake would be drained to the necessary level and the bottom material would be removed and stockpiled utilizing low ground pressure excavation equipment. This material would then be loaded onto trucks using front end loaders and brought to a suitable site for drying and stockpiling. The former town beach could be utilized for equipment staging and the stockpiling of dredged material. This dredged material would ultimately be removed and disposed of elsewhere. The most cost effective disposal would be in Nonotuck Park. Access to the park from the pond could allow quick and inexpensive temporary disposal; with final disposal on town lands or within the park itself. The characteristics of the bottom sediments from the proposed dredging area (Table 6) allow for disposal in upland areas.

Because Nashawannuck Pond is an artificial impoundment, it can be drawn down and excavated by conventional means. Nashawannuck Pond has been drawn down for construction of the dam and outlet structure. Because the proposed dredging is in the upper reaches of the pond, the water level can easily be lowered below the proposed excavation elevations. Historical photographs of the lake bottom taken of the reconstruction of the dam after the hurricane of 1955 confirm this viewpoint.

Consolidation tests done on similar organic lake bottom sediments (BEC, 1986) indicate that seepage stresses which will be induced during the draining of the lake should bring about a consolidation in volume of approximately 25% for the upper 2 meters of loose organic material. These seepage stresses are of about the same order of magnitude (0.1 kg/cm2) as the working pressure applied by the various low ground pressure excavating equipment. This indicates that low ground pressure, track mounted, 2 cubic yard bucketloaders should be able to work in the Nashawannuck Pond sediments without encountering too much difficulty.

It must be emphasized however, that there are several types of construction equipment available for excavating this material (i.e., bulldozers, bucketloaders, scrapers). The exact equipment utilized will be dependent upon what works best for the selected contractor in actual field operation. Extensive field testing, including perhaps a drawdown and pilot excavation program may be warranted.

In order to dredge Nashawannuck Pond by conventional means, the pond would first be drawn down and the sediments in the upstream arms would be given a chance to consolidate. Excavation equipment would then be utilized to remove the bottom materials to the desired elevations. Typically this operation is done by a backhoe or front end loader. The hydrosoil removed in this fashion is then either stockpiled for drying or directly loaded into trucks. If the latter a road will have to constructed so that a fully loaded truck can travel in the pond area. The trucks would exit from the pond from various locations, depending on what area was being dredged; in the Broad Brook arm via a ramp from the former town beach onto Water Street or alternatively into Nonotuck Park.

Another concern is the need to pass the continuing flowing waters of Broad Brook and White Brook through the construction area while excavation is going on. The best approach for minimizing the impact of trucks and construction equipment on the stream is to pipe the stream under crossings. Approximately two 30 ft length of 24" corrugated metal pipe would be needed. To reduce the amount of dirt tracked out of the pond, an anti-trucking mat is strongly recommended at the staging area and the edge of the pond.

Project Duration and Anticipated Impacts

The total time required to dredge Nashawannuck Pond by conventional means is dependent on the equipment utilized. A combination of backhoes, front end loaders or bulldozers, along with enough trucks to keep the excavation equipment working continually (probably four or five 12 CY dump trucks), could maintain a production rate of approximately 800 m^3 (1,050 CY) per day. Approximately 68 working days would be required to dredge the pond.

The project could easily be shortened by increasing the number or size of equipment utilized. There is no cost penalty for doing this with conventional dredging. In fact, it may represent a cost savings for the selected contractor. To be conservative, the dredging project is projected to last two working seasons (fall-winter) with the pond refilled in the summer to allow recreation.

Dredging would alter the nutrient budget of Nashawannuck Pond. This would be through the removal of phosphorus-laden sediments and reduction of the macrophyte "pumping" of phosphorus from the sediments. In this analysis the effect of the latter is not considered. While the macrophytes undoubtedly translocate phosphorus from the sediments, they also remove phosphorus from the water column. The counterbalancing of these factors makes the effect of the removal of the sediments on the phosphorus budget hard to estimate. However, the importance of the macrophyte pumping will increase as watershed management is practiced. Resuspension of bottom material can also lead to remineralization of sediment phosphorus.

Estimates for contribution of sediments and macrophytes from other ponds (BEC, 1988a; 1988b; 1989a; 1989b) range from 5 to 33%, with an average of 18%. For Nashawannuck, dredging is estimated to remove about 5% of the phosphorus budget, or the lower end of the range. The low value is due to the fact that not all of the sediments are going to be removed. This option can be considered to yield a tangible improvement in water quality if coupled with other efforts. In addition, it has significant benefit for recreational use due to the removal of nuisance macrophyte beds.

Costs, Permits and Summary

The cost projection for the conventional excavation of 55,300 m^3 (72,300 CY) of material from Nashawannuck Pond is based upon utilizing the town beach or Nonotuck Park as a temporary disposal/dewatering area. Embankment construction will probably not be required or minimal. Final disposal in Nonotuck Park would greatly reduce transportation costs and represents some potential savings in the project.

It is estimated that it will take approximately six months to dredge the entire pond by conventional means, although the project could be shortened without increasing the costs. Table 19 summarizes the cost estimate for conventional dredging; past experience with similar situations allows BEC to estimate the magnitude of the costs. The total cost of dredging Nashawannuck Pond by conventional means is projected to be $1,120,000.

Dredging is a complicated process and, as such, will require an extensive permit process (Table 26). Aside from the generic state requirements and review; the Executive Office of Environmental Affairs (MEPA) unit would require either an Environmental Impact Report or Environmental Impact Statement. Due to the actions in water resource areas, a Notice of Intent would be required to be filed with the Easthampton Conservation Commission. A Section 404 permit from the U. S. Army Corps of Engineers may be required. A Waterways Permit and a Water Quality Certificate, and a permit from the Division of Solid and Hazardous Waste would be required from the Massachusetts Department of Environmental Quality Engineering.

A monitoring program will be required for the dredging process. The cost of monitoring during dry dredging is estimated at $15,000. Post-project monitoring would cost approximately $4,000.00/year. This program is fully described in a later section.

TABLE 19

CONVENTIONAL EXCAVATION COST SUMMARY

Task		Cost ($)	Maximum Percent Reimbursable Under Clean Lakes Program
A.	Engineering and Design Expenses (Consultant Services)	80,000	75
B.	Excavation Costs		
	1. Bulk Excavation		
	Backhoe $5.50/CY @ 2 CY Bucket	396,000	
	Dozer $2.30/CY @ 21 CY Capacity	96,000	
	Scraper $2.80/CY @ 11 CY Capacity	84,000	
	2. Hauling		
	12 CY Dump 3.0 mi. avg. Round Trip @$2.50/CY	180,000	
	Subtotal	756,000	75
C.	Staging Areas		
	1. Staging area prep. & restore	7,500	
	2. Gravel road 500 ft x 15 ft (6-12" deep) @ $30/CY	17,000	
	3. Two culverts 24" CMP 30 LF @ $25/LF	1,500	
	4 Anti-tracking mat 20′ x 50′	1,000	
	Subtotal	27,000	
D.	Containment Area Construction;		
	1. Preparation, Clearing, Fencing	16,000	
	2. Berm Construction 4,000 CY @$5.00/CY	20,000	
	3. Restoration of Containment Area	16,000	
	Subtotal	52,000	75
E.	Erosion Control	20,000	75
F.	Monitoring	15,000	75
G.	Environmental Permits	20,000	75
	Subtotal	970,000	
	10% Contingency	97,000	
	1988 Total	1,067,000	
	Inflation 5% one yr	54,000	
	PROJECT TOTAL	**1,121,000**	

STORM WATER TREATMENT

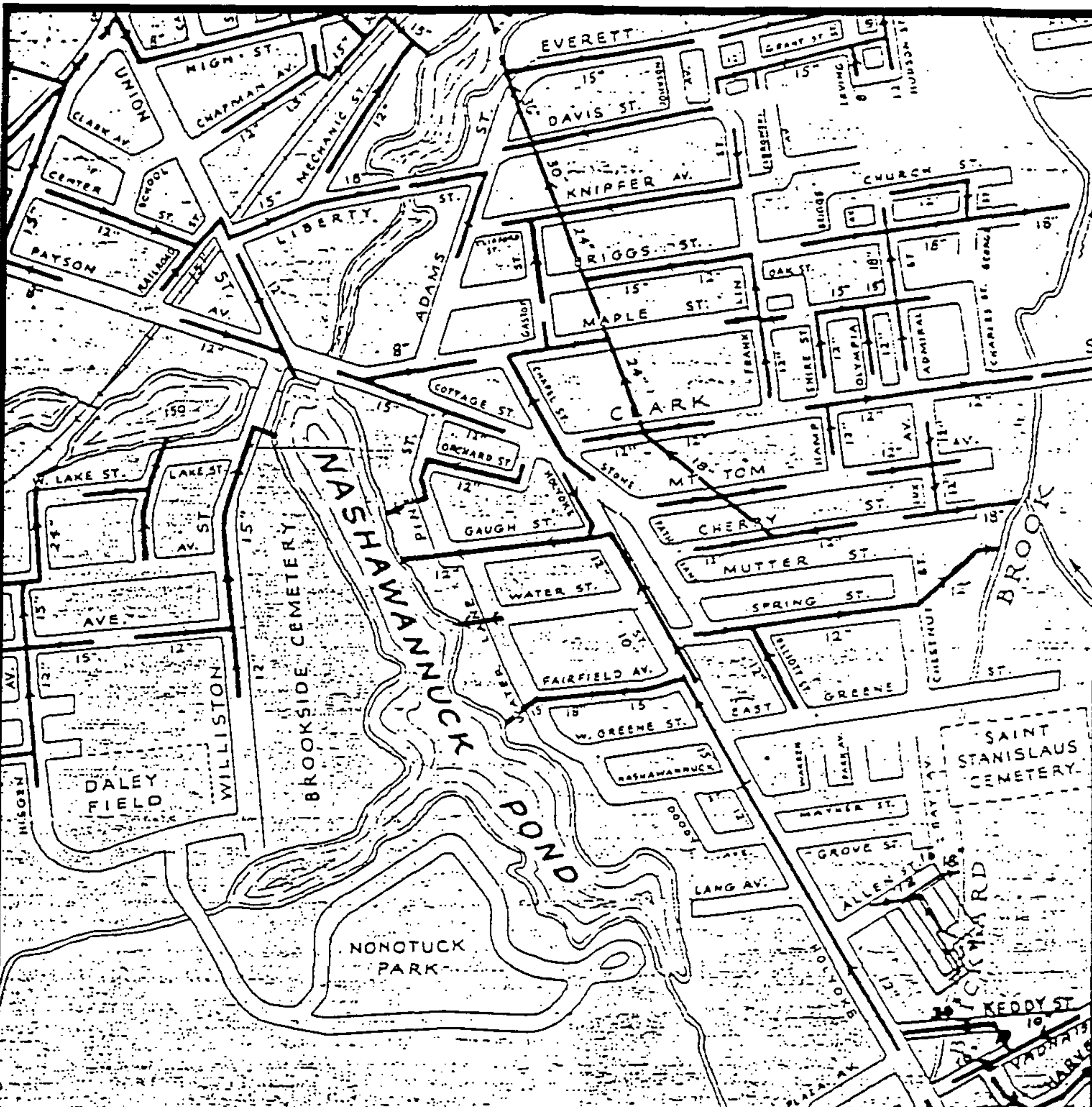
Elements of Storm Drainage Renovations

Reduction of stormwater loading to Nashawannuck Pond will require repair and/or changes to the present system. The existing storm drainage system is shown in Figure 27. Two important differences from the town map are the existence of a previously unmapped drain (NPS-3) at Water Lane and the routing of the drainage of Holyoke St. north of Fairfield Ave. into the Gaugh St. drain (NPS-4). In addition, the pipe from the drain off Pine St. appears to be non-functional (blocked or broken pipe), and the entry of this stormwater is likely to be diffuse.

Analysis from the stormwater surveys indicated that the drain off Fairfield Avenue contributes the most flow and nutrients of any drain during storm events (see Appendix). The location of this pipe at the center of the area of proposed dredging (Figure 24) makes this drain the best candidate for improvement. While improvement of other drains is desirable; the location of their outflows is to the north of Nonotuck Park. Due to the unidirectional flow of Nashawannuck Pond this is "downstream" of the park, so their future improvement will not enhance water quality in the major project area. Further, the pollutants will pass out of the system relatively quickly and not impact the pond ecology as much. These conditions make the northern storm drains less critical to address. Pragmatically, monies spent on their repair will not be as cost-effective as other restoration efforts and are not recommended at this time.

The repair of the Holyoke-Fairfield system is partitioned into two parts : replacement of catchbasins and rerouting of storm flows. The condition of catchbasins on Fairfield Ave. and Holyoke St. merits their replacement. However, any benefits to be derived by better catchbasins will only be realized if a program of annual (or more frequent) maintenance is practiced by the town. An annual cleaning of the catchbasins in questions would cost #3,000.

The second facet of the stormwater drain renovation is the rerouting of flow from Fairfield Ave. to Spring St. Stormwater that would flow off Holyoke Street to Nashawannuck Pond would be diverted to Brickyard Brook, and eventually Lower Millpond. The major cost with these design is the need to relay the lines in Spring St., necessitating a removal of pavement and replacement of existing catchbasins.



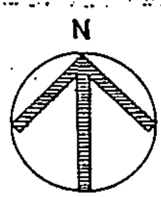


Fig. 27. NASHAWANNUCK POND

EXISTING STORM DRAINAGE SYSTEM LAYOUT

PROJECT NO	86-1117
SCALE	
DATE	
DRAWN BY	MG/RS
___ OF ___ SHTS	

BAYSTATE ENVIRONMENTAL CONSULTANTS INC

Engineers Planners Scientists

296 North Main Street East Longmeadow, MA 01028

Anticipated Impact of System Improvement on Nashawannuck Pond

The reduction in phosphorus through installation of new catchbasins and rerouting of the majority of flow from NPS-2 will provide a limited reduction in the phosphorus (2%) and nitrogen (0.6%) budgets. This translates into reductions of 14 kg TP and 119 kg TN /yr. These reductions will not significantly improve Nashawannuck Pond's water quality. However, a distinction should be made between the ways in which the total phosphorus load is delivered to Nashawannuck Pond. The lake's phosphorus budget is estimated at 692 kg, but it is apparent that not all of this loading appears in the water column long enough to fully impact the pond. The inputs from Wilton Brook and the northern storm drains would pass over the spillway after a relatively short residence time. Since stormwater from NPS-2 is delivered directly to the lower end of the pond and is high in orthophosphate, it is likely that this source of phosphorus is more available to sponsor growth in all of Nashawannuck Pond. Therefore, the functional importance of the reduced phosphorus is more important than the 2% value would imply.

The reduction of phosphorus and nitrogen to Nashawannuck Pond is not the only advantage of this system as the following pollutants are also reduced appreciable amounts : sediment, 75%; trace metals, 75-80%; bacteria, 75% (Schueler, 1987). The last two components are potential hazardous and thus important to reduce, since the present outfall of the NPS-2 system is adjacent to Nonotuck Park and the most popular fishing locations.

Costs, Permits and Summary

The costs associated with implementing the suggested improvements to the storm drainage system are listed in Table 20. The cost of replacing catchbasins is $17,000 for Fairfield Ave. and $29,000 for Holyoke St. This cost assumes that replacement of the catchbasins does not seriously disrupt existing main drainage lines. As most of this system dates from 1919, this may or may not be a realistic assumption. The expense of rerouting flow to Brickyard Brook is $163,000.

Storm drain improvements can be offered to the town as three separate options. The first and least expensive option is replacement of catchbasins on Fairfield Ave and Holyoke St for a cost of $46,000. The second option entails the replacement of catchbasins on Fairfield St. and the rerouting of flow to Brickyard Brook at $180,000. While deletion of the catchbasin repair for Fairfield produces the third option at $163,000.

Permits and/or certificates that are likely to be required (excluding those automatically required for any Clean Lakes

TABLE 20

COSTS ASSOCIATED WITH STORM DRAIN SYSTEM IMPROVEMENTS

Item or Task	Estimate Cost	Maximum Percent Reimbursable Under Clean Lakes Program
Catchbasin Replacement		
Fairfield St.		
1. Remove catchbasins (7 @ $220/per)	1,500	
2. Trenching connections (10 CY @ $5/per)	50	
3. Saw-cut pavement (105 LF @ $2.50/per)	550	
4. Replace catchbasins (7 @ $1,100/per)	7,700	
5. Tie-in lines (110 LF 12" RCP @ $50/LF)	5,500	
6. Backfill (10 CY @ $5/per)	50	
7. Restore Pavement (10 SY @ $5/SY)	50	
8. Ten percent contigency	1,500	
Subtotal	$17,000	75
Holyoke St.		
1. Remove catchbasins (12 @ $220/per)	2,600	
2. Trenching connections (15 CY @ $5/per)	100	
3. Saw-cut pavement (360 LF @ $2.50/per)	900	
4. Replace catchbasins (12 @ $1,100/per)	13,200	
5. Tie-in lines (180 LF 12" RCP @ $50/LF)	9,000	
6. Backfill (15 CY @ $5/per)	100	
7. Restore Pavement (10 SY @ $5/SY)	50	
8. Ten percent contingency	3,000	
Subtotal	$29,000	75
TOTAL	$46,000	75

Item or Task	Estimate Cost	Maximum Percent Reimbursable Under Clean Lakes Program
Rerouting of Storm Drainage to Brickyard Brook		
Demolition of existing structures on Spring Street		
1. Remove catchbasins and manholes (15 @ $220/per)	$3,300	
2. Trenching connections (160 CY @ $5/per)	800	
3. Saw-cut pavement ($2.50/per LF)	10,000	
Installation of replacement structures		
4. Replace pipe (2000 lf 18" RCP @ $50/LF)	100,000	
5. Replace manholes (7 @ $2000/per; including frame and excavation)	14,000	
6. Replace catchbasins (10 @ $1,100/per)	11,000	
7. Tie-in lines (150 LF 12" RCP @ $50/LF)	7,500	
8. Backfill (160 CY @ $5/per)	800	
9. Restore Pavement (80 SY @ $5/SY)	400	
10. Ten percent contigency	15,000	
Subtotal	$162,800	75
Restoration Options		
1. Replacement of catchbasins on Fairfield and Holyoke Streets	$ 46,000	75
2. Replace catchbasins on Fairfield. Reroute drainage north on Holyoke to Spring St. and to Brickyard Bk.	$180,000	75
3. Reroute drainage north on Holyoke to Spring St. and to Brickyard Bk. No improvements to Fairfield.	$163,000	75

General Notes :

1. This assumes that no existing main drainage lines (circa 1919) will be impacted and need to be replaced upon catchbasin replacement.
2. This scheme will only have success if regular maintenance is done to keep the catchbasin sumps clean from debris.
3. The number of catchbasins in area is 19. Annual maintenance is estimated to take 1.5 hr/CB or 30 hours. If cleaning by a two man crew at $100/hr is assumed; then annual maintenance costs are about $3,000.

Program involvement, i.e.. Fair Housing, Discrimination, etc.) are a Notice of Intent (Wetlands Protection Act), a Waterways Permit, and a Water Quality Certificate. The agencies from which these permits are obtained and are filed are listed in Table 26.

Treatment of stormwater is always important in a lake with limited summer hydrologic inputs. The impact on water quality is often severe. The amount of phosphorus removed by this method is deceptively small, given the availability of the phosphorus inputs to impact considerable lengths of the pond. The location of the drainage outfall near the popular park and access areas makes treatment more imperative.

URBAN HOUSEKEEPING EDUCATION PROGRAM

This refers to adjacent residents' practices that are potentially detrimental to water quality in Nashawannuck Pond. These practices include: unwise application of fertilizer, pesticides and herbicides to lawns and grounds; pouring of waste oils, paints, solvents, etc. into local storm drains; lack of maintenance of shoreline; inadequate disposal of pet residue and dumping of trash or organic materials such as leaves or lawn clippings. Rectification of these practices is addressed by an educational program teaching the tenets of ecologically sound "urban housekeeping". The target of the educational program should be the entire town, but most especially the residents in close proximity to Nashawannuck Pond.

While performance of a storm drain system can be improved through engineering, equally important is the reduction in the practice of using the storm drain system as a convenient dumping place for watershed residents for oils, chemicals or related liquid waste. This practice is often widespread and is obvious from samples taken during the storm sampling Thoughtless introduction of noxious or hazardous materials into storm drains can undo most of the benefits arising from proposed improvements.

The increasing popularity of treatment of lawns by commercial fertilizing companies (e.g., ChemLawn) has negative impacts for the water quality of the adjacent pond. Runoff from lawns carries large amounts of fertilizer, pesticides and herbicides into the storm gutters and eventually, into the lake. In the case of abutting residences, delivery is directly to the pond. While not denying citizens the right to a greener lawn, the effect of these practices should be emphasized. Particularly in the case of commercial application, the amount and type of chemicals, as well as the form and timing of application is determined by a company which has no vested interest in preserving water quality, only in "guaranteeing" results. Residents should realize that the price of a greener lawn may well include a greener lake. In more practical terms, the better the condition of the lake, the higher the resale value of the abutting homes.

Fertilizer management considers the proper timing and amount of fertilizer to optimize plant growth with minimal impact on the pond (USEPA, 1988) Alternatively, substitution of low-phosphorus compounds (e.g. Lakeside) or organic fertilizers (which do not leach out as easily) can be tried. a further step is "naturalistic landscaping". Naturalistic landscaping reduces the size of the lawn, replanting buffer strips with wetland shrubs and trees more capable of better nutrient and sediment control under low maintenance conditions. (Lake Cochuiate Watershed Association, 1984).

Shoreline maintenance should be a regular part of the outdoor cleaning done by abutting residents. If not done, the bank may be destabilized and slump; putting unwanted earthen materials into the pond. Here again, planting of a vegetated buffer strip can be useful way to consolidate the bank. The Brookside Cemetery banks of Nashawannuck Pond suffer from gullying due to unregulated runoff from road surfaces. Elsewhere, containment construction for the keeping the bank intact appears to be deteriorated. A careful inspection of the shoreline should be done by town officials to identify areas of significant erosion or potential bank failure. Some of these areas are slated to be restored under proposed actions (see next section). Other area will have to be addressed by either town or individual abutter action.

The chemical impact of these actions on the phosphorus budget will probably be slight (<1.0%), but impact on people's attitudes is the more important gain. As adjacent residents become aware of the land-pond connection, the less likely they are to commit environmental abuses. Further, effort spend by individual abutters to clean up their shoreline translates into a constituency who and are more likely to prevent future degradation of the pond. While the lake abutters have the most to directly gain by an improved pond, all the citizens of Easthampton share the benefits in their use of Nashawannuck Pond and Nonotuck Park.

Cost and Summary

Overall, these issues should be addressed with educational materials that can be included in a "packet" produced for the urban and abutter housekeeping program. Compliance of the public with environmentally-sound practices will not be complete, but this addresses those residents who would observe the proper measures if only they were aware of them. Costs associated with this education are for printing of materials and distribution of them at town meetings or other appropriate occasions. Door-to-door distribution should be made in the portions of Easthampton whose storm drains go into Nashawannuck Pond. A shoreline inspection by town officials (town engineer ?) is recommended. As this option is educational, no permit requirements are invoked. The cost of printing the needed educational material is estimated at $5,000. Sources of information include state and regional clearinghouses (see Appendix).

RESTORATION OF EROSION AREAS

Elements and Anticipated Impacts of Program

Portions of the shoreline have deteriorated and are eroding sediment into Nashawannuck Pond. While fluctuations of seasonal water levels, heavy ice cover, storm and wave action have all contributed to the present state, much of the problem resides in human use. In the most popular areas, unregulated vehicular traffic has greatly exacerbated soil compaction and erosional runoff. Stabilization of these areas and better control of access is necessary to check current erosion and prevent future breakdown.

Four areas have been designated for extensive restoration and enhancement. These peninsulas or points are identified on Figure 24. Two of these are accessible from Brookside Cemetery and two are reached through Nonotuck Park. Each is prominently used for fishing and related outdoor activities. The intent in restoring these points is to limit the vehicular access which originally caused the majority of the problem, regrade and restore the shoreline and improve the appearance and recreational environment of the areas. In conjunction with the dredging program, these points will become focal points of fishing and viewing activity and will solidify the aesthetic linkage between Nashawannuck Pond and Nonotuck Park/Brookside Cemetery.

Two general approaches to the point restoration are considered. The first scheme, shown in Figure 28 is the less involved and less costly. It attempts to meet the minimum requirements for both erosion repair and recreational function. Elements of Scheme I include bollards to prevent vehicular traffic, grading and rip-rapping of the shoreline and a low maintenance stone dust path to direct foot traffic. The proposed users under Scheme I would be mostly fishermen, who used these points for their ease of casting into deeper waters.

Scheme II includes both the bollards and the rip-rapped edge (Figure 29). The stone dust walk is replaced by a concrete walk with steps and railing. A low concrete wall abutts the pond and benchs are placed for aesthetic viewpoints. Additional improvements could be made to provide for handicap access. Overall, Scheme II represents a more ambitious treatment that will draw additional people to these points. Both schemes could easily be incorporated in a potential trail system on the western side that would link the upper and lower shoreline recreational areas on the pond. In addition to the accessible points, presently stressed areas could be identified for protection against further foot traffic. Edge treatment for these areas are shown in Figure 30. Shrubs are proposed as an additional barrier to unwanted pedestrians.

Figure 28. Proposed Point Restoration Plan - Scheme I.

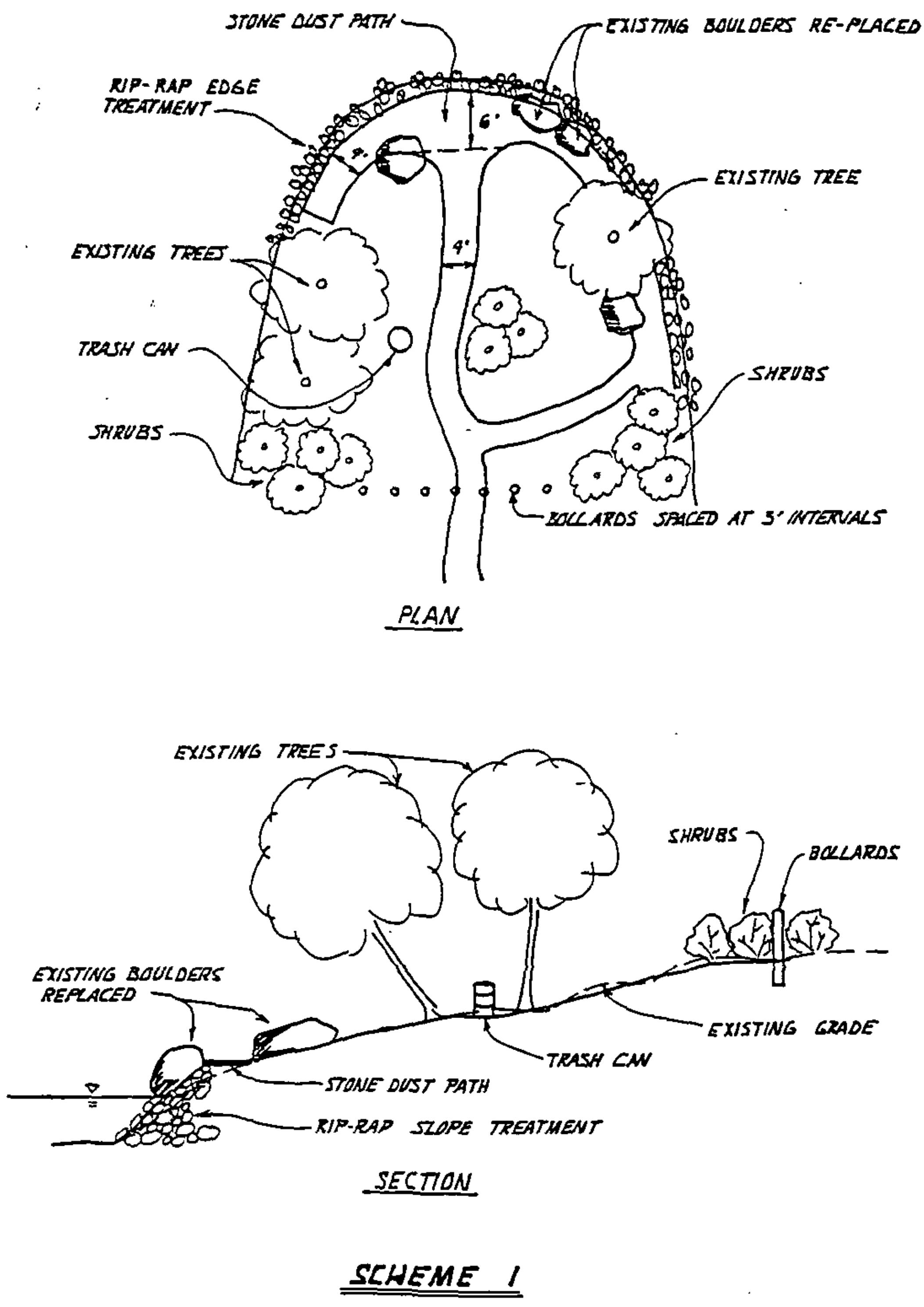


Figure 29. Proposed Point Restoration Plan - Scheme II.

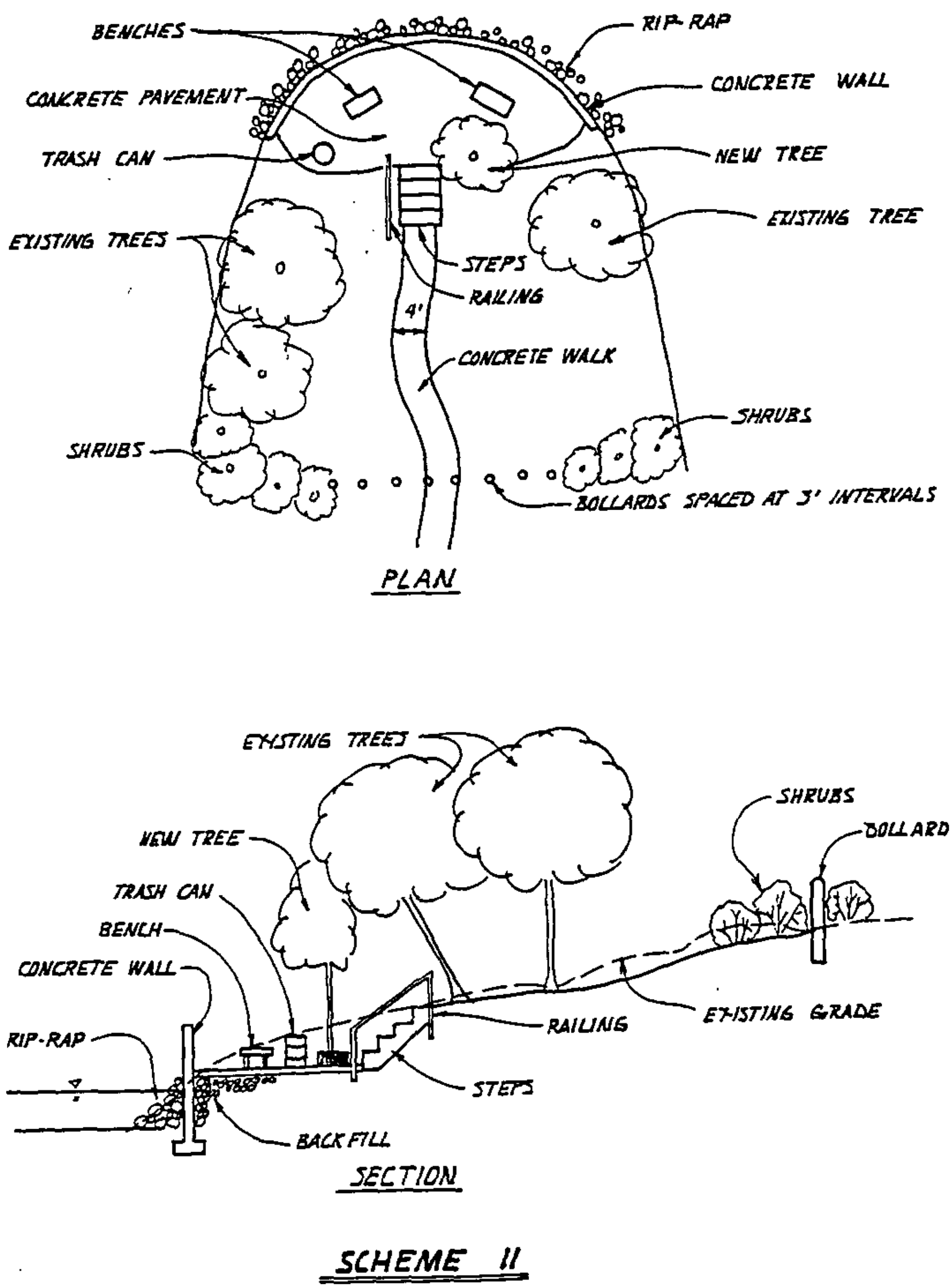
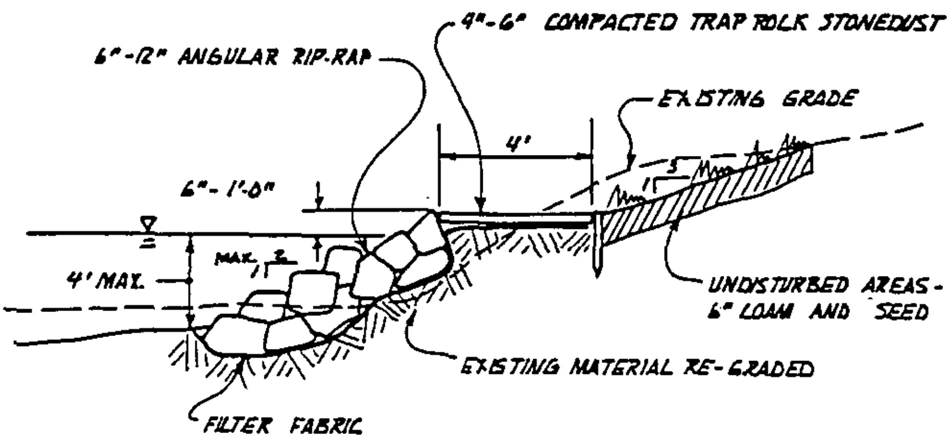
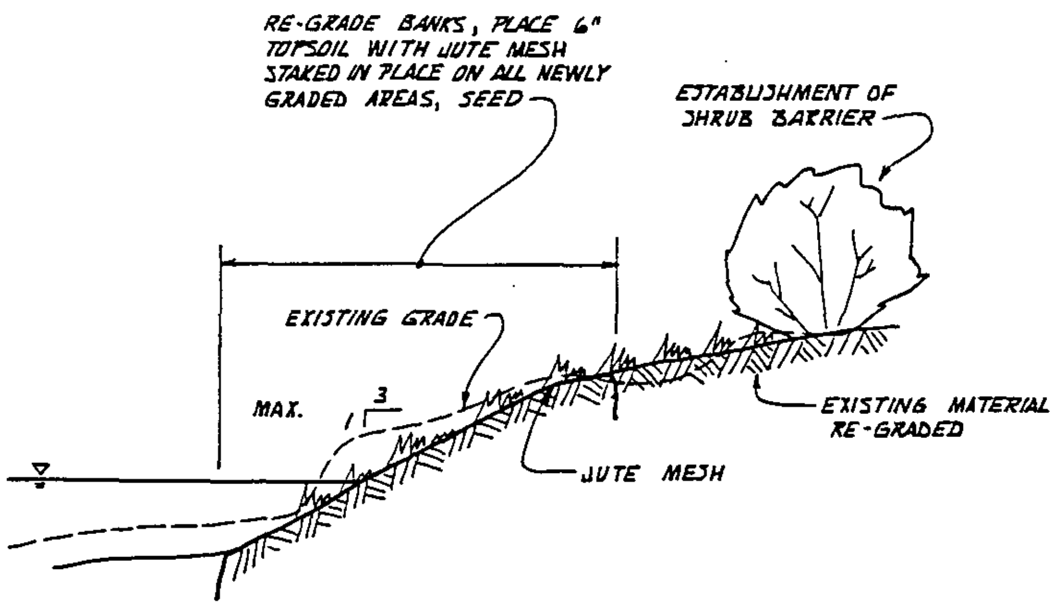


Figure 30. Proposed Alternative Edge Treatments.



EDGE TREATMENT - POPULATED AREAS
NTS



EDGE TREATMENT - RESTRICTED AREA
NTS

For either scheme additional effort should be made by Easthampton to provide more codified and accessible parking for the users. Location of a limited number (8 ?) of parking spaces in the buffer areas between Brookside Cemetery and Nonotuck Park seems reasonable. [Note : the funding for these parking spaces is not sought as a part of this pond restoration package].

The repair and up-grading of the four eroded points is expected to be accomplished in the same time frame as the dry dredging, or when the pond is drawn down. The sequencing of work (i.e., which points are treated when) is expected to follow the dredging activities. Obviously, since these points are likely to serve as equipment access points during the excavation, repair and restoration need to await finish of the sediment removal in that area. Mostly likely, activities will move in a downstream fashion. As with the dredging, most of the point reconstruction will take place during fall and winter months.

The point restoration program will not detectably decrease the nutrient budget. Some of the phosphorus associated with eroded materials will be removed or prevented in the future. More importantly, rehabilitation of these access points, in combination with the increased depths and reduced weeds, will provide much more quality recreation, primarily fishing, than is now possible. In addition, the improved pond conditions will encourage use of Nonotuck Park and provide the citizens of Easthampton with newly created scenic vistas.

Costs, Permits and Summary

The costs associated with the bank stabilization program are listed in Table 20. These are broken down by task item for the two schemes. The amount required to the minimal repairs to the four points following Scheme I is $61,300. The more enhanced treatment proposed in Scheme II is priced at $147,500.

The environmental permits required by the point restoration program are a Notice of Intent (Easthampton Conservation Commission) and a Water Quality Certificate (DWPC). The US Army Corps of Engineers Section 404 permit and the DEQE (Chapter 91) Waterways License are also needed. Note that Chap. 628 grants will cover only those costs associated with the attainment of Section 404 and MEPA EIR permits. The agencies from which these permits are obtained and filed are listed in Table 25.

The bank stabilization program is designed to remove eroded and slumping boundaries of the pond before they fail and put additional sediment into Nashawannuck Pond. Regrading of these slopes and rip-rapping provide for future protection of the shoreline integrity of Nashawannuck Pond. Control of access to these points and enhancement of their recreational function provides a pleasant exploitation of the improved pond conditions that dredging and watershed management provides.

TABLE 21

COSTS ASSOCIATED WITH POINT RESTORATION PROGRAM

Item or Task	Estimated Cost For Single Area	Max. % Under Clean Lakes Program
SCHEME I		
Basic Erosion Containment		
Engineering and Design	1500	75
Site survey	500	75
Excavation of existing material 350 CY @ $5/CY	1750	75
Temporary Cover (jute mesh) 500 SF and sediment control (filter fabric) 700 SF @ $0.75/SF	900	75
Placement of rip-rap 80 CY @ $22/CY	1760	75
Grading and replacment of existing material 350 CY @ $3.50/CY	1225	75
Seeding and Loam 250 SY @ $5.00/SY	1250	75
Environmental Permits	750	75
Ten percent contigency fund	960	75
Subtotal	$10,595	
Site Enhancement		
Installation of stone dust path 125 SY @ $2.50/SY	315	
Path edge placement 600 LF @ $1.50/LF	900	
Boulder relocation 4 @ $12.50/rock	50	
Shrubs 11 @ 4 SF @ $2.25/SF	100	
Bollards 9 @ $35/bollard	315	
Trash cans 2 @ $300/can	600	
Restore eroded parking areas 100 SY @ $20/SY	2000	
Ten percent contigency fund	440	
Subtotal	$4,720	
Project includes Four erosion areas @ $15,315	$61,260	
Rounded	$61,300	
PROJECT TOTAL	**$61,300**	

TABLE 21 continued

Item or Task	Estimated Cost For Single Area	Max. % Under Clean Lakes Program
SCHEME II		
Basic Erosion Stabilization		
Engineering and Design	1500	75
Site survey	500	75
Excavation of existing material 350 CY @ $5/CY	1750	75
Temporary Cover (jute mesh) 500 SF and sediment control (filter fabric) 300 SF @ $0.75/SF	600	75
Placement of rip-rap 40 CY @ $22/CY	900	75
Installation of concrete retaining wall 140 LF @ $125/SY	17500	75
Grading 150 CY @ $1.50/CY	225	75
Backfill (haul and place) 50 CY @ $6.00/CY	300	75
Environmental Permits	750	75
Ten percent contigency fund	2400	75
Subtotal	$26,425	
Site Enhancement		
Engineering and Design	1500	
Concrete pavement 400 SF @ $2/SF	800	
Concrete steps	300	
Railing 10 LF @ $28/LF	280	
Concrete path (4' wide) 180 LF @ $7.50/LF	1350	
Boulder relocation 4 @ $12.50/rock	50	
Trees 2 @ $300/tree	600	
Shrubs 11 @ 4 SF @ $2.25/SF	100	
Benches 2 @ $800/bench	1600	
Bollards 9 @ $35/bollard	315	
Trash cans 2 @ $300/can	600	
Restore eroded parking areas 100 SY @ $20/SY	2000	
Ten percent contigency fund	950	
Subtotal	$10,445	
Project includes Four erosion areas @ $36,870	$147,480	
Rounded	$147,500	
PROJECT TOTAL	**$147,500**	

RECOMMENDED MANAGEMENT APPROACH

After consideration of the lake and watershed characteristics and the available options for improving or preserving the existing conditions, the following actions are recommended for the management of Nashawannuck Pond.

1. Conduct a winter drawdown by lowering the dam's bascule gate. Exercise this option at 2-3 year intervals to reduce the density of nuisance littoral macrophytes.

2. Conduct a bottom water (hypolimnetic) release to remove anoxic water and promote mixing and oxygenation. This can be done during late summer with the existing dam structure and sluiceways.

3. Institute a vigorous non-point source reduction program in the Nashawannuck Pond watershed to reduce nutrient loadings from diffuse runoff. Look to acquire areas critical to maintenance of watershed water quality.

4. Install low stone gabion weirs in the upper arms of Nashawannuck Pond to provide for both wetland protection during drawdown and mitigation of watershed erosion.

5. Drawdown the pond level and excavate 72,000 CY of bottom deposits from the central portion of the pond. This will remove plants and organic muck and restore summer recreational function to the pond area most closely associated with Nonotuck Park.

6. Reduce the influence of stormwater flow in Nashawannuck Pond. Improve performance of storm drain system by increased maintenance or replacement of catch basins. Potentially remove some storm flow by rerouting to Brickyard Brook via Spring St. This is likely to require extensive work on Spring St.

7. Promote the concepts of sound "urban housekeeping" in the immediate vicinity of Nashawannuck to reduce the amount of nutrient loadings to the storm drain system in the town. Provide funds for an educational program to spread these concepts.

8. Stabilize and rebuild four badly eroded "points" in Nonotuck Park and Brookside Cemetery on the western shoreline of Nashawannuck Pond. Provide essential reconstruction and/or more expanded features to control and enhance fishermen's access.

Discussion of Recommended Options

Management options #1 and #2 can be attempted at any time, since neither is especially dependent upon outside funding. Some monies may be required for analysis and completion of detailed drawdown and/or release plan, or this can be attempted by the Town Engineer. Coordination will need to be made with the Easthampton Conservation Commission to plan the timing of these water withdrawals. Contact should be made with the industrial users (Mill Works and Easthampton Dye Co.) to inform them, but neither of these water intakes will be impacted by these actions.

Option #3 involves the education of a large constituency as to the potential problems caused by unwise watershed practices. Contact with other municipalities for the purpose of establishing a consensus watershed management plant is essential. The proposed regional aquifer council is a organization that could potentially enlarge its scope to include watershed protection. This would also be the proper organization to seek funding when the non-point source program becomes available in the future. The more localized "urban housekeeping program (options #7) should be encouraged and supervised by the Easthampton Conservation Commission, who should act to distribute educational materials.

Option #4 is the installation of the gabion weirs. This is a relatively low cost option, and next to the watershed management has the most impact on reducing the nutrient loading. It is a very cost-effective means to help the lake. Option #5 involves the removal of macrophyte-sediment accumulations in areas near Nonotuck Park where high much of the recreation occurs. This is clearly the option which has the greatest impact on the pond. It is also critical to improved recreation in the pond and abutting park. If this option is not exercised, there is little utility in either option #6 (stormwater diversion and/or system improvement) and option #8 (access point restoration). The amount of weeds would preclude any real benefit arising from these improvements if the pond is not dredged.

Option #8 represents the final stage of the restoration of Nashawannuck Pond; the enhancement of recreational facilities based on improved water quality and increased depth in the pond. If desired by the town, it is possible that another area (e.g., near the entrance to Brookside Cemetery) could be substituted for one of the originally designated points. Acquisition of land along the western shore provides the potential for a pond-length path. It is reasonable that both ends of this trails would be "anchored" by an improved access point. It should be noted that only basic stabilization of the shoreline is fundable under the MA Clean Lake Program. Other features, recommended to enhance the restoration, would require additional funding sources.

The costs of the full slate of lake management options total to approximately $1,560,000. Given about 70% of the costs being assumed by the MA Clean Lakes Program, the Easthampton share is about $421,000. To some this may seem an insurmountable sum to raise at the local level. Clearly, it is a step not likely taken. Commitment of this size sum by the town of Easthampton will take a concerted effort by citizens' groups, town officials, local and state politicians, conservancy groups, and local businessmen.

To ameliorate the funding situations, the town of Easthampton could devise a sequence under which funding for these options is sought. It is possible to apply to the Clean Lakes Program for one, some or all of the recommended options. By applying for a lesser package at first, the town of Easthampton can try for some of the smaller improvements, while bidding its time on the larger items, particularly the dredging.

The elements of a low-cost restoration package would be options #1-4 and #7. Implementation of options #5, #6 and #8 could be sought as a "future" pond restoration package, with option #5 to be considered the essential item. By dividing the options list into two packages, the town of Easthampton can seek funding for the low-cost plan at $98,700, of which it is responsible for about $25,700.

Four considerations arise from this strategy. First, reducing the monies sought to a sum under $100,000 should make the Nashawannuck Pond project more competitive for funding by the Clean Lakes Program. Second, there is a good possibility that by postponing major cost item commitments, funds from the proposed MA non-point source program will become available. This program has much potential for reducing nutrient loading in Nashawannuck Pond including the necessary funds to institute real improvements. As the watershed is cleaned up, water quality in Nashawannuck Pond improves, and recreational opportunities increase. As tributary inputs go done, the impact of the proposed improvements goes up and this should increase the competitiveness of the project in the implementation prioritization.

On the other hand, the third consideration is that watershed management may be too late if the majority of land use decisions are made in the next few years. This appears to be a critical point in time for the watershed, as much farmland is being converted into residential developments. Pragmatically, changes in water quality could worsen, the condition of Nashawannuck Pond too poor to restore even after improvements. Lastly, is simply the time factor. As option implementation is delayed, their costs can rise, sometimes precipitously. Delay will only increase what seems a large financial burden into a larger one.

Decision-makers in Easthampton need to consider all these factors when making the town's choices.

Anticipated Impacts of Proposed Management Actions

The expected changes in the phosphorus budget of Nashawannuck Pond following various management options is shown in Table 22. The largest reduction (20%) is anticipated through reduction of nutrient loadings due to watershed management. This amount may be even higher if a non-point source program is initiated in the future. The construction of the gabion weirs is expected to eliminate 9% of the budget. The macrophyte/sediment removal accomplished by the excavation is expected to make a 5% reduction on the phosphorus budget. Hypolimnetic release eliminates 2% of the phosphorus budget, as does improvements in the storm drainage system. Depending on the intensity with which these urban housekeeping educational programs are pursued, a reduction of 1% is expected. Winter drawdown and the access point restoration, while improving recreational pursuits are not assumed to affect the nutrient budgets in a significant way. Overall an expected reduction of 39% of the present phosphorus budget is estimated.

These improvements would still leave the pond above the Vollenweider permissable value for phosphorus loading. This says that even these improvements in water quality will not change the eutrophic status of the lake. However, Nashawannuck Pond is likely to be more mesotrophic in nature following improvements than this analysis suggests. Two factors which mitigate the projected loading are the rapid flushing rate of Nashawannuck Pond and the location of the inputs. The Vollenweider analysis is less valid when the lake does not act like a completely mixed reaction (Dillon, 1975). The quick flushing of the lake will help to lessen the impact of the chemicals, even after the morphometric changes by the proposed dredging are achieved. Secondly, a substantial part of the phosphorus budget (20%) comes in via Wilton Brook. This means that the lower part of the lake where the improvements are slated is unlikely to be affected by these inputs. Finally, a large portion of the phosphorus budget arrives during winter months. Therefore, the phosphorus is more likely to move completely through the system rather than be retained as the lake will be biologically inactive and have less adsorption due to the removal of the organic sediments. During the summer months when the flows are considerably lower, the pooling action and reductions made by the gabion weirs should be maximized. Overall, there should be reasonably clear water around the confluence of the White and Broad Brooks, and summer water quality in this area should be better than the Vollenweider model indicates.

TABLE 22

ANTICIPATED IMPACTS OF PROPOSED MANAGEMENT ACTIONS ON THE PHOSPHORUS BUDGET OF NASHAWANNUCK POND

Total phosphorus load (kg/yr)	692
Calculated critical load (kg/yr) 1	232
Calculated permissable load (kg/yr) 2	117
Reduction necessary to reach critical load (%)	67
Reduction necessary to reach permissable load (%)	83
Anticipated reduction (%) resulting from:	
Winter drawdown	0
Hypolimentic Release	2
Watershed Management	20
Gabion Weirs	9
Dredging of Sediments	5
Improvement of storm drain system	2
Urban Housekeeping Education	1
Access Point Restoration	0
Total anticipated phosphorus load reduction	39%

1 - Load above which excessive productivity is expected on a frequent basis.
2 - Load below which excessive productivity is expected only very rarely.

The relative lifetime expectancy of the improvements gained by the various options needs to be considered. The effectiveness of the water level drawdown in checking macrophyte growth in the exposed areas is expected to be 2 to 3 years. However, this option can be repeated indefinitely as long as the bascule gate is operable. Similarly, the short-term benefits of the hypolimnetic release is short-lived (weeks to months) but can be repeated as needed.

Watershed management, is effectively practiced has a long-term benefit, since directing the location and the intensity of residential development will yield fairly permanent changes in land use. The abutter education program hopes to changes unwise residential practices. While these changes may be permanent in a few individuals, it can be expected that as people are not reminded of their actions' consequences or there is a large turnover of the neighboring population, unsound practices will start to reemerge. There may be the need for periodic 2-3 yr redistribution of materials or display boards at town meetings.

The installation of gabion weirs will help prevent future sedimentation of Nashawannuck Pond. This treatment will be effective until too much material gathers behind the gabion weirs and is not clean out. The town of Easthampton would be responsible for eventually removing accumulated sediment from behind the gabion weirs, so there is a future (5 yr) operation/maintenance cost involved. However, since much of the nearby land is already developed and if best management practices are introduced into the watershed, the rate of sediment accumulation should be significantly slower than the last 25 years. If the gabion weirs are faithfully maintained, there is no foreseeable end to their usefulness. Similarly, the redesigned storm drain system should yield permanent improvements to water quality entering Nashawannuck Pond, provided that maintenance of the system is vigorously pursued.

The effectiveness of the dredging program will be enhanced by the gabion weirs and the factors affecting the sedimentation rate (see above). Migration of sediment in the lake will be retarded by the heavy macrophyte growth in the upper area of Nashawannuck Pond. It is expected that the lifetime of the dredging would be approximately 20 to 30 years.

The restoration of the eroded points to accessible fishing and scenic viewpoints would require maintenance as would any park facility. The presence of the designated parking areas would keep vehicles off the areas and prolong the stability of the bank as well as their pleasant appearance.

Monitoring Program

For any of the high cost management options, monitoring of water quality during construction activity will be mandated. The cost of this construction monitoring ($15,000) is included in the dredging program, since this is the key element of the high cost options package. This monitoring operation would include surface water quality sampling during operations, as well as post-treatment monitoring of the lake. The number of water samples and stations should reflect the location and construction schedule. The timing should coincide with the bank stabilization operations to insure that excess suspended solids and turbidity are prevented from passing downstream. It is expected that most work will be done when the outlet is not flowing to avoid any passage of suspended solids. Prevention of downstream problems is best accomplished by the cooperative planning of the project between the contractor and the environmental monitoring body, probably the Easthampton Conservation Commission which will sets the Order of Conditions under which work may proceed.

In addition to the construction activity, a post-implementation monitoring program will be necessary to assess the success of remedial actions and aid in the formulations of appropriate management policies. Specific objectives of the monitoring program for Nashawannuck Pond and its watershed include monitoring progress of the watershed management and urban housekeeping programs, evaluation of the effectiveness of the gabion weirs and storm drain improvements, determination of water quality during and after the hypolimnetic withdrawal and sediment removal. The elements of the program and associated cost estimates are presented in Table 23.

The monitoring program should be tailored to which pond restoration options are implemented. Two three year plans are suggested. The low-cost plan (options #1-#4, #7) would require a yearly check of macrophyte density, monitoring of in-lake water quality, and an annual sampling of tributary water quality. The suggested location of the in-lake sampling station would be at the northern end (NP-5). Tributary sampling stations along the three major brooks are already established. The suggested sampling frequencies, parameters to be tested and personnel requirements are given in Table 23. The total cost for the three year monitoring program for the low cost management options would be $10,200.

Following implementation of the high cost management options, a sampling program of two in-lake stations should be maintained for three years after dredging and storm drain improvements to ascertain resultant water quality. In-lake water quality would be monitored above and below the dredging areas. The storm drains would be sampled to see the improvement in catch basin

TABLE 23

COST OF THREE YEAR MONITORING PROGRAM
ASSOCIATED WITH MANAGEMENT OPTIONS

Item or Task	Estimated Cost ($)
Low-Cost Management Options	
First Year	
1.) Macrophyte Survey Field Evaluation of plant density; in August; 1 day @ $450/day.	450
2.) In-lake water quality monitoring Sampling at NP-5 site @ 4 times/year. Analysis for NO_3, NH_3, TKN, TP, TFP alkalinity, Secchi, chlorophyll a, TSS, cond, pH, FC; T, DO @ $190/sample.	760
3.) Tributary monitoring Sampling at 6 sites @ 1 times/year. Analysis for NO_3, TP, FC, TSS, cond, pH, Cl, flow @ $125/sample.	750
4.) Labor costs for monitoring Five days @ $450/day	2,250
First year total	4,210
Second Year	
1.) Macrophyte Survey Recheck of earlier survey in August; 0.5 day @ $500/day.	250
2.) In-lake water quality monitoring Sampling at NP-5 site @ 2 times/year. Analysis for NO_3, NH_3, TKN, TP, TFP alkalinity, Secchi, chlorophyll a, TSS, cond, pH, FC; T, DO @ $200/sample.	400
3.) Tributary monitoring Sampling at 6 sites @ 1 times/year. Analysis for NO_3, TP, FC, TSS, cond, pH, Cl, flow @ $140/sample.	840
4.) Labor costs for monitoring Three days @ $500/day	1,500
Second year total	2,990
Third Year (Items 1-4) Same as second year	
Third year total	2,990
Total Costs	**$10,190**
ROUND TO	**$10,200**

TABLE 23 (continued)

Item or Task	Estimated Cost ($)
High Cost Management Options	
First Year	
1.) Macrophyte Monitoring Field Evaluation of plant density; in August; 1 day @ $450/day.	450
2.) In-lake water quality monitoring Sampling at 2 sites @ 2 times/year. Analysis for NO_3, NH_3, TKN, TP, FC, alkalinity, Secchi, chlorophyll a, TSS, cond, pH, FC; T, DO @ $190/sample.	760
3.) Storm drain water quality monitoring Sampling at 4 sites @ 2 times/year. Analysis for NO_3, NH_3, TKN, TP, FC, TSS, cond, pH, FC FS; @ $150/sample.	1,200
4.) Labor costs for monitoring Four days @ $450/day	1,800
First year total	4,210
Second Year	
1.) Macrophyte Monitoring Recheck of earlier survey; in August; 1 day @ $500/day.	500
2.) In-lake water quality monitoring Sampling at 2 sites @ 2 times/year. Analysis for NO_3, NH_3, TKN, TP, FC, alkalinity, Secchi, chlorophyll a, TSS, cond, pH, FC; T, DO @ $200/sample.	800
3.) Storm drain water quality monitoring Sampling at 4 sites @ 1 times/year. Analysis for NO_3, NH_3, TKN, TP, FC, TSS, cond, pH, FC FS; @ $175/sample.	700
4.) Labor costs for monitoring Four days @ $500/day	2,000
Second year total	4,000
Third Year (Items 1-4) Same as second year	
Third year total	4,000
Total Costs	**$12,210**
ROUND TO	**$12,200**

repair, maintenance and/or re-routing. The suggested sampling frequencies, parameters to be tested and personnel requirements are also given in Table 23. The total cost for the three year monitoring program for the high cost management options would be $12,200.

FUNDING ALTERNATIVES

The costs of the recommended management options for Nashawannuck Pond and the local share of those costs are shown in Table 24. Several sources of funding may be available for management activities in the Nashawannuck Pond watershed, but the Clean Lakes Program represents the single most important and versatile source of support. The initial funding needs of the proposed project could best be met through the Massachusetts Clean Lakes Program. Other potential funding sources include the Federal Clean Lakes Program and Land and Water Conservation Fund. The Small Watershed Protection Program from the Soil Conservation Service is a possibility. Other funding possibilities from Massachusetts include the Rivers and Harbors Program, the Self Help Program. Land acquisition is fundable from the Aquifer Lands Acquisition Program or Agricultural Preservation Program. Notes on potential funding sources are given in Table 25.

Up to 75% of the costs associated with capital investments in the management of the lake are reimbursable under the Clean Lakes Program. Maintenance and operation expenses are not reimbursable, a real consideration in the choice of management alternatives. Expenses associated with actions covered by other programs are not reimbursable unless it can be demonstrated that funds could not be obtained from the appropriate programs. Future watershed management may be eligible under the proposed MA Non-Point Source Program that is currently seeking funding by the legislature.

TABLE 24

COSTS OF RECOMMENDED MANAGEMENT OPTIONS FOR NASHAWANNUCK POND

Management Option	Available Funding	Cost	Local Share
Water Level Drawdown	Chap. 628	$ 1000	$ 250
Bottom water Release	Chap. 628	$ 500	$ 125
Watershed Management	Chap. 628.	$30,000	$7,500
Install Gabion Weirs	Chap. 628.	$52,000	$13,000
Excavate Pond Sediments (1)	Chap. 628.	$1,121,000	$280,250
Redesign Storm Drain System	Chap. 628.	$46-180,000	$11.5-45,000
Abutter Education Program	Chap. 628.	$5,000	$1,250
Rehabilitation of Scenic/Fishing Areas (2)	Chap. 628.	$61.3-147,500	$29.5-68,225
Post-Implementation Monitoring (3 yr)	Chap. 628.	$10.2-22,400	$2,550-5,600
APPROXIMATE ROUNDED TOTALS :		**$1.33-1.56 M**	**$346-421,200**

(1) Costs include construction activity monitoring.
(2) Fundable (Chap. 628) tasks includes only basic bank stabilization.

TABLE 25

POTENTIAL FUNDING SOURCES FOR THE PROPOSED RESTORATION OF NASHAWANNUCK POND

Source	Funding Level	Notes
Massachusetts Clean Lakes Program (Ch. 628 of the Acts of 1981, DEQE)	75%	Sound Program; July 1 application deadline; likely source.
Federal Clean Lakes Program (sec. 314 of PL 92-500, USEPA)	50%	Financially 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.
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 Comm. for land acquisition; open space plan required.
Mass. Urban Self Help Chap. 933, Acts of 1977	(up to) 90%	Acquisition and development of parks and recreational lands for communities with Cons. and Rec. Commissions
Aquifer Lands Aquisition Program, Ch. 286, Sec 5 and 20, Acts of 1982. (DEQE)	100% for studies under 50K; total,250K	Monies available if public water supply wells are to be developed.
Agricultural Preservation Restriction Program (APR) Ch. 780, Acts of 1977 (Food/Agriculture)	100% of purchase of development rights.	Considerable funds have been committed to this program.
Non-Point Source Pollution Control Program (DWPC)	75%	Proposed legislation only. $5 million annual budget over ten year period.

CONTACT AGENCIES

Funding by the Massachusetts Clean Lakes Program requires the review and approval of this document by the Division of Water Pollution Control, Division of Fisheries and Wildlife, and Massachusetts Historical Commission. The petitioning organization (Town of Easthampton) must provide evidence of public access and a certificate of title to the project site. Zoning or land use actions resulting from consideration of the information in this report may be subject to approval under Executive Order 215 (Fair Housing). Local review is by the Easthampton Planning Department, Department of Public Works, Conservation Commission, Parks Department and Board of Selectmen. Review activities are to be coordinated by the Easthampton Town Planner.

Funding of the proposed options all must meet compliance with state requirements such as Fair Housing and Wage Rate Compliance, as well as mandated review by the Executive Office of Environmental Affairs (MEPA Unit) and the Easthampton Conservation Commissions (regarding actions in water resource areas). Some restoration options have extensive environmental permit processing. The agencies to be contacted and the likely permit requirements are indicated on Table 26.

Table 26. 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. Water Level Control	Hypolimnetic Release	Gabion Weirs	Dredging Program	Storm Drain Renovation	Access Pts Restoration
Title to Project Site	Lakes Section, DWPC, DEQE Lyman School, Westview Bldg. Westborough, MA 01581 508-366-9181	None, submit w/appl.			X	X	X	X
Intergovernmental Agreement	Lakes Section, DWPC, DEQE Lyman School, Westview Bldg. Westborough, MA 01581 508-366-9181	Local approval req'd			X	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			X	X	X	X
Commission Against Discrimination	MA Comm. Against Discrimination 1 Ashburton Place Boston, MA 02108 617-727-7309	120			X	X	X	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.			X	X	X	X
MA Env. Policy Act (ENF Review)	Exec. Off. Env. Affairs (MEPA) 100 Cambridge St., 20th Floor Boston, MA 02202 617-727-5830	30 *	X	X	X	X	X	X
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	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	X	X	X
Div. Fisheries and Wildlife	Div. Fisheries and Wildlife Field Headquarters Westborough, MA 01581 508-366-4470	15 **	X	X	X	X		X
US Army Corps of Engrs (Sec 404)	Regulatory Branch, USACOE 424 Trapelo Rd. Waltham, MA 02254 1-800-362-4367	120 ***			X	X		X
Div. Waterways (Chap. 91)	Div. of Wetlands and Waterways DEQE, 1 Winter St. Boston, MA 02108 617-292-5519	90			X	X	X	X
DWPC Water Quality	Permits Section, DWPC, DEQE 1 Winter St. Boston, MA 02108 617-292-5673	90		X		X	X	
Wetlands Protection Act	Easthampton Conserv. Commission Town Hall Easthampton, MA 01027 413-527-0818	42	X	X	X	X	X	X
Div. Solid and Hazardous Waste	Div. Solid Waste, DEQE 5 Commonwealth Ave. Woburn, MA 01801 617-935-2160	***				X		
NPDES Discharge Permit	Regulatory Branch, DWPC, DEQE 1 Winter St. Boston, MA 02108 617-292-5673	90					X	

X Permit required by agency.

? Permit may or may not be required; agency makes determination.

* 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.

ENVIRONMENTAL EVALUATION

Environmental Notification Form

Appendix B contains the Environmental Notification Form (ENF) which must be filed under the Massachusetts Environmental Policy Act (MEPA). The MEPA unit will evaluate the proposed actions and their potential impacts and make a determination regarding the need for an impact study prior to implementation. The ENF also serves as a useful summary document for the project. Preparation of a detailed Notive or Intent, which is filed with the Conservation Commission under the Wetlands Protection Act, may satisfy questions likely to be raised by the MEPA unit staff.

Comments by Interested Parties

Copies of this report were sent to the Easthampton Board of Selectmen, the Easthampton Conservation Commission, the Easthampton Department of Public Works, the Easthampton Planning Department, the Easthampton Parks Department, the Division of Water Pollution Control, the Division of Fisheries and Wildlife, the Massachusetts Historical Commission, and the Natural Heritage Program for review. Comments by these parties have been addressed in this report or appended to it (Appendix), as warrented. Written and verbal comments received by citizens and agencies during the course of the project have also been addressed and/or summarized.

Two public meetings were held by BEC, Inc. during the study period to inform interested parties of progress and solicit comments. Summaries of the comments and questions raised at the first (6/25/87) and second (8/18/88) public meetings are given in the Appendix. A videotape of this latter meeting was made for later showing at appropriate meetings. Comments made by meeting participants have been incorporated into this report wherever possible.

Relation to Existing Plans and Projects

The proposed lake restoration and management plan is entirely consistent with all stated objectives and community-sponsored activities in the watershed. The proposed in-lake actions will improve lake conditions without impairment to downstream flows or water quality. The findings of the Aquifer Lands Acquisition Study (IEP, 1988) have been reviewed, and are consistent with the current report. Proposed improvements to Nonotuck Park (denied funding under the latest round of Urban Self Help) have been reviewed and changes have been suggested for consistency with the goals of the proposed pond restoration. The greenbelt between White Brook Middle School and Nonotuck Park suggested by the

Master Plan Revision Study (Landuse, 1988) is consistent with the proposed watershed management. The use of the bordering lands of the Brookside Cemetary for a footpath linking the upper and lower portions of Nashawannuck Pond provides additional incentive for restoration of the scenic access points.

FEASIBILITY SUMMARY

An evaluation of possible management options at Nashawannuck Pond was conducted and those alternatives which were not appropriate or feasible were eliminated. The remaining and recommended options include: water level control, hypolimnetic release, institution of a watershed and urban nutrient management program, redesign of stormwater system, installation of gabion weirs, removal of major sediment accumulations, and rehabilitation of fishing access points. The tentative implementation schedule and associated costs are presented in Table 27. Note that administrative costs are considered to be covered by the normal budget of Easthampton town officials, such as the town engineer or town planner.

The recommended options constitute a long-term pond and watershed management program. The first step includes inexpensive pond management options; water level control and hypolimnetic release. The second and more important step is a comprehensive program aimed at reducing non-point watershed nutrient loadings, through a program of best management practices and land use planning. In addition, an educational program aimed at teaching local Easthampton residents in the fundamentals of environmentally sound "urban housekeeping" is recommended. The third and more costly step includes engineering changes in the stormwater system, installation of gabion weirs, drawdown and excavation of the 72,300 CY material from the bottom of Nashawannuck Pond. The final step is rehabilitation and enhancement to four key access points for fishing and views of Nashawannuck Pond. Most of these options are to be exercised to improve the relationship between Nonotuck Park and the pond. Monitoring programs are included for both the smaller and larger scale options.

Potential funding sources have been discussed, with the Massachusetts Clean Lake Program targeted as the likely primary source for the pond restoration options. Other funding sources are available for acquisition of land areas and improving recreational facilities. A future state program may provide the bulk of funding for a non-point watershed program. The recommended options will improve pond water quality, but not dramatically change it. Improvement of recreational quality in Nashawannuck Pond is the realistic goal Given the large expenses involved in the restoration (> $1.3 million); it should be noted that Easthampton can apply for Phase II funding for one, two or all of the options at its discretion and not disqualify itself for future funding applications. Separation of the restoration options into low-cost and high-cost options packages is discussed.

TABLE 27

SCHEDULE AND COSTS FOR IMPLEMENTATION OF MANAGEMENT OPTIONS FOR NASHAWANNUCK POND.

MANAGEMENT OPTION	SPRING 1990	SUMMER 1990	FALL 1990	WINTER 1990	SPRING 1991	SUMMER 1991	FALL 1991	WINTER 1991	SPRING 1992	SUMMER 1992	FALL 1992	WINTER 1992	YEAR 1993	YEAR 1993	PROJECT TOTALS
Administration	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0
Water Level Drawdown		X 500	X 500	X 0			X 0	X 0							1000
Hypolimnetic Release		X 500				X 0				X 0				X 0	500
Watershed Reduction Program		X 6,000	X 6,000	X 6,000	X 6,000	X 6,000									30,000
Gabion Weirs			X 26,000	X 26,000											52,000
Dredging Program		X 300,000	X 205,000	X 205,000			X 205,000	X 206,000							1,121,000
Storm Drain System					X	X	X								
Catch Basin Replacement					16,000	15,000	15,000								46,000
Rerouting + CB replace.					60,000	60,000	60,000								180,000
Urban Housekeeping Awareness Program			X 1,000	X 1,000	X 3,000										5,000
Restoration of Points		X	X	X			X	X							
Scheme I.		13,300	11,000	11,000			11,000	11,000							61,300
Scheme II.		47,500	25,000	25,000			25,000	25,000							147,500
Monitoring					X	X	X	X	X	X	X	X	X	X	
Low-Cost Package					1,050	1,050	1,050	1,050	750	750	750	750	3,000		10,200
High-Cost Package									1,050	1,050	1,050	1,050	4,000	4,000	12,200
TOTAL COSTS															
Low-Cost Package		7,000	33,500	33,000	10,050	7,050	1,050	1,050	750	750	750	750			98,700
High-Cost Package		347,500	230,000	230,000	60,000	60,000	290,000	231,000	1,050	1,050	1,050	1,050	4,000	4,000	1,460,700

REFERENCES

APHA, AWWA, AND WPCF. 1985. Standard Methods for the Examination of Water and Wastewater (16th Edition). Published jointly by the authoring associations.

Baystate Environmental Consultants, Inc. 1988a. Final Report. Diagnostic / Feasibility Study for the Management of Buttonwood Pond; New Bedford, Massachusetts. East Longmeadow, MA. 252 pp.

Baystate Environmental Consultants, Inc. 1988b. Final Report. Diagnostic / Feasibility Study for the Management of Dimmock Pond; Springfield, Massachusetts. East Longmeadow, MA. 253 pp.

Baystate Environmental Consultants, Inc. 1989a. Final Report. A Diagnostic / Feasibility Study for the Management of Forge Pond; Granby, Massachusetts. East Longmeadow, MA. 349 pp.

Baystate Environmental Consultants, Inc. 1989b. Draft Final Report. A Diagnostic / Feasibility Study for the Management of Prindle Pond; Charlton, Massachusetts. East Longmeadow, MA.

Brezonik, P.L. 1973. Nitrogen Sources and Cycling in Natural Waters. USEPA 660/3-73-002.

Carroll, W. 1985. History of Nashawannuck Pond Dam. Handout produced for Pascommuck Trust. Easthampton, MA.

Chapra, S. 1975. Comment on: "An Empirical method of estimating the retention of phosphorus in lakes" by W.B. Kirchner and P.J. Dillon. Water Resour. Res. 11:1033-1034.

Cooke, G.D., E.B. Welch, S.A. Peterson, and P.R. Newroth. 1986. Lake and Reservoir Restoration. Butterworths, Boston, MA.

Dillon, P.J. 1975. The phosphorus budget of Cameron Lake, Ontario : The importance of flushing rate to the degree of eutrophy of lakes. Limnol. Oceanogr. 20: 28-39.

Dillon, P.J., and F.H. Rigler. 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. J. Fish. Res. Bd. Canada 31: 1519-1522.

Dunne, T. and L.B. Leopold. 1978. Water in environmental planning. W.H. Freeman and Company, San Francisco, CA.

Fassett, N.C. 1957. A Manual of Aquatic Plants; University of Wisconsin Press Madison. WI.

Goldman, C.R., and A.J. Horne. 1983. Limnology. McGraw-Hill Co., New York.

Hanson, J.M., and W.C. Leggett. 1982. Empirical prediction of fish biomass and yield. Can. J. Fish. Aquat. Sci. 39:257-263.

Higgins, G.R., and J.M. Colonell, 1971. Hydrologic Factors in the Determination of Watershed Yields. Water Resour. Res. Ctr., Univ. Mass., Amherst, MA.

IEP, Inc. 1988. Aquifer Land Acquisition Study; Easthampton, MA. Northborough, MA.

Jones, J.R., and R.W. Bachmann. 1976. Prediction of phosphorus and chlorophyll levels in lakes. J. Water Poll. Control Fed. 48:2176-2184.

Kirchner, W.B., and P.J. Dillon. 1975. An empirical method of estimating the retention of phosphorus in lakes. Water Resour. Res. 11:182-183.

Kopp, J.F., and G.D. McKee. 1979. Methods for Chemical Analysis of Water and Wastes. USEPA 600/4-79-020, Wash., D.C.

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

Landuse, Inc. 1987. Easthampton Master Plan Revision Study. Hadley, MA.

Larsen, D.P., and H.T. Mercier. 1976. Phosphorus retention capacity of lakes. J. Fish. Res. Bd. Canada 33:1742-1750.

Larsen, G.J. and B.D. Stone. 1980. Late Wisconsin Glaciation of New England. Symposium Proceedings. Kendall Hunt Publishing Company, Dubuque, IA.

Lee. G.F., and R.A. Jones. 1986. Evaluation of detergent phosphate bans on water quality. Lakeline, Vol. 6, #1. NALMS, Washington, D.C.

Martin, D.M., and D.R. Goff. 1972. The Role of Nitrogen in the Aquatic Environment. Contribution #2. Academy of Natural Sciences of Philadelphia, PA.

Martin, E.H. 1988. Effectiveness of an urban runoff detention pond - wetlands system. J. Env. Engr. 114 : 810-827.

Massachusetts Department of Environmental Management. 1987. Nashawannuck Pond Dam Inspection Report. Keyes Associates, Wethersfield, CT.

Massachusetts Division of Fisheries and Wildlife. 1912. Fishery Survey of Nashawannuck Pond. MDFW, Westborough, MA.

Massachusetts Division of Fisheries and Wildlife. 1928. Fishery Survey of Nashawannuck Pond. MDFW, Westborough, MA.

Massachusetts Division of Fisheries and Wildlife. 1952. Fishery Survey of Nashawannuck Pond. MDFW, Westborough, MA

Massachusetts Division of Fisheries and Wildlife. 1956. Fishery Survey of Nashawannuck Pond. MDFW, Westborough, MA.

Massachusetts Division of Fisheries and Wildlife. 1958. Fishery Survey of Nashawannuck Pond. MDFW, Westborough, MA.

Massachusetts Division of Fisheries and Wildlife. 1980. Fishery Survey of Nashawannuck Pond. MDFW, Westborough, MA.

Massachusetts Division of Water Pollution Control. 1979. Certification for Dredging, Dredged Material Disposal, and Filling in Waters. 314 CMR, Vol. 12-534.

Massachusetts Division of Water Pollution Control. 1984. Baseline Water Quality Studies of Nashawannuck Pond. MDWPC, Westborough, MA.

Massachusetts Division of Water Pollution Control. 1985. Massachusetts Surface Water Quality Standards. Publication #14371-115-100-3-86-CR.

Massachusetts Division of Water Pollution Control. 1986. Baseline Water Quality Studies of Nashawannuck Pond. MDWPC, Westborough, MA.

Massachusetts Division of Water Pollution Control. 1988. Non-point Sources Assessment Report. MDWPC, Westborough, MA.

Massachusetts River Basin Planning Program. 1984. Agricultural Water Quality Study. United States Department of Agriculture and Massachusetts Agricultural Experiment Station.

Mills, E.L., Green, D.M. and A.S. Schiavone. 1987. Use of zooplankton size to assess the community structure of fish population in freshwater lakes. Trans. Am. Fish. Soc. 116 : 369-378.

Mitchell, D.F., Wagner, K.J. and C. Asbury. 1988. Direct Measurement of groundwater flow and quality as a lake management tool. Lake and Reservoir Management 4 : 169-178.

National Oceanographic and Atmospheric Administration. 1986. Climatography of the United States, Number 20, Climatic Summaries for Selected Sites, 1951-1980. NOAA, Asheville, NC.

National Oceanographic and Atmospheric Administration. 1987. Climatography of the United States, Number 21, Massachusetts. NOAA, Asheville, NC.

National Oceanographic and Atmospheric Administration. 1988. Climatography of the United States, Number 22, Massachusetts. NOAA, Asheville, NC.

North American Lake Management Society. 1985. A Layman's Bibliography of Lake Management. NALMS, Merrifield, VA.

Nurnberg, G.K. 1984. The prediction of internal phosphorus load in lakes with anoxic hypolimnia. Limnol. Oceanogr. 29:111-124.

Oglesby, R.T., and W.R. Schaffner. 1978. Phosphorus loadings to lakes and some of their responses: Part II: Regression models of summer phytoplankton standing crops, winter total phosphorus, and transparency of New York lakes with known phosphorus loadings. Limnol. Oceanogr. 23:135-145.

Reckhow, K.H., M.N. Beaulac, and J.T. Simpson. 1980. Modeling Phosphorus Loading and Lake Response under Uncertainty: A Manual and Compilation of Export Coefficients. USEPA 440/5-80-011, Washington, D.C.

Reynold, C.S. 1980. Phytoplankton periodicity: its motivations, mechanisms and manipulations. Ann. Report. Freshwater Biol. Assoc. 50:60-75.

Robert S. Means Company. 1987. Means Heavy Construction Cost Data, 1987. E. Norman Peterson Publishers, Kingston, MA.

Sawyer, C.N. 1947. Fertilization of lakes by agriculture and urban drainage. N.E. Water Works Assn. J. 61:109-127.

Schueler, T.R. 1987. Controlling urban runoff : A practical manual for planning and designing urban BMP's. Washington Metropolitan Water Resources Planning Board. Washington, D.C.

Smith, V.H. 1982. The nitrogen and phosphorus dependence of algal biomass in lakes: an empirical and theoretical analysis. Limnol. and Oceanog. 27:1101-1111.

Soil Conservation Service. 1978. Soil Survey of Hampden County, Massachusetts, Central Part. United States Department of Agriculture and Massachusetts Agricultural Experiment Station.

Soil Conservation Service. 1981. Soil Survey of Hampshire County, Massachusetts, Central Part. United States Department of Agriculture and Massachusetts Agricultural Experiment Station

Sopper, W.E., and H.W. Lull. 1970. Streamflow Characteristics of the Northeastern United States. Penn State Univ. Bull. 766, Univ. Park, PA.

Tchobanoglous, G. and E.D. Schroeder. 1985. Water Quality. Addison-Wesley Publishing Company, Reading, MA.

United States Environmental Protection Agency. 1976. Quality Criteria for Water. USEPA, Washington, D.C.

United States Environmental Protection Agency. 1988. The Lake and Reservoir Restoration and Guidance Manual. Office of Water Criteria and Standards Division. Non-Point Sources Branch. Washington, D.C.

United States Geological Survey. 1979. Easthampton Quadrangle Sheet, 7.5 Minute Series. USGS, Bethesda, MD.

United States Geological Survey. 1972. Mount Tom Quadrangle Sheet, 7.5 Minute Series. USGS, Bethesda, MD.

United States Geological Survey. 1977. Limiting Values for Water Quality Alert System. USGS Circular, August 22, 1977. USGS, Trenton, NJ.

United States Geological Survey. 1987. Water Resources Data. Massachusetts - Rhode Island Water Year. USGS Water-Data Report MA-RI-85-1.

University of Massachusetts. 1975. Land use and vegetative cover mapping. Easthampton Quadrangle. Massachusetts Map Down Program. Department of Forestry and Wildlife Management, Amherst, MA.

Vollenweider, R.A. 1968. Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters, with Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication. Tech. Rept. to OECD, Paris, France.

Vollenweider, R.A. 1975. Input-output models with special references to the phosphorus loading concept in limnology. Schweiz. Z. Hydrol.37:53-62.

Vollenwieder, R.A. 1982. Eutrophication of Waters: Monitoring, Assessment, and Control. OECD, Paris, France.

Wagner, K.J., and R.T. Oglesby. 1984. Incompatibility of common lake management objectives. Pages 97-100 in: Lake and Reservoir Management. Proc. of the Third Annual Conf. NALMS. USEPA, Washington, D.C.

Wetzel, R.G. 1983. Limnology. 2nd edition. Saunders Co., Philadelphia, PA.

Zen, E. 1983. Bedrock Geologic Map. USGS and MA DPW, Boston, MA.

APPENDIX A

Educational Information About Watershed Management Practices.

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.

<u>Ground Water in General</u>

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.

Streamside Management Zones (Buffer strips): Considerations in streamside management include maintaining the natural vegetation along a stream, limiting livestock access to the stream, and where vegetation has been removed planting buffer strips. Buffer strips are strips of plants (grass, trees, shrubs) between a stream and an area being disturbed by man's activities that protects the stream from erosion and nutrient impacts.

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Good to excellent, reported to reduce sediment from feedlots on 4 percent slope by 79 percent.
b) Nitrogen (N)	Good to excellent, reported to reduce nitrogen from feedlots on 4 percent slope by 84 percent.
c) Phosphorus (P)	Good to excellent, reported to reduce phosphorus from feedlots on 4 percent slope by 67 percent.
d) Runoff	Good to excellent, reported to reduce runoff from feedlots on 4 percent slope by 67 percent.
2. Capital Costs	Good, moderate costs for fencing material to keep out livestock and for seeds or plants.
3. Operation and Maintenance	Excellent, minimal upkeep.
4. Longevity	Excellent, maintain itself indefinitely.
5. Confidence	Fair, because of the lack of intensive scientific research.
6. Adaptability	May be used anywhere. Limitations on types of plants that may be used between geographic areas.
7. Potential Treatment Side Effects	With trees, shading may increase the diversity and number of organisms, in the stream with the possible reduction in algae.
8. Concurrent Land Management Practices	Conservation tillage, animal waste management, livestock exclusion, fertilizer management, pesticide management, ground cover maintenance, proper construction, use, maintenance of haul roads and skid trails.

Source : USEPA, 1988.

Best management practices (Cont.)

Maintain Natural Waterways: This practice disposes of tree tops and slash in areas away from waterways. Prevents the buildup of damming debris. Stream crossings are constructed to minimize impacts on flow characteristics.

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Fair to good, prevents acceleration of bank and channel erosion.
b) Nitrogen (N)	Unknown, contribution would be from decaying debris.
c) Phosphorus (P)	Unknown, contribution would be from decaying debris.
d) Runoff	Fair to good, prevents deflections or constrictions of stream water flow which may accelerate bank and channel erosion.
2. Capital Cost	Low, supervision required to ensure proper disposal of debris.
3. Operation and Maintenance	Low, if proper supervision during logging is maintained, otherise $160-$800 per 100 ft stream.
4. Longevity	Good.
5. Confidence	Good.
6. Adaptability	Excellent.
7. Potential Treatment Side Effects	None identified.
8. Concurrent Land Management Practices	Proper design and location of haul and skid trails; Streamside management zones.

Grassed Waterways: A practice where broad and shallow drainage channels (natural or constructed) are planted with erosion-resistant grasses.

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Good to excellent (60 to 80 percent reduction).
b) Nitrogen (N)	Unknown.
c) Phosphorus (P)	Unknown.
d) Runoff	Moderate to good.
2. Capital Cost	Moderate.
3. Operation and Maintenance	Low, but may interfere with the use of large equipment.
4. Longevity	Excellent.
5. Confidence	Good.
6. Adaptability	Excellent.
7. Potential Treatment Side Effects	None identified.
8. Concurrent Land Management Practices	Conservative tillage, integrated pest management, fertilizer management, animal waste management.

Source : USEPA, 1988.

Riprap: A layer or loose rock or aggregate placed over a soil surface susceptible to erosion.

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Good, based on visual observations.
b) Nitrogen (N)	Unknown.
c) Phosphorus (P)	Unknown.
d) Runoff	Poor.
2. Capital Cost	Low to high, varies greatly.
3. Operation and Maintenance	Low.
4. Longevity	Good, with proper rock size.
5. Confidence	Poor to good.
6. Adaptability	Excellent.
7. Potential Treatment Side Effects	In streams, erosion may start in a new, unprotected place.
8. Concurrent Land Management Practices	Streamside (lake) management zone.

Interception or Diversion Practices: Designed to protect bottom land from hillside runoff, divert water from areal sources of pollution such as barnyards or to protect structures from runoff. Diversion structures are represented by any modification of the surface that intercepts or diverts runoff so that the distance of flow to a channel system is increased.

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Fair to good (30 to 60 percent reduction).
b) Nitrogen (N)	Fair to good (30 to 60 percent reduction).
c) Phosphorus (P)	Fair to good (30 to 60 percent reduction).
d) Runoff	Poor, not designed to reduce runoff but divert runoff.
2. Capital Cost	Moderate to high, may entail engineering design and structures.
3. Operation and Maintenance	Fair to good.
4. Longevity	Good.
5. Confidence	Poor to good, largely unknown.
6. Adaptability	Excellent.
7. Potential Treatment Side Effects	None identified.
8. Concurrent Land Management Practices	Since the technique can be applied under multiple situations (i.e., agriculture, silviculture, construction) appropriate best management practices associated with individual situations should be applied.

Source : USEPA, 1988.

Sediment Traps: Sediment traps are temporary structures made of sandbags, straw bales, or stone. Their purpose is to detain runoff for short periods of time so heavy sediment particles will drop out. Typically, they are applied within and at the periphery of disturbed areas.

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Good, coarse particles.
b) Nitrogen (N)	Poor.
c) Phosphorus (P)	Poor.
d) Runoff	Fair
2. Capital Cost	Low
3. Operation and Maintenance	Low, require occasional inspection and prompt maintenance.
4. Longevity	Poor to good.
5. Confidence	Poor.
6. Adaptability	Excellent.
7. Potential Treatment Side Effects	None identified.
8. Concurrent Land Management Practices	Agricultural, silviculture or other construction best management practices could be incorporated depending on situation.

Surface Roughening: On construction sites, the surface of the exposed soil can be roughened with conventional construction equipment to decrease water runoff and slow the downhill movement of water. Grooves are cut along the contour of a slope to spread runoff horizontally and increase the water infiltration rate.

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Good.
b) Nitrogen (N)	Unknown.
c) Phosphorus (P)	Unknown.
d) Runoff	Good.
2. Capital Cost	Low, but requires timing and coordination.
3. Operation and Maintenance	Low, temporary protective measure.
4. Longevity	Short-term.
5. Confidence	Unknown.
6. Adaptability	Excellent.
7. Potential Treatment Side Effects	None identified.
8. Concurrent Land Management Practices	Nonvegetative soil stabilization.

Source : USEPA, 1988.

Porous Pavement: *Porous pavement is asphalt without fine filling particles on a gravel base.*

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Good.
b) Nitrogen (N)	Good.
c) Phosphorus (P)	Good.
d) Runoff	Good to excellent.
2. Capital Costs	Moderate, slightly more expensive than conventional surfaces.
3. Operation and Maintenance	Potentially expensive, requires regular street maintenance program and can be destroyed in freezing climates.
4. Longevity	Good, with regular maintenance (i.e., street cleaning), in southern climates. In cold climates, freezing and expansion can destroy.
5. Confidence	Unknown.
6. Adaptability	Excellent.
7. Potential Treatments Side Effects	Groundwater contamination from infiltration of soluble pollutants.
8. Concurrent Land Management Practices	Runoff detention/retention.

Flood Storage (Runoff Detention/Retention): Detention facilities treat or filter out pollutants or hold water until treated. Retention facilities provide no treatment. Examples of detention/retention facilities include ponds, surface basins, underground tunnels, excess sewer storage and underwater flexible or collapsible holding tanks.

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Poor to excellent, design dependent.
b) Nitrogen (N)	Very poor to excellent, design dependent.
c) Phosphorus (P)	Very poor to excellent, design dependent.
d) Runoff	Poor to excellent, design dependent.
2. Capital Costs	Dependent on type and size. Range from $100 to $1,000, per acre served, depending on site. These costs include capital costs and operational costs.
3. Operation and Maintenance	Annual cost per acre of urban area served has ranged from $10 to $125 depending on site.
4. Longevity	Good to excellent, should last several years.
5. Confidence	Good, if properly designed.
6. Adaptability	Excellent.
7. Potential Treatment Side Effects	Groundwater contamination with retention basins.
8. Concurrent Land Use Practices	Porous pavements.

Source : USEPA, 1988.

Best management practices (cont.)

Street Cleaning: Streets and parking lots can be cleaned by sweeping which removes large dust and dirt particles or by flushing which removes finer particles. Sweeping actually removes solids so pollutants do not reach receiving waters. Flushing just moves the pollutants to the drainage system unless the drainage system is part of the sewer system. When the drainage system is part of the sewer system, the pollutants will be treated as wastes in the sewer treatment plant.

CRITERIA	REMARKS
1. *Effectiveness*	
a) Sediment	Poor, not proven to be effective.
b) Nitrogen (N)	Poor, not proven to be effective.
c) Phosphorus (P)	Poor, not proven to be effective.
d) Runoff	No effect.
2. Capital Costs	High, because it requires the purchase of equipment by community.
3. Operation and Maintenance	Unknown but reasonable vehicular maintenance would be expected.
4. Longevity	Poor, have to sweep frequently throughout the year.
5. Confidence	Poor.
6. Adaptability	To paved roads, might not be considered a worthwhile expenditure of funds in communities less than 10,000.
7. Potential Treatment Side Effects	Unknown.
8. Concurrent Land Management Practices	Detention/Sedimentation basins.

Source : USEPA, 1988.

Animal Waste Management: A practice where animal wastes are temporarily held in waste storage structures until they can be utilized or safely disposed. Storage units can be constructed of reinforced concrete or coated steel. Wastes are also stored in earthen ponds.

CRITERIA	REMARKS
1. Effectiveness	
a) *Sediment*	*Not applicable.*
b) Nitrogen (N)	Good to excellent.
c) Phosphorus (P)	Good to excellent.
d) *Runoff*	*Not applicable.*
2. Capital Costs	High because of the necessity of construction and disposal equipment.
3. Operation and Maintenance	Unknown.
4. Longevity	Unknown.
5. Confidence	Fair to excellent if properly managed.
6. Adaptability	Good.
7. Potential Treatment Side Effects	The use of earthen ponds can possibly lead to ground-water contamination.
8. Concurrent Land Management Practices	Fertilizer management.

Nonvegetative Soil Stabilization: Examples of temporary soil stabilizers include mulches, nettings, chemical binders, crushed stone, and blankets or mats from textile material. Permanent soil stabilizers include coarse rock, concrete, and asphalt. The purpose of soil stabilizers is to reduce erosion from construction sites.

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Excellent.
b) Nitrogen (N)	Poor.
c) Phosphorus (P)	Poor.
d) Runoffs	Poor on steep slopes with straw mulch, otherwise good.
2. Capital Costs	Low to high, depending on technique applied.
3. Operation and Maintenance	Moderate.
4. Longevity	Generally a temporary solution until a more permanent cover is developed. Excellent for permanent soil stabilizer.
5. Confidence	Good.
6. Adaptability	Excellent.
7. Potential Treatment Side Effects	No effect on soluble pollutants.
8. Concurrent Land Management Practices	Runoff detention/retention.

Source : USEPA, 1988.

Crop Rotation: Where a planned sequence of crops are planted in the same area of land. For example, plow based crops are followed by pasture crops such as grass or legumes in two to four year rotations.

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Good when field is in grasses or legumes
b) Nitrogen (N)	Fair to good.
c) Phosphorus (P)	Fair to good.
d) Runoff	Good when field is in grasses or legumes.
2. Capital Costs	High if farm economy reduced. Less of a problem with livestock which can use plants as food.
3. Operation and Maintenance	Moderate, increased labor requirements. May be off-set by lower nitrogen additions to the soil when corn is planted after legumes, and reduction in pesticide application.
4. Longevity	Good.
5. Confidence	Fair to good.
6. Adaptability	Good, but some climatic restrictions.
7. Potential Treatment Side Effects	Reduction in possibility of groundwater contamination.
8. Concurrent Land Management Practices	Range and pasture management.

Terraces: Terraces are used where contouring, contour strip cropping, or conservation tillage do not offer sufficient soil protection. Used in long slopes and slopes up to 12 percent; terraces are small dams or a combination of small dams and ditches that reduce the slope by breaking it into lesser or near horizontal slopes.

CRITERIA	REMARKS
1. Effectiveness	
a. Sediment	Fair to good.
b. Nitrogen (N)	Unknown.
c. Phosphorus (P)	Unknown.
d. Runoff	Fair, more effective in reducing erosion than total run-off volume.
2. Capital Cost	High initial costs.
3. Operation and Maintenance	Periodic maintenance cost, but generally offset by increased income.
4. Longevity	Good with proper maintenance.
5. Confidence	Good to excellent.
6. Adaptability	Fair, limited to long slopes and slopes up to 12 percent.
7. Potential Treatment Side Effect	If improperly designed or used with poor cultural and management practices, they may increase soil erosion.
8. Concurrent Land Management Practices	Fertilizer and pesticide management.

Source : USEPA, 1988.

Contour Farming: A practice where the farmer plows across the slope of the land. This practice is applicable on farm land with a 2-8 percent slope.

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Good on moderate slopes (2 to 8 percent slopes), fair on steep slopes (50 percent reduction).
b) Nitrogen (N)	Unknown.
c) Phosphorus (P)	Fair.
d) Runoff	Fair to good, depends on storm intensity.
2. Capital Costs	No special effect.
3. Operation and Maintenance	No special effect.
4. Longevity	Poor, it must be practiced every time the field is plowed.
5. Confidence	Poor, not enough information.
6. Adaptability	Good, limited by soil, climate, and slope of land. May not work with large farming equipment on steep slopes.
7. Potential Treatment Side Effects	Side effects not identified.
8. Concurrent Land Management Practices	Fertilizer management, integrated pesticide management, possibly streamside management.

Contour Stripcropping: This practice is similar to contour farming where the farmer plows across the slope of the land. The difference is that strips of close growing crops or meadow grasses are planted between strips of row crops like corn or soybeans. Whereas contour farming can be used on 2-8 percent slopes, contour stripcropping can be used on 8-15 percent slopes.

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Good, 8 to 15 percent slopes, provides the benefits of contour plowing plus buffer strips.
b) Nitrogen (N)	Unknown, assumed to be fair to good.
c) Phosphorus (P)	Unknown, assumed to be fair to good.
d) Runoff	Good to excellent.
2. Capital Costs	No special effect unless farmer cannot use the two crops.
3. Operation and Maintenance	No special effect.
4. Longevity	Poor, must be practiced year after year.
5. Confidence	Poor, not enough information.
6. Adaptability	Fair to good, may not work with large farming equipment on steep slopes.
7. Potential Treatment Side Effects	Side effects not identified.
8. Concurrent Land Management Practices	Fertilizer management, integrated pesticide management.

Source : USEPA, 1988.

Best management practices (cont.)

Range and Pasture Management: The objective of range and pasture management is to prevent overgrazing because of too many animals in a given area. Management practices include spreading water supplies, rotating animals between pastures, spreading mineral and feed supplements or allowing animals to graze only when a particular plant food is growing rapidly.

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Good, prevents soil compaction which reduces infiltration rates.
b) Nitrogen (N)	Unknown.
c) Phosphorus (P)	Unknown.
d) Runoff	Good, maintains some cover which reduces runoff rates.
2. Capital Costs	Low, but may have to develop additional water sources.
3. Operation and Maintenance	Low.
4. Longevity	Excellent.
5. Confidence	Good to excellent. Farmer must have a knowledge of stocking rates, vegetation types, and vegetative conditions.
6. Adaptability	Excellent.
7. Potential Treatment Side Effects	None identified.
8. Concurrent Land Management Practices	Livestock exclusion, riparian zone management and crop rotation.

Source : USEPA, 1988.

Best management practices (Cont.)

Haul Roads and Skid Trails: This practice is implemented prior to logging operations. It involves the appropriate site selection and design of haul road and skid trails. Haul roads and skid trails should be located away from streams and lakes. Recommended guidelines for gradient, drainage, soil stabilization, and filter strips should be followed. Routes should be situated across slopes rather than up or down slopes. If the natural drainage is disrupted, then artificial drainage should be provided. Logging operations should be restricted during adverse weather periods. Other goods practices include ground covers (rock or grass) closing roads when not in use, closing roadways during wet periods, and returning main haul roads to prelogging conditions when logging ceases.

CRITERIA	REMARKS
1. Effectiveness	
a) Sediment	Good if grass cover is used on haul roads (45 percent reduction); Excellent if crushed rock is used as ground cover (92 percent reduction).
b) Nitrogen (N)	Unknown.
c) Phosphorus (P)	Unknown.
d) Runoff	Unknown.
2. Capital Cost	High, grass cover plus fertilizer S5.37/100 ft roadbed, crushed rock (6 in) S179.01/100 ft roadbed.
3. Operation and Maintenance	High, particularly with grass which may have to be replenished routinely and may not be effective on highly traveled roads.
4. Longevity	Unknown.
5. Confidence	Good for ground cover, poor for nutrients.
6. Adaptability	Good.
7. Potential Treatment Side Effects	Potential increase in nutrients to water course if excess fertilizers are applied.
8. Concurrent Land Management Practices	Maintain natural waterways.

Source : USEPA, 1988.

APPENDIX B

Environmental Notification Form.

ENVIRONMENTAL NOTIFICATION FORM

I. SUMMARY

A. Project Identification

1. Project Name Nashawannuck Pond
   Address/Location Easthampton, MA
   Nonotuck Park
   City/Town Easthampton, MA 01027
2. Project Proponent Town of Easthampton
   Address Town Hall, Easthampton, MA 01027
3. Est. Commencement Fall, 1989 . Est. Completion Continuing .
   Approx. Cost $ 98,700 . Status of Project Design 35 % 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.
   0.05 acres 2,500 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.

Project is a Phase II (Implementation) Project for the restoration of Nashawannuck Pond, Easthampton, MA. Project includes a winter drawdown to check nuisance macrophyte growths, limited bottom water releases, installation of gabion weirs at two sites to prevent sedimentation and protect wetlands during drawdown. Other measures include education programs for both wetland residents and urban abutters.

The winter drawdown will be 1.5M in depth and will expose 50%± of pond bottom. The drawdown will use the existing bascule gate and be conducted during late-early winter to minimize impact to emergent wetland plants. Bottom water releases will be conducted in summer to remove oxygen poor water from pond. Receiving "stream" is shallow concrete spillway that will enhance re-aeration.

Installation of gabion weirs is proposed at White Brook with disturbance of 500± sq. ft. of wetland area and at Broad Brook with 2000± sq. ft. of wetland being altered.

A post-construction monitoring plan for three years is also included in project.

Copies of the complete ENF may be obtained from (proponent or agent):
Name: Peter Klejna Firm/Agency: Easthampton Planning Dept.
Address: Town Hall Annex Phone No. 413-527-8782

1986 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.
U.S. Army Corps Of Engineers	Sec. 404 Permit	Applicability determination needed
MA Division of Waterways	Chapter 91	Applicability determination needed
MA Div. Water Pollution Control	Water Quality Certificate	Applicability determination needed

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

Agency Name	Funding Amount
MA Division Water Pollution Control	$73,000

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

2. List the alternatives which have been considered.

Alternatives which have been considered and rejected include: no action, harvesting, biocides, hypolimnetic aeration, nutrient inactivation. Alternatives proposed for future restoration include: dredging, stormwater diversion, and bank stabilization.

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 ______.

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.
See Figures 1,3,12,16,24 in BEC D/F Report

B. State total area of project: ____0.05____ acres.
Estimate the number of acres (to the nearest 1/10 acre) directly affected that are currently:

1. Developed .... ____ acres
2. Open Space/ Woodlands/Recreation <0.1 acres
3. Wetlands .... <0.1 acres
4. Floodplain .... ____ acres
5. Coastal Area .... ____ acres
6. Tidelands .... ____ acres
7. Productive Resources
   Agriculture .... ____ acres
   Forestry .... ____ acres
8. Other .... ____ acres

C. *Provide the following dimensions, if applicable:*

	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.*

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: Nashawannuck Pond is a public recreational pond. Drawdown and installation of gabion weirs will temporarily disrupt recreational activity. Timing of drawdown will mitigate impacts and improve conditions are expected as a result of the project.

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

Explanation and Source: Yes, the project site is within Nashawannuck Pond or at its shoreline. A town boat landing and park (Nonotuck) are located along the shoreline.

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:

None known (see letter from M.H.C.)

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

Explanation and Source:

None known (see letter from M.H.C.)

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:

No rare or endangered species are reported for Nashawannuck Pond (see letter from MA Natural Heritage Program). Drawdown and gabion weirs will impact present fish population, but benefits to fishing likely to outweigh impacts (see letter from MA D.F.W).

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: 5)
Explanation and Source:

Some trees may be removed in installation of gabion weirs. The project will result in reduction in aquatic macrophyte abundance in Nashawannuck Pond.

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, no agricultural lands are involved.

D. Water Quality and Quantity
1. Might the project result in significant changes in drainage patterns?
Explanation and Source:

No, hydrologic impacts to Nashawannuck Pond will remain the same.

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:

Yes, a temporary increase in suspended solids may result from placement of gabion weirs. Long-term reduction in sediments entering from tributaries is expected.

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, project will be conducted in Nashawannuck 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:

Some reduction of current load from septic systems in watershed is anticipated as result of education and watershed management.

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, there is a town well at Nonotuck Park. However, this is a deep well which does not draw upon the surface waters of Nashawannuck Pond. There is an intervening clay layer that prevents recharge from the pond. (IEP, 1988).

9. Does the operation of the project result in any increased consumption of water?
   Approximate consumption ________ gallons per day. Likely water source(s) ________
   Explanation and Source:

   NO

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:

      NO

   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, construction dust may be generated in Nonotuck Park during installation of gabion. Some smell may be associated with bottom water release (ammonical or "fishy" smells of natural origin).

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, area of bottom water release is industrially zoned and located near busy intersection (Rt. 141).

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, construction noises associated with installation of gabion weirs.

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:

Yes, residential areas and Nonotuck Park will receive noise during installation of gabion weirs, but level of noise not high nor sustained for greater than construction period.

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, project will result in better protected wetlands and an improved aesthetic appearance to the pond.

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

Explanation and Source:

Temporary and negligible visual impairment during gabion installation. Slight change in pond appearance due to gabion weirs, which do not protrude above water line during normal pool conditions.

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.

Project is consistent with water quality and recreational goals (see letter from Easthampton).

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 ______

COMMENTS OF FIRST PUBLIC MEETING

The first public meeting for the Nashawannuck Pond Diagnostic/Feasibility Study was held on June 25, 1987 at the Town Hall in Easthampton. In attendance were representatives from BEC, Inc. Dr. David Mitchell and Ms. Rebecca Sherer; the State Project Officer, Mr. Steve Nathan; the Town Engineer, Mr. Roland Laramee; representing the Easthampton Conservation Commmission and the Pascommuck Trust, Mr. Mike Tautznik; representing the Easthampton Planning Board, Mr. Bob Pinkos; and 6 local residents. Dr. Mitchell gave a slide presentation and brief overview of the aims of the study and some of the preliminary results. Then the meeting was opened up for comments and questions from the public. Much of the discussion centered on how to make the residents of Easthampton more aware of the pond and its restoration.

COMMENTS OF SECOND PUBLIC MEETING

The second public meeting for the Nashawannuck Pond Diagnostic/Feasibility Study was held on August 18, 1988 at the White Brook Middle School Road in Easthampton. In attendance were representatives from BEC, Inc., Dr. David Mitchell and Ms. Rebecca Sherer; from the MA DWPC, Mr. Steven Nathan, from the Town of Easthampton, Selectmen Mr. Daniel Gallagher and Mr. John Poulin; Mr. Peter Klejna, the Town Planner, Mr. Michael Tautznik (Conservation Commission, Pascommuck Trust), Mr. Robert Pinkos (Planning Board); as well as about 15 residents.

After brief introductory remarks by Messers Klejna and Tautznik, Dr. Mitchell and Ms. Sherer gave a slide and overhead presentation of the results and recommendations of the study; outlining possible courses of action for protection and restoration of Nashawannuck Pond. [The presentation was videotaped for future showings at local functions.] The meeting was opened up for comments and questions. The following is a listing of the comments and questions raised at this meeting.

- Why is storm drainage detrimental to the system ? (Poor water quality more than offsets any benefits that limited amount of additional flushing brings to the pond).

- Comment clarifying where the three sluiceways in the dam go to. (Sluiceway #1 (west end) goes into "Mill Works", Sluiceway #3 (east end) goes to "Dye Works"; while Sluiceway #2 has no direct industrial connection and flow goes directly to spillway).

- Does the nitrogen loading appear to be derived from agriculture ? (The high levels of nitrogen are indicative of cultural eutrophication, but agriculture is not the sole culprits, other sources : lawn fertilizers, septic systems, storm drains, etc.)

- Is the percentage of nutrient loadings ascribed to storm drainage a combination of point and non-point sources ? (The percentage of 3.8% was due to point sources, the amount coming out of pipes directly into the pond).

- Will there be instructions given in the D/F study to show the town how to proceed for a water level drawdown ? (A recommended elevation for the bascule gate will be given; operation of the gate is straightforward).

- What are the environmental permitting associated with the drawdown ? (A brief discussion on the likely permits required for this optiont was given).

- Does the low quality of the water arising from non-point sources in the watershed make this an especially appropriate "demonstration" watershed for the proposed MA Non-Point Sources Program ? (It would appear so, based on the importance of watershed loadings in determining lake water quality, and the identification of the watershed as a "high priority" watershed in the joint USDA-MA Agricultural Water Quality Survey).

- Does the recent Aquifer Land Acquistion Study provide useful information with regard to watershed management. (It is only one of a number of existing programs that can effectively reduce watershed loadings. It is important to coordinate these various programs via planning at the level of a watershed or aquifer basin.

- Since installation of the gabion weir helps improve water quality, why not at other points in the Broad Brook watershed ? (While applicable, site characteristics and ownership are issues that discount most other sites).

- What are the potential uses of the material dredged from the pond ? (This material is probably best utilized in Nonotuck Park for needed topsoil or fill; alternatively agricultural usage or landfill cover are two other options).

- Why not collect all the storm drains going into Nashawannuck Pond and route them into one large pipe that discharges either at the deep basin or past the dam ? (Unlikely to be technically or economically attractive option; Mr. Nathan provided some experiences from another project which bears this out).

- Isn't catch basin maintenance an important component of improved performance in storm drains ? (Yes, the degraded condition of most catch basins in the Nashawannuck Pond vicinity was emphasized, as was the importance of proper maintenance. It is probably the largest single determinant of storm water quality).

- Is watershed non-point reduction a planning issue ? (Yes, very much so. Again (see above), the coordination between municipal and planning boards is a key to implementing any meaningful change on such a large watershed).

- Roughly four-hundred residential units in the White Brook watershed are in the preliminary planning stages, should the Planning Board allow direct storm drainage to White Brook ? (While solutions are site-specific, the Planning Board should look to have water quality addressed in the design of storm drain systems, not just the quantity of water during storm events.)

- The general status of the Nashawannuck Pond fishery and the impact of reducing the amount of macrophytes was discussed.

- Are the fish in Nashawannuck Pond safe to eat ? (Given that there is no definitive testing (tissue analysis) of the fish; the best advice is to eat only the stocked trout (whose flesh largely reflects hatchery conditions) or the mid-water feeders (bass, yellow perch, etc). In the absence of testing, avoidance of the eating of bottom feeding fish (brown bullhead or "hornpout") is probably prudent).

- How long is the present Clean Lakes Program Bond Act viable ? (Until 1991, with anticipated but not guaranteed renewal).

- If nothing is done to the pond what will happen ? (The pond is probably close to full biological potential right now, physical factors such as light availability or flushing rate are dictating amount of production. Failure to act now will not cause irretrievable damage, but no improvement can be expected. What will be lost is the opportune moment to coordinate many planning issues (housing, aquifer, lake) together most efficiently. Further, Mr. Nathan reminded the audience is that time is the most costly factor in the equation; what costs "X" today, is 2-3 "X" next year, and so on).

- The importance of wheelchair accessibility to many of the recreational access points being discussed was brought up by a member of the audience. (There are two scheme being presented to the town, one is more amenable to handicapped accessibility).

TOWN OF EASTHAMPTON

TOWN HALL

EASTHAMPTON, MASSACHUSETTS 01027

June 28, 1989

Mr. Stephen Nathan
Clean Lakes Program
Division of Water Pollution Control
DEQE
Westview Building, Lyman School
Westborough, Mass. 01581

Re: Town's Acceptance of Phase I Report; request to be retained on priority list for future phase II funding.

Dear Steve,

On behalf of the Town of Easthampton, I wish to indicate that the Diagnostic/Feasibility Study for the Management of Nashawannuck Pond, Easthampton, Massachusetts is entirely satisfactory. We feel that Baystate Environmental Consultants, Inc. did an excellent job.

Also, the Town desires that this project described in the report be placed or kept on a priority list for future Phase II funding. In the meantime, the Nashawannuck Pond Steering Committee is going to investigate the low cost/no cost managment options described in the report. This may include winter drawdown and summer bottom releases.

Thanks for your continuing assistance.

Sincerely,

Peter B. Klejna
Town Planner

cc: Michael Tautznik, Nashawannuck Pond Steering Committee

BAYSTATE
NVIRONMENTAL
CONSULTANTS
INC.

Scientists
Engineers
Planners

September 15, 1988

Mr. Jay Copeland
Environmental Reviewer
Massachusetts Natural Heritage Program
Division of Fisheries and Wildlife
100 Cambridge Street
Boston, MA 02202

Dear Mr. Copeland

Baystate Environmental Consultants (BEC), Inc., as part of the review process for the Diagnostic /Feasibility Study for Nashawannuck Pond, Easthampton, are contacting the Massachusetts Natural Heritage Program for information regarding rare species and ecologically significant natural communities in the vicinity of Nashawannuck Pond. We request that you forward your findings to us in letter form at your earliest convenience.

We have enclosed a project summary detailing suggested restoration options for the lake, as well as a locus map of the Nashawannuck Pond watershed; taken from the USGS Easthampton topographic quadrangle map. Should your office need any additional information, please do not hesitate to contact me.

Thank you for your cooperation in this matter.

Very truly yours,

BEC, Inc.

David F. Mitchell

David F. Mitchell, Ph.D.
Senior Environmental Scientist

d.221

296 North Main Street
East Longmeadow, MA 01028
(413) 525-3822

Massachusetts Natural Heritage Program

20 October 1988

Mr. David Mitchell
Baystate Environmental Consultants, Inc.
296 North Main Street
East Longmeadow, MA 01028

Re: Diagnostic/Feasibility Study
Nashawannuck Pond
Easthampton, MA

Dear Mr. Mitchell:

Thank you for contacting the Natural Heritage and Endangered Species Program regarding rare species and ecologically significant natural communities in the vicinity of Nashawannuck Pond in Easthampton, Massachusetts, as described in your 4 October 1988 letter.

At this time, we are not aware of any rare plants or animals or ecologically significant natural communities at Nashawannuck Pond. However, we have documented Swamp Lousewort (*Pedicularis lanceolata*), listed by the Massachusetts Division of Fisheries and Wildlife as Endangered, and Wood Turtle (*Clemmys insculpta*), a Species of Special Concern, along Broad Brook. We also have a record for Spotted Turtle (*Clemmys guttata*), a Species of Special Concern, at "Boy Scout Pond" which is associated with Broad Brook. The areas in which these rare species occur have been outlined in red on the enclosed topographic map. Fact sheets describing the habitat, biology, distribution and status of Wood Turtle and Spotted Turtle have been enclosed for your reference.

If your project plans change, or if additional fieldwork and research results in an update of our database, this evaluation may require reconsideration.

Please note that rare species data should not be made public, in order to protect vulnerable habitats and populations from degradation through collecting and visitation (please see attached "Notice to Recipients..."). In cases where permission is given by this office for publication of data in

Division of Fisheries and Wildlife 100 Cambridge Street, Boston, Mass. 02202 (617) 727-9194,-3151

environmental information documents, the NHESP should be credited as the source of this information.

Sincerely,

Karen Pelto

Karen Pelto
Environmental Review Assistant

KP:kp

cc: town file, chrono file

BAYSTATE
ENVIRONMENTAL
CONSULTANTS
INC.

Scientists
Engineers
Planners

September 15, 1988

Ms. Brona Simon
State Archaeologist
Technical Services Division
Massachusetts Historical Commission
80 Boyleston Street
Boston, MA 02116

Dear Ms. Simon,

Baystate Environmental Consultants (BEC), Inc., as part of the review process for the Diagnostic /Feasibility Study for Nashawannuck Pond, Easthampton, are contacting the Massachusetts Historical Commission for information regarding significant historic or archaeological resources in the vicinity of Nashawannuck Pond. We request that you forward your findings to us in letter form at your earliest convenience.

We have enclosed a project summary detailing suggested restoration options for the lake, as well as a locus map of the Nashawannuck Pond watershed; taken from the USGS Easthampton topographic quadrangle map. Should your office need any additional information, please do not hesitate to contact me.

Thank you for your cooperation in this matter.

Very truly yours,

BEC, Inc.

David F. Mitchell

David F. Mitchell, Ph.D.
Senior Environmental Scientist

d.221

296 North Main Street
East Longmeadow, MA 01028
(413) 525-3822

Commonwealth of Massachusetts

Division of Fisheries & Wildlife

Richard Cronin, *Director*

October 28, 1988

Mr. David F. Mitchell, Ph.D.
Baystate Environmental Consultants, Inc.
296 North Main Street
East Longmeadow, MA 01028

RE: Nashawannuck Pond Diagnostic/Feasibility Study, Easthampton, MA

The Division of Fisheries and Wildlife has completed its review of the above referenced report and offers the following comments with respect to the recommended restoration plan:

- <u>experimental winter drawdown</u> - as proposed, the surface area of the pond will be reduced from 22 acres to approximately 9 acres, a 59% reduction. This substantial loss of available recreation area will undoubtedly be met with opposition, at least initially. An informative pre-drawdown announcement detailing the overall program should be developed so that the general and sporting public will have an understanding of the reasons for the drawdown, the schedule, and so forth.

  The actual drawdown should be done slowly to minimize the tendency of fish to follow outflow. It would seem that a bascule gate is functionally capable of being dropped or lowered quickly, this action should be guarded against. While the volume of the pond will be substantially reduced and the fish population will be utilizing approximately 50% of the original volume, we do not foresee the prospects of a winterkill as high. The small volume will be flushed or changed over quickly. This action should be sufficient to avoid a condition where available oxygen for fish is severely depleted.

  The wetland areas should be closely monitored (as suggested) to determine whether more water depth is required.

  Finally, with respect to drawdown, the MDFW usually includes Nashawannuck Pond for fall trout stocking.

Field Headquarters
Westborough, Massachusetts 01581 (617) 366-4470
An Agency of the Department of Fisheries, Wildlife & Environmental Law Enforcement

Lowering of the water in the fall would be in direct conflict with this as it makes boat launching virtually impossible and severely restricts shoreline access for fishing. Any drawdown schedule must include notification to this agency at least 30 days prior to the commencement date so that we may adjust our trout stocking accordingly.

- o <u>bottom water (hypolimnetic) release</u> - page 101 states that all the sluiceways are protected by trashracks but does not describe the specifications of the trashracks. The rainbow trout *(Salmo gairdneri)* is the primary hatchery cultured trout stocked in Nashawannuck Pond. It is a species which has always demonstrated a tendency to move downstream if no precautions are taken to prevent it from doing so. The hypolimnetic release and subsequent mixing of anoxic bottom water with water from the oxygenated upper layer should mean that coldwater fish, such as the rainbow trout, will indeed inhabit the bottom areas. In doing this, it will also put these fish in the same "zone" as the entrance to sluiceway #2. Unless the vertical spacing of the existing trashrack is of a size small enough to prevent trout (9-12 inches average size) from passing between them, we are concerned that a considerable number of trout may escape from the pond. The physical attributes of the sluiceway #2 trashrack should be evaluated with regard to this matter.

  What will be the impacts to downstream aquatic life when the oxygen-poor hypolimnetic water is discharged?

- o <u>reduction of nutrient loadings from diffuse runoff</u> - no particular concerns or comments

- o <u>wetland protection via gabion weirs</u> - if implemented, might these structures present impassable barriers to migrating fish, particularly to white suckers? The MDFW has documented that this species is present in the Nashawannuck Lake fish population. It is conceivable that substantial numbers of adult suckers, if unable to traverse the gabions, would concentrate below the gabion outlets. Here they would be susceptible to both legal an possibly illegal harvest. Actually, the reduction or even demise of this species from the population could well prove beneficial to the overall fish population.

  Will these shallow wetland area pools provide suitable habitat conditions during the winter for fish which may voluntarily or involuntarily remain in them?

- o <u>dredging of 72,000 cubic yards of bottom sediments from the central portion of the pond</u> - as mentioned previously, any drawdown schedule must include timely notification to the MDFW so that we may reallocate trout scheduled for stocking in the fall. Since this pond is managed as a put-and-take trout fishery, the increase in depth and enlargement of open water area should prove beneficial. As mentioned on page 124, a monitoring program will be required for the dredging process.

- o <u>reduce the influence of stormwater flow</u> - the MDFW supports this action, which will help limit nutrient inputs to the pond.

- o <u>an educational program</u> - same as above

- o <u>stabilize and rebuild four badly eroded "points" in Nonotuck Park and Brookside Cemetery</u> - our initial reaction to this proposal is to favor Scheme I, the less involved or artificial of the two. Discussion with our Connecticut Valley District fisheries manager indicates that this point is used to stock trout from. Presently the Nanotuck Park road is blocked off, and while difficult, we manage to by-pass the blockages with our tank truck to get as close to the water as possible. The installation of bollards will, of course, make it impossible to maneuver a 2 ton tank truck down to the water's edge. It is advisable for the health of the trout and for personnel assigned their distribution to avoid carrying trout in nets any further than necessary, hence our interest in maintaining vehicle access off this point. Perhaps a gate structure could be considered. We would be glad to discuss this matter further.

Please contact me should you have any questions concerning any of these comments.

Sincerely,

Robert P. Madore

Robert P. Madore
Aquatic Biologist II

cc. Herm Covey, MDFW - CVD
MDWPC - Clean Lakes
EOEA - Mepa Unit

APPENDIX D

Data and Calculations.

1. Water Quality Data.

Table 1. Monitored Physical, Chemical and Biological Parameters for Nashawannuck pond and its Tributaries for the period April 1987 to March 1988.

FLOW (CFS) IN THE NASHAWANNUCK POND SYSTEM

STATION DATE	NP-1	NP-2	NP-3	NP-6
04/16/87	23.00	3.00	4.90	34.10
04/30/87	17.80	2.30	3.70	23.80
05/14/87	9.50	1.35	2.00	12.90
05/28/87	18.40	1.60	2.10	0.00
06/09/87	10.40	.33	1.20	13.80
06/25/87	7.60	.42	.74	12.90
07/09/87	5.50	.29	.64	14.80
07/22/87	5.85	.12	.30	6.00
08/06/87	4.00	.13	.93	5.80
08/20/87	5.50	.05	.70	5.80
09/03/87	3.60	.04	.32	4.00
09/24/87	5.80	.40	2.10	15.00
10/21/87	7.60	.49	1.62	8.60
11/18/87	9.50	2.00	3.10	15.70
12/16/87	10.80	1.70	5.40	19.80
01/20/88	10.30	.25	4.90	15.70
02/23/88	10.20	.50	3.20	13.60
03/21/88	12.80	1.10	1.90	10.00
MAXIMUM	23.00	3.00	5.40	34.10
MINIMUM	3.60	.04	.30	0.00
MEAN	9.90	.89	2.21	12.91

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

STATION DATE	NP-1	NP-2	NP-3	NP-6
04/16/87	39.10	5.10	8.33	57.97
04/30/87	30.26	3.91	6.29	40.46
05/14/87	16.15	2.29	3.40	21.93
05/28/87	31.28	2.72	3.57	0.00
06/09/87	17.68	.56	2.04	23.46
06/25/87	12.92	.71	1.26	21.93
07/09/87	9.35	.49	1.09	25.16
07/22/87	9.94	.20	.51	10.20
08/06/87	6.80	.22	1.58	9.86
08/20/87	9.35	.09	1.19	9.86
09/03/87	6.12	.07	.54	6.80
09/24/87	9.86	.68	3.57	25.50
10/21/87	12.92	.83	2.75	14.62
11/18/87	16.15	3.40	5.27	26.69
12/16/87	18.36	2.89	9.18	33.66
01/20/88	17.51	.42	8.33	26.69
02/23/88	17.34	.85	5.44	23.12
03/21/88	21.76	1.87	3.23	17.00
MAXIMUM	39.10	5.10	9.18	57.97
MINIMUM	6.12	.07	.51	0.00
MEAN	16.83	1.52	3.75	21.94

TEMPERATURE (C) IN THE NASHAWANNUCK POND SYSTEM

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	5.0	4.5	7.2	6.2	7.0	7.0		4.8	6.3
04/30/87	5.0	4.0	5.5	7.0	5.5	6.0		4.5	5.2
05/14/87	9.0	10.4	14.1	12.5	9.8	12.6		6.3	13.2
05/28/87	8.8	11.3	16.1	14.0	10.8	14.0		6.9	15.5
06/09/87	9.4	11.2	16.1	15.8	11.0	15.5	11.5	7.2	15.7
06/25/87	10.4	12.8	16.8	18.1	12.8	18.3	14.0	9.0	18.5
07/09/87	9.9	13.1	17.9	18.1	12.7	18.5	12.4	9.5	18.2
07/22/87	12.0	16.0	21.5	25.7	17.1	25.2	18.3	13.3	25.2
08/06/87	10.0	13.7	19.8	18.9	12.5	18.5	12.8	9.3	18.7
08/20/87	9.4	13.4	19.2	19.1	13.0	19.4	12.1	9.5	19.4
09/03/87	6.5	10.9	13.2	13.4	12.2	13.8	11.7	9.1	13.8
09/24/87	7.1	9.8	11.2	11.2	9.7	11.8		9.0	11.5
10/21/87	6.1	6.9	8.0	7.2	4.3	7.4		5.1	7.8
11/18/87	4.5	5.0	4.0	2.2	.9	2.2		.9	2.0
12/16/87	0.0	-1.5	-.8	-.5	0.0	-1.0		-.5	-1.0
01/20/88	-1.0	-1.0	-1.0	-1.0	0.0	-1.0		0.0	-1.0
02/23/88	3.8	.8	1.0	3.5	2.2	2.8		5.0	1.9
03/21/88	2.40	.9	3.3						4.6
MAXIMUM	12.0	16.0	21.5	25.7	17.1	25.2	18.3	13.3	25.2
MINIMUM	-1.0	-1.5	-1.0	-1.0	0.0	-1.0	11.5	-.5	-1.0
MEAN	6.6	7.9	10.2	11.3	8.3	11.2	13.3	6.4	10.9

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

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	11.8	12.8	11.0	12.4	11.0	12.2		11.0	11.6
04/30/87	12.2	12.7	12.0	13.0	12.4	12.4		7.2	12.4
05/14/87	11.8	12.6	10.8	13.0	12.2	12.2		6.1	10.7
05/28/87	10.4	9.4	8.7	11.8	10.9	11.8		.7	10.9
06/09/87	9.4	10.1	7.6	9.6	9.2	9.4	6.1	.5	9.0
06/25/87	9.4	7.4	18.1	10.7	1.5	11.1	10.9	.4	10.5
07/09/87	10.3	8.5	8.4	14.2	3.5	12.4	5.0	.3	12.6
07/22/87	8.6	5.5	8.8	10.9	2.0	9.8	11.3	.2	10.1
08/06/87	8.8	7.8	9.4	12.8	4.2	10.4	5.6	.7	10.8
08/20/87	6.6	7.1	7.7	11.2	2.5	9.4	2.2	.6	11.0
09/03/87	11.2	10.2	8.6	13.7	13.7	9.3	3.2	.2	8.6
09/24/87	11.2	10.3	10.2	12.4	9.9	9.0		.3	8.2
10/21/87	10.8	7.3	8.4	13.4	6.0	11.7		4.6	11.9
11/18/87	11.5	11.4	12.5	13.2	12.0	14.3		9.8	13.7
12/16/87	14.0	14.2	14.6	13.1	6.3	12.7		9.2	12.8
01/20/88	14.2	15.2	15.5	15.4	7.8	13.3		7.0	11.0
02/23/88	13.5	12.8	12.5	11.5	8.0	11.0		1.0	10.0
03/21/88	13.2	12.2	12.6						11.0
MAXIMUM	14.2	15.2	18.1	15.4	13.7	14.3	11.3	11.0	13.7
MINIMUM	6.6	5.5	7.6	9.6	1.5	9.0	2.2	.2	8.2
MEAN	11.1	10.4	11.0	12.5	7.8	11.3	6.3	3.5	10.9

PERCENT OXYGEN SATURATION IN NASHAWANNUCK POND

STATION DATE	NP-1	NP-2	NP-3	NP-4S
04/16/87	92	99	91	100
04/30/87	96	97	95	107
05/14/87	102	113	105	122
05/28/87	90	86	88	115
06/09/87	82	92	77	97
06/25/87	84	70	148	113
07/09/87	91	81	89	150
07/22/87	80	56	100	134
08/06/87	78	75	103	138
08/20/87	58	68	83	121
09/03/87	91	92	82	131
09/24/87	93	91	93	113
10/21/87	87	60	71	111
11/18/87	89	89	95	96
12/16/87	96	93	98	88
01/20/88	94	101	103	102
02/23/88	102	90	88	87
03/21/88	97	86	94	
MEAN	89	85	95	113
MAXIMUM	102	113	148	150
MINIMUM	58	56	71	87

PERCENT OXYGEN SATURATION IN NASHAWANNUCK POND

STATION DATE	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	91	101		86	94
04/30/87	98	100		56	98
05/14/87	108	115		49	102
05/28/87	98	115		6	109
06/09/87	83	94	56	4	91
06/25/87	14	118	106	3	112
07/09/87	33	132	47	3	134
07/22/87	21	119	120	2	123
08/06/87	39	111	53	6	116
08/20/87	24	102	20	5	120
09/03/87	128	90	30	2	83
09/24/87	87	83		3	75
10/21/87	46	97		36	100
11/18/87	84	104		69	99
12/16/87	43	84		62	85
01/20/88	53	88		48	73
02/23/88	58	81		8	72
03/21/88					85
MEAN	65	102	62	26	98
MAXIMUM	128	132	120	86	134
MINIMUM	14	81	20	2	72

ORTHOPHOSPHORUS (UG/L) IN THE NASHAWANNUCK POND SYSTEM

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	10	40	10	10	10	10		10	10
04/30/87	10	40	30	30	30	20		30	30
05/14/87	10	10	10	10	10	10		10	10
05/28/87	10	10	10	10	10	10		10	10
06/09/87	10	10	10	10	26	10	25	88	10
06/25/87	13	25	25	10	14	10	14	59	10
07/09/87	16	26	20	10	30	10	18	16	10
07/22/87	17	28	39	10	10	16	22	45	10
08/06/87	12	20	10	10	24	10	21	55	10
08/20/87	17	35	10	10	17	10	25	51	10
09/03/87	10	10	10	10	10	10	10	46	10
09/24/87	19	30	22	11	51	22		60	19
10/21/87	10	20	10	10	10	10		40	10
11/18/87	10	10	10	10	10	10		33	10
12/16/87	24	31	14	21	24	31		14	21
01/20/88	20	80	30	20	30	30		30	30
02/23/88	20	40	20	30	20	30		30	40
03/21/88	20	20	10						20
MAXIMUM	24	80	39	30	51	31	25	88	40
MINIMUM	10	10	10	10	10	10	10	10	10
MEAN	14	27	17	14	20	15	19	37	16

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

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	40	60	110	70	60	80		80	90
04/30/87	35	53	60	21	34	51		43	64
05/14/87	40	80	62	50	65	56		58	82
05/28/87	124	117	94	95	86	82		103	104
06/09/87	73	42	65	47	45	59	34	88	51
06/25/87	33	63	62	42	56	35	47	144	57
07/09/87	25	53	40	23	77	21	48	66	17
07/22/87	50	64	127	50	41	38	90	133	49
08/06/87	46	53	49	31	77	32	77	209	36
08/20/87	48	63	98	17	70	23	57	62	41
09/03/87	30	40	60	40	60	40	70	140	30
09/24/87	27	31	69	23	110	37		61	39
10/21/87	30	92	50	50	50	40		80	60
11/18/87	50	70	50	50	240	120		160	48
12/16/87	40	54	46	42	60	49		46	40
01/20/88	52	76	48	40	38	41		33	31
02/23/88	40	80	30	80	40	60		50	60
03/21/88	70	60	70						60
MAXIMUM	124	117	127	95	240	120	90	209	104
MINIMUM	25	31	30	17	34	21	34	33	17
MEAN	47	64	66	45	71	51	60	92	53

AMMONIA NITROGEN (MG/L) IN THE NASHAWANNUCK POND SYSTEM

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	.01	.01	.01	.01	.01	.01		.01	.01
04/30/87	.01	.01	.01	.01	.01	.01		.01	.02
05/14/87	.01	.01	.01	.01	.01	.01		.01	.01
05/28/87	.04	.15	.07	.01	.01	.04		.03	.05
06/09/87	.03	.11	.32	.07	.10	.10	.18	.25	.11
06/25/87	.02	.05	.07	.02	.03	.02	.03	.06	.03
07/09/87	.01	.04	.01	.01	.01	.01	.02	.01	.01
07/22/87	.01	.04	.01	.01	.02	.01	.02	.06	.01
08/06/87	.02	.04	.01	.01	.01	.01	.08	.01	.01
08/20/87	.03	.02	.01	.02	.04	.05	.05	.05	.04
09/03/87	.01	.03	.02	.01	.01	.04	.20	.40	.10
09/24/87	.02	.04	.03	.03	.03	.18		.58	.15
10/21/87	.10	.10	.10	.10	.10	.10		.10	.10
11/18/87	.12	.08	.12	.10	.05	.04		.08	.05
12/16/87	.01	.01	.01	.01	.01	.01		.01	.01
01/20/88	.07	.22	.28	.19	.29	.23		.22	.15
02/23/88	.01	.03	.01	.01	.01	.01		.01	.01
03/21/88	.01	.01	.01						.02
MAXIMUM	.12	.22	.32	.19	.29	.23	.20	.58	.15
MINIMUM	.01	.01	.01	.01	.01	.01	.02	.01	.01
MEAN	.03	.06	.06	.04	.04	.05	.08	.11	.05

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

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	.47	3.19	.92	.56	.62	.83		.60	.72
04/30/87	3.40	1.20	3.40	1.00	1.30	.70		.80	.78
05/14/87	.82	.41	.63	.65	.70	.65		.59	.57
05/28/87	.95	1.31	.53	.50	.70	.61		.39	.61
06/09/87	.62	.90	.43	.42	.23	.65	.27	.27	.98
06/25/87	.91	.19	.39	.46	.59	.73	.52	.25	.25
07/09/87	1.18	3.77	.16	.41	.63	.42	.37	.38	.39
07/22/87	.99	2.07	.17	.20	.53	.22	.39	.16	.23
08/06/87	1.07	2.23	.02	.05	.59	.16	.35	.47	.16
08/20/87	1.00	1.10	.05	.15	.23	.16	.32	.34	.15
09/03/87	.73	1.38	.26	.08	.32	.23	.25	.30	.31
09/24/87	1.42	2.88	.76	.54	.63	.59		.48	.51
10/21/87	1.20	2.90	.80	.90	.11	.79		.90	.72
11/18/87	.94	1.90	.60	1.30	1.10	.94		1.10	.86
12/16/87	1.00	1.60	.87	1.20	1.30	.91		.89	.89
01/20/88	1.30	3.83	.90	1.80	1.60	1.60		1.50	1.60
02/23/88	.93	2.20	.80	1.90	.97	1.20		1.10	1.30
03/21/88	1.00	2.36	.76						.79
MAXIMUM	3.40	3.83	3.40	1.90	1.60	1.60	.52	1.50	1.60
MINIMUM	.47	.19	.02	.05	.11	.16	.25	.16	.15
MEAN	1.11	1.97	.69	.71	.71	.67	.35	.62	.66

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

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	.20	.41	.42	.70	.16	.27		.26	.35
04/30/87	.25	.40	.26	.16	.23	.31		.33	.31
05/14/87	.14	.21	.34	.31	.20	.19		.29	.30
05/28/87	.35	.67	.41	.34	.37	.35		.60	.22
06/09/87	.14	.68	.57	.59	.56	.41	.64	.88	.33
06/25/87	.13	.03	.03	.01	.01	.36	.05	.14	.06
07/09/87	.42	.38	1.30	.51	2.83	1.30	1.32	1.18	.59
07/22/87	.18	.40	.71	.23	.30	.38	.96	1.36	.54
08/06/87	.17	.41	.32	.20	.66	.34	.78	2.20	.27
08/20/87	.26	.49	.67	.42	.60	.67	.67	2.00	.33
09/03/87	.04	.27	.40	.25	.41	.37	.73	1.60	.44
09/24/87	.17	.56	.68	.54	1.30	.65		.88	.54
10/21/87	.12	.49	.32	.26	.36	.33		.60	.31
11/18/87	.23	.55	.31	.28	.22	.48		.41	.38
12/16/87	.29	.35	.28	.33	.26	.21		.27	.26
01/20/88	.24	.59	.42	.32	.29	.24		.25	.30
02/23/88	.21	.46	.30	.76	.25	.60		.43	.44
03/21/88	.17	.42	.25						.20
MAXIMUM	.42	.68	1.30	.76	2.83	1.30	1.32	2.20	.59
MINIMUM	.04	.03	.03	.01	.01	.19	.05	.14	.06
MEAN	.21	.43	.44	.37	.53	.44	.74	.80	.34

NITROGEN TO PHOSPHORUS RATIOS IN THE NASHAWANNUCK POND SYSTEM

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	38	137	28	41	30	31		25	27
04/30/87	238	69	139	126	103	45		60	39
05/14/87	55	18	36	44	32	34		35	24
05/28/87	24	39	23	20	28	27		22	18
06/09/87	24	86	35	49	40	41	61	30	59
06/25/87	72	8	15	26	25	71	28	6	12
07/09/87	146	179	83	91	103	187	80	54	131
07/22/87	53	88	16	20	46	36	34	26	36
08/06/87	61	114	16	19	37	36	34	29	27
08/20/87	60	58	17	76	27	82	40	86	27
09/03/87	59	94	25	19	28	34	32	31	57
09/24/87	134	253	48	107	40	77		51	61
10/21/87	100	8	51	53	21	64		43	39
11/18/87	53	69	38	70	13	22		22	59
12/16/87	74	80	57	81	60	56		57	66
01/20/88	68	122	54	116	110	102		121	140
02/23/88	65	76	84	76	70	68		70	66
03/21/88	38	106	33						38
MEAN	76	89	44	61	48	60	44	45	51
MAXIMUM	238	253	139	126	110	187	80	121	140
MINIMUM	24	8	15	19	13	22	28	6	12

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

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	7.0	7.3	6.9	7.0	7.0	7.0		6.9	6.9
04/30/87	7.1	7.0	7.0	7.3	7.2	7.1		7.1	7.2
05/14/87	7.1	6.2	7.2	7.5	7.5	7.4		7.2	7.3
05/28/87	7.1	6.9	7.1	7.5	7.4	7.3		7.0	7.3
06/09/87	7.2	7.1	7.1	7.2	7.2	7.1	6.9	6.9	7.1
06/25/87	7.2	7.2	7.3	7.5	7.7	7.5	7.9	7.1	7.7
07/09/87	7.3	7.2	7.7	8.7	7.9	7.8	7.1	7.0	7.8
07/22/87	7.2	7.1	7.7	8.1	7.6	8.2	7.5	7.2	8.2
08/06/87	7.3	7.2	7.7	9.0	7.6	7.6	7.2	7.1	8.5
08/20/87	7.3	7.2	7.6	7.7	7.5	7.7	7.3	6.9	7.5
09/03/87	7.2	7.2	7.0	8.0	7.9	7.2	6.9	6.9	7.1
09/24/87	7.2	7.2	7.0	7.5	7.4	6.9		6.9	7.0
10/21/87	7.1	6.9	7.0	7.6	7.3	7.2		7.0	7.1
11/18/87	7.1	6.9	6.9	7.0	7.2	7.2		7.2	7.2
12/16/87	7.0	7.2	6.9	7.4	7.2	7.3		7.3	7.3
01/20/88	7.0	7.0	7.1	7.0	7.1	7.1		7.1	7.1
02/23/88	5.9	6.1	6.3	6.3	6.3	6.4		6.4	6.5
03/21/88	6.6	6.6	6.8						6.7
MAXIMUM	7.3	7.3	7.7	9.0	7.9	8.2	7.9	7.3	8.5
MINIMUM	5.9	6.1	6.3	6.3	6.3	6.4	6.9	6.4	6.5
MEAN	7.0	7.0	7.1	7.5	7.4	7.3	7.3	7.0	7.3

CONDUCTIVITY (UMHOS/CM) IN THE NASHAWANNUCK POND SYSTEM

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	119	162	103	106	108	106		97	99
04/30/87	124	142	103	121	113	119		120	122
05/14/87	132	41	126	130	127	128		120	126
05/28/87	126	121	128	130	131	131		129	130
06/09/87	152	220	138	137	138	138	142	143	138
06/25/87	143	220	137	135	136	136	137	142	136
07/09/87	143	220	109	126	130	126	132	140	127
07/22/87	149	215	133	131	142	130	140	143	130
08/06/87	138	210	119	113	123	122	140	142	123
08/20/87	137	190	111	101	117	118	124	132	118
09/03/87	146	210	118	118	124	136	148	152	138
09/24/87	176	236	131	150	169	135		134	135
10/21/87	205	249	196	197	202	192		199	192
11/18/87	162	180	152	169	169	162		165	162
12/16/87	229	133	138	151	158	143		147	140
01/20/88	198	194	232	177	201	158		169	159
02/23/88	139	138	109	111	130	107		129	109
03/21/88	130	150	95						110
MAXIMUM	229	249	232	197	202	192	148	199	192
MINIMUM	119	41	95	101	108	106	124	97	99
MEAN	153	179	132	135	142	135	138	141	133

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

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	34.0	35.0	24.0	25.0	25.0	28.0		25.0	23.0
04/30/87	38.0	36.0	26.0	30.0	42.0	34.0		32.0	31.0
05/14/87	39.5	8.4	32.0	36.0	37.0	35.0		33.0	35.0
05/28/87	35.0	32.0	32.0	39.0	39.0	40.0		38.0	38.0
06/09/87	45.6	56.0	33.8	42.6	42.0	40.1	45.2	45.6	40.5
06/25/87	46.0	61.0	37.0	43.0	42.0	42.0	41.0	49.0	41.0
07/09/87	48.9	62.6	30.5	50.6	45.6	41.4	48.1	49.4	41.8
07/22/87	48.0	65.0	38.0	42.0	48.0	42.0	48.0	55.0	43.0
08/06/87	47.3	64.5	33.6	34.0	37.8	42.0	56.3	58.8	40.3
08/20/87	47.0	72.0	27.0	30.0	37.0	43.0	47.0	47.0	41.0
09/03/87	51.0	74.0	32.0	36.0	38.0	45.0	51.0	53.0	45.0
09/24/87	43.0	47.0	24.0	33.0	33.0	31.0		31.0	30.0
10/21/87	46.4	44.0	31.3	37.9	37.9	34.4		38.1	35.0
11/18/87	35.0	31.0	25.0	38.0	38.0	37.0		37.0	36.0
12/16/87	38.1	33.3	27.4	38.7	35.7	34.8		34.4	32.6
01/20/88	37.0	31.0	23.0	40.0	39.0	39.0		40.0	42.0
02/23/88	29.6	16.7	18.5	14.8	22.2	20.4		22.2	16.7
03/21/88	35.7	40.3	21.3						29.6
MAXIMUM	51.0	74.0	38.0	50.6	48.0	45.0	56.3	58.8	45.0
MINIMUM	29.6	8.4	18.5	14.8	22.2	20.4	41.0	22.2	16.7
MEAN	41.4	45.0	28.7	35.9	37.6	37.0	48.1	40.5	35.6

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

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	9.2	2.8	4.0	2.0	15.0	28.0		25.0	23.0
04/30/87	8.4	4.4	2.8	4.4	12.0	3.6		7.6	5.2
05/14/87	4.4	5.2	2.4	3.2	28.0	1.6		19.6	3.6
05/28/87	21.0	7.2	4.0	1.2	12.0	1.6		3.6	1.6
06/09/87	7.2	2.4	5.2	6.8	8.8	.8	5.6	26.4	3.2
06/25/87	4.8	10.0	5.6	2.8	6.0	1.6	4.0	21.5	2.4
07/09/87	9.2	5.2	12.4	2.8	34.5	2.4	10.0	13.5	2.8
07/22/87	2.0	.8	7.2	.8	2.0	.7	5.0	3.6	2.0
08/06/87	1.6	3.2	.8	.4	48.4	1.2	4.4	20.0	.8
08/20/87	4.0	18.0	4.0	1.6	11.0	.4	3.6	9.0	.4
09/03/87	4.4	1.2	2.0	1.6	8.4	3.6	6.4	15.0	19.0
09/24/87	3.2	4.2	2.8	6.0	2.8	4.4		4.8	3.6
10/21/87	1.6	2.8	2.4	2.4	5.6	2.8		17.2	.4
11/18/87	4.8	7.5	4.5	1.2	49.0	4.0		42.0	12.0
12/16/87	.4	6.0	3.6	.8	35.7	34.8		34.4	32.6
01/20/88	8.8	14.0	2.0	3.6	1.2	2.0		2.8	4.8
02/23/88	4.0	14.0	.4	1.2	.4	4.4		3.6	.8
03/21/88	1.2	8.8	.8						.4
MAXIMUM	21.0	18.0	12.4	6.8	49.0	34.8	10.0	42.0	32.6
MINIMUM	.4	.8	.4	.4	.4	.4	3.6	2.8	.4
MEAN	5.6	6.5	3.7	2.5	16.5	5.8	5.6	15.9	6.6

CHLORIDE (MG/L) IN THE NASHAWANNUCK POND SYSTEM

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	15.0	19.0	17.0	13.0	15.0	19.0		17.0	20.0
04/30/87	17.0	19.0	19.0	18.0	18.0	17.0		16.0	18.0
05/14/87	19.3	7.2	21.3	18.8	20.0	18.8		18.4	19.3
05/28/87	16.0	16.0	19.0	18.0	18.0	17.0		17.0	16.0
06/09/87	19.3	29.2	20.9	18.0	17.4	17.6	19.3	18.8	19.3
06/25/87	16.0	16.0	15.0	16.0	16.0	33.0	21.0	17.0	16.0
07/09/87	14.7	31.3	18.0	19.3	18.0	20.1	19.3	17.6	19.3
07/22/87	16.0	31.0	20.0	16.0	17.0	18.0	15.0	16.0	16.0
08/06/87	17.6	33.0	20.9	16.8	15.9	16.3	16.3	18.8	15.9
08/20/87	16.0	28.0	16.0	16.0	16.0	16.0	14.0	16.0	17.0
09/03/87	20.0	30.0	17.0	16.0	17.0	17.0	19.0	18.0	19.0
09/24/87	21.0	27.0	18.0	26.0	21.0	18.0		16.0	15.0
10/21/87	16.1	20.1	21.8	19.3	19.3	17.4		18.4	19.1
11/18/87	21.0	22.0	23.0	21.0	22.0	20.0		20.0	20.0
12/16/87	44.0	18.0	21.0	20.0	18.0	20.0		19.0	19.0
01/20/88	35.0	28.0	56.0	23.0	34.0	18.0		20.0	16.0
02/23/88	25.9	17.6	25.9	23.8	28.0	25.9		32.2	25.9
03/21/88	18.4	17.6	16.3						17.8
MAXIMUM	44.0	33.0	56.0	26.0	34.0	33.0	21.0	32.2	25.9
MINIMUM	14.7	7.2	15.0	13.0	15.0	16.0	14.0	16.0	15.0
MEAN	20.5	22.8	21.4	18.8	19.4	19.4	17.7	18.6	18.3

TURBIDITY (J.T.U) IN THE NASHAWANNUCK POND SYSTEM

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-4B	NP-5S	NP-5M	NP-5B	NP-6
04/16/87	1.40	2.20	2.40	2.40	2.90	3.60		4.30	3.40
04/30/87	.60	3.00	2.70	2.30	2.70	2.40		2.70	2.90
05/14/87	.45	1.60	1.50	1.50	7.50	.80		7.70	1.65
05/28/87	1.50	1.40	1.75	2.00	2.10	1.50		2.50	3.00
06/09/87	1.20	1.80	2.30	1.40	2.20	1.50	1.50	7.50	1.50
06/25/87	.83	2.25	2.50	.62	1.28	.30	.98	5.50	.60
07/09/87	.75	3.00	2.80	.70	18.00	.60	4.10	6.45	.90
07/22/87	1.00	2.20	5.00	1.50	2.60	1.00	5.00	6.50	1.50
08/06/87	.90	3.30	2.80	1.10	6.50	2.20	5.60	9.90	2.50
08/20/87	1.20	1.00	3.20	.32	.60	.50	.72	.85	.61
09/03/87	.57	2.10	1.40	.95	1.00	1.70	28.00	8.00	2.25
09/24/87	.66	.52	3.20	.80	1.80	1.30		8.00	1.20
10/21/87	4.00	5.00	5.00	5.00	5.00	4.00		12.00	3.00
11/18/87	1.00	4.50	2.80	1.75	2.00	1.75		3.20	2.55
12/16/87	1.75	8.80	2.20	1.00	1.80	1.35		1.80	1.55
01/20/88	2.00	12.50	5.10	2.30	5.10	1.60		3.60	3.40
02/23/88	2.70	8.00	2.40	5.70	4.60	5.80		7.70	7.40
03/21/88	1.80	4.10	3.20						.18
MAXIMUM	4.00	12.50	5.10	5.70	18.00	5.80	28.00	12.00	7.40
MINIMUM	.45	.52	1.40	.32	.60	.30	.72	.85	.18
MEAN	1.35	3.74	2.90	1.84	3.98	1.88	6.56	5.78	2.23

SECCHI DISK TRANSPARENCY (M) IN THE NASHAWANNUCK POND SYSTEM

STATION DATE	NP-4	NP-5
04/16/87	2.30	1.70
04/30/87	1.75	1.70
05/14/87	2.00	2.10
05/28/87	2.30	2.20
06/09/87*	2.50	2.50
06/25/87*	2.50	2.50
07/09/87	1.90	2.50
07/22/87*	2.50	2.00
08/06/87	2.50	2.50
08/20/87	2.50	2.20
09/03/87*	2.25	2.10
09/24/87*	2.40	2.20
10/21/87	2.50	2.40
11/18/87	1.70	2.00
12/16/87	2.00	2.60
01/20/88	2.00	3.10
02/23/88	1.20	1.20
03/21/88		
MAXIMUM	2.50	3.10
MINIMUM	1.20	1.20
MEAN	2.16	2.21

* = SDT for NP-4 was to bottom or in weeds.

2. Biological Data.

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

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-5S	NP-6
04/16/87	4	200	700	100	48	24
04/30/87	100	100	600	200		
05/14/87	14	106	14	2	1	2
05/28/87	56	0	600	36	16	5
06/09/87	16	100	100	9	4	15
06/25/87	117	223	100	5	6	2
07/09/87	300	200	100	2	10	13
07/22/87	400	1000	100	1	100	12
08/06/87	TNTC	TNTC	TNTC	0	TNTC	TNTC
08/20/87	100	2500	100	100	4	2
09/03/87	60	100	40	0	10	20
09/24/87	100	520	230	20	100	40
10/21/87	190	3000	1000	170	10	20
11/18/87	180	180	130	140	80	70
12/16/87	60	1300	52	39	100	6300
01/20/88	50	240	720	10	10	10
02/23/88	50	10	110	20	10	10
03/21/88	10	10	10			10
MAXIMUM	400	3000	1000	200	100	6300
MINIMUM	4	0	10	0	1	2
MEAN (GEOMETRIC)	106	576	277	50	34	410

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

STATION DATE	NP-1	NP-2	NP-3	NP-4S	NP-5S	NP-6
04/16/87	26	101	69	11	20	27
04/30/87	76	150	150	19		
05/14/87	18	16	76	4	0	5
05/28/87	1000	7400	700	53	4	27
06/09/87	*	*	*	*	*	*
06/25/87	234	2100	38	1500	98	11500
07/09/87	1700	2900	12000	2400	2400	42
07/22/87	200	1700	65	6	7	12
08/06/87	21000	53000	29000	21000	15000	9000
08/20/87	7000	4000	4100	2200	4000	3600
09/03/87	13000	22000	38000	15000	13000	750
09/24/87	13000	19000	100000	27000	10000	11000
10/21/87	50000	35000	36000	16000	40000	100000
11/18/87	26000	80000	80000	28000	11000	7000
12/16/87	7200	8000	8000	4700	7000	6300
01/20/88	10000	100000	31000	520	280	260
02/23/88	14000	22000	29000	29000	59000	81000
03/21/88	5000	3000	8000			10000
MAXIMUM	50000	100000	100000	29000	59000	100000
MINIMUM	18	16	38	4	0	5
MEAN (GEOMETRIC)	9968	21198	22129	9213	10787	15033

* INCUBATOR BREAKDOWN

Nashawannuck Phytoplankton

STATION NP-4

NP-4 041687

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	28
Fragilaria	77
CHLOROPHYTA	
Eudorina	112
Pediastrum	112
Scenedesmus	28
CRYPTOPHYTA	
Cryptomonas	35
CYANOPHYTA	
Gomphosphaeria	42
TOTAL	434
BACILLARIOPHYTA	105
CHLOROPHYTA	252
CRYPTOPHYTA	35
CYANOPHYTA	42

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	19.6
Fragilaria	154
CHLOROPHYTA	
Eudorina	44.8
Pediastrum	22.4
Scenedesmus	2.8
CRYPTOPHYTA	
Cryptomonas	47.2
CYANOPHYTA	
Gomphosphaeria	1.2
TOTAL	292.1
BACILLARIOPHYTA	173.6
CHLOROPHYTA	70
CRYPTOPHYTA	47.2
CYANOPHYTA	1.2

STATION NP-5

NP-5 041687

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	7.8
Cyclotella	3.9
Cymbella	3.9
Fragilaria	39
Synedra	46.8
CHLOROPHYTA	
Scenedesmus	31.2
CRYPTOPHYTA	
Cryptomonas	23.4
TOTAL	156
BACILLARIOPHYTA	101.4
CHLOROPHYTA	31.2
CRYPTOPHYTA	23.4

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	5.4
Cyclotella	9.7
Cymbella	5.8
Fragilaria	78
Synedra	37.4
CHLOROPHYTA	
Scenedesmus	46.8
CRYPTOPHYTA	
Cryptomonas	23.4
TOTAL	206.7
BACILLARIOPHYTA	136.5
CHLOROPHYTA	46.8
CRYPTOPHYTA	23.4

NP-4 043087

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	24.7
Fragilaria	110.2
Synedra	32.3
CHLOROPHYTA	
Coelastrum	30.4
Scenedesmus	15.2
CRYPTOPHYTA	
Cryptomonas	136.8
TOTAL	349.6
BACILLARIOPHYTA	167.2
CHLOROPHYTA	45.6
CRYPTOPHYTA	136.8

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	17.2
Fragilaria	220.4
Synedra	1453.5
CHLOROPHYTA	
Coelastrum	6.0
Scenedesmus	22.8
CRYPTOPHYTA	
Cryptomonas	158.4
TOTAL	1878.5
BACILLARIOPHYTA	1691.1
CHLOROPHYTA	28.8
CRYPTOPHYTA	158.4

NP-5 043087

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	14.5
Fragilaria	23.2
Melosira	5.8
Synedra	11.6
CHRYSOPHYTA	
Synura	243.6
CRYPTOPHYTA	
Cryptomonas	278.4
TOTAL	577.1
BACILLARIOPHYTA	55.1
CHRYSOPHYTA	243.6
CRYPTOPHYTA	278.4

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	10.1
Fragilaria	46.4
Melosira	13.9
Synedra	92.9
CHRYSOPHYTA	
Synura	194.8
CRYPTOPHYTA	
Cryptomonas	278.4
TOTAL	636.5
BACILLARIOPHYTA	163.2
CHRYSOPHYTA	194.8
CRYPTOPHYTA	278.4

Nashawannuck Phytoplankton (continued)

NP-4 051487

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	43.2
Fragilaria	54
Synedra	3.6
CRYPTOPHYTA	
Cryptomonas	853.2
Other cryptophytes	115.2
CYANOPHYTA	
Anabaena	54
TOTAL	1123.2
BACILLARIOPHYTA	100.8
CRYPTOPHYTA	968.4
CYANOPHYTA	54

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	30.2
Fragilaria	108
Synedra	28.8
CRYPTOPHYTA	
Cryptomonas	853.2
Other cryptophytes	23.0
CYANOPHYTA	
Anabaena	167.4
TOTAL	1210.6
BACILLARIOPHYTA	167.0
CRYPTOPHYTA	876.2
CYANOPHYTA	167.4

NP-5 051487

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	174.8
Cyclotella	3.8
Fragilaria	102.6
Melosira	7.6
Synedra	11.4
CHRYSOPHYTA	
Dinobryon	95
CRYPTOPHYTA	
Cryptomonas	7.6
TOTAL	402.8
BACILLARIOPHYTA	300.2
CHRYSOPHYTA	95
CRYPTOPHYTA	7.6

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	122.3
Cyclotella	9.5
Fragilaria	205.2
Melosira	71.4
Synedra	231.8
CHRYSOPHYTA	
Dinobryon	285
CRYPTOPHYTA	
Cryptomonas	7.6
TOTAL	932.9
BACILLARIOPHYTA	640.3
CHRYSOPHYTA	285
CRYPTOPHYTA	7.6

NP-4 052887

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	24.8
Fragilaria	74.4
Navicula	3.1
Synedra	6.2
CHLOROPHYTA	
Eudorina	49.6
Staurastrum	3.1
CRYPTOPHYTA	
Cryptomonas	644.8
TOTAL	806
BACILLARIOPHYTA	108.5
CHLOROPHYTA	52.7
CRYPTOPHYTA	644.8

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	17.3
Fragilaria	148.8
Navicula	15.5
Synedra	279
CHLOROPHYTA	
Eudorina	19.8
Staurastrum	37.2
CRYPTOPHYTA	
Cryptomonas	644.8
TOTAL	1162.5
BACILLARIOPHYTA	460.6
CHLOROPHYTA	57.0
CRYPTOPHYTA	644.8

NP-5 052887

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	22.4
Cyclotella	5.6
CRYPTOPHYTA	
Cryptomonas	644
TOTAL	672
BACILLARIOPHYTA	28
CRYPTOPHYTA	644

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	15.6
Cyclotella	14
CRYPTOPHYTA	
Cryptomonas	644
TOTAL	673.6
BACILLARIOPHYTA	29.6
CRYPTOPHYTA	644

Nashawannuck Phytoplankton (continued)

NP-4 060987

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	84
CHLOROPHYTA	
Eudorina	44.8
CRYPTOPHYTA	
Cryptomonas	579.6
Other cryptophytes	1162
TOTAL	1870.4
BACILLARIOPHYTA	84
CHLOROPHYTA	44.8
CRYPTOPHYTA	1741.6

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	58.8
CHLOROPHYTA	
Eudorina	58.2
CRYPTOPHYTA	
Cryptomonas	579.6
Other cryptophytes	232.4
TOTAL	929.0
BACILLARIOPHYTA	58.8
CHLOROPHYTA	58.2
CRYPTOPHYTA	812

NP-5 060987

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	393.3
Synedra	2.3
CHLOROPHYTA	
Coelastrum	36.8
Eudorina	18.4
Scenedesmus	18.4
CRYPTOPHYTA	
Cryptomonas	795.8
Other cryptophytes	641.7
CYANOPHYTA	
Chroococcus	195.5
TOTAL	2102.2
BACILLARIOPHYTA	395.6
CHLOROPHYTA	73.6
CRYPTOPHYTA	1437.5
CYANOPHYTA	195.5

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	275.3
Synedra	18.4
CHLOROPHYTA	
Coelastrum	22.0
Eudorina	23.9
Scenedesmus	27.6
CRYPTOPHYTA	
Cryptomonas	795.8
Other cryptophytes	128.3
CYANOPHYTA	
Chroococcus	78.2
TOTAL	1369.6
BACILLARIOPHYTA	293.7
CHLOROPHYTA	73.6
CRYPTOPHYTA	924.1
CYANOPHYTA	78.2

NP-4 062587

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	142.5
Fragilaria	82.5
Tabellaria	13.5
CHLOROPHYTA	
Oocystis	9
Scenedesmus	12
Staurastrum	6
CRYPTOPHYTA	
Cryptomonas	252
Other cryptophytes	945
CYANOPHYTA	
Chroococcus	42
PYRRHOPHYTA	
Ceratium	4.5
TOTAL	1509
BACILLARIOPHYTA	238.5
CHLOROPHYTA	27
CRYPTOPHYTA	1197
CYANOPHYTA	42
PYRRHOPHYTA	4.5

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	99.7
Fragilaria	165
Tabellaria	40.5
CHLOROPHYTA	
Oocystis	27
Scenedesmus	18
Staurastrum	72
CRYPTOPHYTA	
Cryptomonas	252
Other cryptophytes	189
CYANOPHYTA	
Chroococcus	16.8
PYRRHOPHYTA	
Ceratium	1080
TOTAL	1960.0
BACILLARIOPHYTA	305.2
CHLOROPHYTA	117
CRYPTOPHYTA	441
CYANOPHYTA	16.8
PYRRHOPHYTA	1080

NP-5 062587

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	3037.5
Fragilaria	191.7
CHLOROPHYTA	
Closterium	2.7
Eudorina	21.6
Scenedesmus	64.8
Staurastrum	24.3
CRYPTOPHYTA	
Cryptomonas	291.6
CYANOPHYTA	
Aphanothece	51.3
Chroococcus	216
PYRRHOPHYTA	
Ceratium	5.4
TOTAL	3906.9
BACILLARIOPHYTA	3229.2
CHLOROPHYTA	113.4
CRYPTOPHYTA	291.6
CYANOPHYTA	267.3
PYRRHOPHYTA	5.4

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	2126.2
Fragilaria	383.4
CHLOROPHYTA	
Closterium	10.8
Eudorina	28.0
Scenedesmus	97.2
Staurastrum	291.6
CRYPTOPHYTA	
Cryptomonas	291.6
CYANOPHYTA	
Aphanothece	10.2
Chroococcus	86.4
PYRRHOPHYTA	
Ceratium	1296
TOTAL	4621.5
BACILLARIOPHYTA	2509.6
CHLOROPHYTA	427.6
CRYPTOPHYTA	291.6
CYANOPHYTA	96.6
PYRRHOPHYTA	1296

Nashawannuck Phytoplankton (continued)

NP-4 070987

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	24.5
Fragilaria	21
Synedra	7
CRYPTOPHYTA	
Cryptomonas	112
Other cryptophytes	133
CYANOPHYTA	
Chroococcus	105
PYRRHOPHYTA	
Ceratium	7
TOTAL	409.5
BACILLARIOPHYTA	52.5
CRYPTOPHYTA	245
CYANOPHYTA	105
PYRRHOPHYTA	7

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	17.1
Fragilaria	42
Synedra	56
CRYPTOPHYTA	
Cryptomonas	112
Other cryptophytes	26.6
CYANOPHYTA	
Chroococcus	42
PYRRHOPHYTA	
Ceratium	1680
TOTAL	1975.7
BACILLARIOPHYTA	115.1
CRYPTOPHYTA	138.6
CYANOPHYTA	42
PYRRHOPHYTA	1680

NP-5 070987

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	193.5
Fragilaria	2184.4
Synedra	245.1
CHLOROPHYTA	
Scenedesmus	34.4
Other green algae	25.8
CHRYSOPHYTA	
Chromulina	34.4
CRYPTOPHYTA	
Cryptomonas	262.3
Other cryptophytes	425.7
PYRRHOPHYTA	
Ceratium	25.8
TOTAL	3431.4
BACILLARIOPHYTA	2623
CHLOROPHYTA	60.2
CHRYSOPHYTA	34.4
CRYPTOPHYTA	688
PYRRHOPHYTA	25.8

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	135.4
Fragilaria	4368.8
Synedra	1960.8
CHLOROPHYTA	
Scenedesmus	3.4
Other green algae	258
CHRYSOPHYTA	
Chromulina	34.4
CRYPTOPHYTA	
Cryptomonas	262.3
Other cryptophytes	85.1
PYRRHOPHYTA	
Ceratium	6192
TOTAL	13300.3
BACILLARIOPHYTA	6465.0
CHLOROPHYTA	261.4
CHRYSOPHYTA	34.4
CRYPTOPHYTA	347.4
PYRRHOPHYTA	6192

NP-4 072287

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	1731.3
CHLOROPHYTA	
Closterium	2.9
Scenedesmus	34.8
Other green algae	58
CRYPTOPHYTA	
Cryptomonas	185.6
Other cryptophytes	58
CYANOPHYTA	
Anabaena	43.5
Aphanizomenon	87
TOTAL	2201.1
BACILLARIOPHYTA	1731.3
CHLOROPHYTA	95.7
CRYPTOPHYTA	243.6
CYANOPHYTA	130.5

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	1751.8
CHLOROPHYTA	
Closterium	11.6
Scenedesmus	52.2
Other green algae	58
CRYPTOPHYTA	
Cryptomonas	185.6
Other cryptophytes	58
CYANOPHYTA	
Anabaena	134.8
Aphanizomenon	4.3
TOTAL	2256.4
BACILLARIOPHYTA	1751.8
CHLOROPHYTA	121.8
CRYPTOPHYTA	243.6
CYANOPHYTA	139.2

NP-5 072287

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	36.3
Fragilaria	683.1
Synedra	5115
CHLOROPHYTA	
Eudorina	52.8
Oocystis	39.6
Scenedesmus	13.2
Staurastrum	3.3
Other green algae	19.8
CYANOPHYTA	
Chroococcus	237.6
Coelosphaerium	396
Oscillatoria	1023
PYRRHOPHYTA	
Ceratium	108.9
TOTAL	7728.6
BACILLARIOPHYTA	5834.4
CHLOROPHYTA	128.7
CYANOPHYTA	1656.6
PYRRHOPHYTA	108.9

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	25.4
Fragilaria	1366.2
Synedra	40920
CHLOROPHYTA	
Eudorina	68.6
Oocystis	118.8
Scenedesmus	19.8
Staurastrum	39.6
Other green algae	198
CYANOPHYTA	
Chroococcus	95.0
Coelosphaerium	11.8
Oscillatoria	12.8
PYRRHOPHYTA	
Ceratium	26136
TOTAL 69012.24	
BACILLARIOPHYTA	42311.6
CHLOROPHYTA	444.8
CYANOPHYTA	119.7
PYRRHOPHYTA	26136

Nashawannuck Phytoplankton (continued)

NP-4 080687

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	11160
CHLOROPHYTA	
Chlamydomonas	4.5
Euastrum	4.5
Eudorina	72
Scenedesmus	18
CYANOPHYTA	
Anabaena	13.5
Chroococcus	189
PYRRHOPHYTA	
Ceratium	13.5
TOTAL	11475
BACILLARIOPHYTA	11160
CHLOROPHYTA	99
CYANOPHYTA	202.5
PYRRHOPHYTA	13.5

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	17424
CHLOROPHYTA	
Chlamydomonas	1.8
Euastrum	4.5
Eudorina	28.8
Scenedesmus	27
CYANOPHYTA	
Anabaena	41.8
Chroococcus	75.6
PYRRHOPHYTA	
Ceratium	3240
TOTAL	20843.5
BACILLARIOPHYTA	17424
CHLOROPHYTA	62.1
CYANOPHYTA	117.4
PYRRHOPHYTA	3240

NP-5 080687

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	2145
CHLOROPHYTA	
Other green algae	93.6
CYANOPHYTA	
Anabaena	136.5
Chroococcus	854.1
Microcystis	117
Oscillatoria	409.5
PYRRHOPHYTA	
Ceratium	39
TOTAL	3794.7
BACILLARIOPHYTA	2145
CHLOROPHYTA	93.6
CYANOPHYTA	1517.1
PYRRHOPHYTA	39

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	4290
CHLOROPHYTA	
Other green algae	93.6
CYANOPHYTA	
Anabaena	423.1
Chroococcus	341.6
Microcystis	23.4
Oscillatoria	8.1
PYRRHOPHYTA	
Ceratium	9360
TOTAL	14539.9
BACILLARIOPHYTA	4290
CHLOROPHYTA	93.6
CYANOPHYTA	796.3
PYRRHOPHYTA	9360

NP-4 082087

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	175.5
CHLOROPHYTA	
Coelastrum	124.8
Spirogyra	15.6
Staurastrum	11.7
Other green algae	624
CRYPTOPHYTA	
Cryptomonas	66.3
CYANOPHYTA	
Anabaena	58.5
Aphanizomenon	97.5
Aphanothece	468
PYRRHOPHYTA	
Ceratium	7.8
TOTAL	1649.7
BACILLARIOPHYTA	175.5
CHLOROPHYTA	776.1
CRYPTOPHYTA	66.3
CYANOPHYTA	624
PYRRHOPHYTA	7.8

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	351
CHLOROPHYTA	
Coelastrum	74.8
Spirogyra	3120
Staurastrum	140.4
Other green algae	6240
CRYPTOPHYTA	
Cryptomonas	66.3
CYANOPHYTA	
Anabaena	181.3
Aphanizomenon	4.8
Aphanothece	93.6
PYRRHOPHYTA	
Ceratium	1872
TOTAL	12144.4
BACILLARIOPHYTA	351
CHLOROPHYTA	9575.2
CRYPTOPHYTA	66.3
CYANOPHYTA	279.8
PYRRHOPHYTA	1872

NP-5 082087

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	66
Synedra	48
CHLOROPHYTA	
Eudorina	24
Kirchneriella	84
Scenedesmus	24
Staurastrum	3
CHRYSOPHYTA	
Dinobryon	18
CRYPTOPHYTA	
Cryptomonas	96
CYANOPHYTA	
Anabaena	720
Aphanizomenon	1215
Chroococcus	735
Microcystis	1590
Oscillatoria	1200
TOTAL	5823
BACILLARIOPHYTA	114
CHLOROPHYTA	135
CHRYSOPHYTA	18
CRYPTOPHYTA	96
CYANOPHYTA	5460

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	132
Synedra	384
CHLOROPHYTA	
Eudorina	9.6
Kirchneriella	8.4
Scenedesmus	36
Staurastrum	36
CHRYSOPHYTA	
Dinobryon	54
CRYPTOPHYTA	
Cryptomonas	96
CYANOPHYTA	
Anabaena	2232
Aphanizomenon	60.7
Chroococcus	294
Microcystis	61.5
Oscillatoria	240
TOTAL	3644.2
BACILLARIOPHYTA	516
CHLOROPHYTA	90
CHRYSOPHYTA	54
CRYPTOPHYTA	96
CYANOPHYTA	2888.2

Nashawannuck Phytoplankton (continued)

NP-4 090387

TAXON	CELLS/ML
CHLOROPHYTA	
Cosmarium	3.8
Staurastrum	11.4
CRYPTOPHYTA	
Cryptomonas	22.8
CYANOPHYTA	
Aphanizomenon	741
PYRRHOPHYTA	
Ceratium	3.8
TOTAL	782.8
CHLOROPHYTA	15.2
CRYPTOPHYTA	22.8
CYANOPHYTA	741
PYRRHOPHYTA	3.8

TAXON	UG/L
CHLOROPHYTA	
Cosmarium	3.0
Staurastrum	136.8
CRYPTOPHYTA	
Cryptomonas	22.3
CYANOPHYTA	
Aphanizomenon	37.0
PYRRHOPHYTA	
Ceratium	912
TOTAL	1111.6
CHLOROPHYTA	139.8
CRYPTOPHYTA	22.8
CYANOPHYTA	37.0
PYRRHOPHYTA	912

NP-5 090387

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	46.4
Fragilaria	153.7
CHLOROPHYTA	
Scenedesmus	11.6
Staurastrum	5.8
CYANOPHYTA	
Anabaena	58
Aphanizomenon	1508
Chroococcus	232
Microcystis	2291
Oscillatoria	174
EUGLENOPHYTA	
Trachelomonas	205.9
PYRRHOPHYTA	
Ceratium	2.9
TOTAL	4689.3
BACILLARIOPHYTA	200.1
CHLOROPHYTA	17.4
CYANOPHYTA	4263
EUGLENOPHYTA	205.9
PYRRHOPHYTA	2.9

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	32.4
Fragilaria	307.4
CHLOROPHYTA	
Scenedesmus	17.4
Staurastrum	69.6
CYANOPHYTA	
Anabaena	179.8
Aphanizomenon	75.4
Chroococcus	92.8
Microcystis	458.2
Oscillatoria	3.4
EUGLENOPHYTA	
Trachelomonas	1091.2
PYRRHOPHYTA	
Ceratium	696
TOTAL	3023.8
BACILLARIOPHYTA	339.8
CHLOROPHYTA	87
CYANOPHYTA	809.6
EUGLENOPHYTA	1091.2
PYRRHOPHYTA	696

NP-4 092487

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	62.7
CHLOROPHYTA	
Closterium	1.9
Cosmarium	3.8
Scenedesmus	7.6
Staurastrum	1.9
Ulothrix	11.4
CRYPTOPHYTA	
Cryptomonas	3.8
CYANOPHYTA	
Aphanizomenon	323
TOTAL	416.1
BACILLARIOPHYTA	62.7
CHLOROPHYTA	26.6
CRYPTOPHYTA	3.8
CYANOPHYTA	323

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	125.4
CHLOROPHYTA	
Closterium	7.6
Cosmarium	3.0
Scenedesmus	11.4
Staurastrum	22.8
Ulothrix	114
CRYPTOPHYTA	
Cryptomonas	3.8
CYANOPHYTA	
Aphanizomenon	16.1
TOTAL	304.1
BACILLARIOPHYTA	125.4
CHLOROPHYTA	158.8
CRYPTOPHYTA	3.8
CYANOPHYTA	16.1

NP-5 092487

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	30
CHLOROPHYTA	
Scenedesmus	18
CRYPTOPHYTA	
Cryptomonas	7.5
CYANOPHYTA	
Aphanizomenon	135
Microcystis	112.5
EUGLENOPHYTA	
Trachelomonas	7.5
TOTAL	310.5
BACILLARIOPHYTA	30
CHLOROPHYTA	18
CRYPTOPHYTA	7.5
CYANOPHYTA	247.5
EUGLENOPHYTA	7.5

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	60
CHLOROPHYTA	
Scenedesmus	27
CRYPTOPHYTA	
Cryptomonas	7.5
CYANOPHYTA	
Aphanizomenon	6.7
Microcystis	22.5
EUGLENOPHYTA	
Trachelomonas	39.7
TOTAL	163.5
BACILLARIOPHYTA	60
CHLOROPHYTA	27
CRYPTOPHYTA	7.5
CYANOPHYTA	29.2
EUGLENOPHYTA	39.7

Nashawannuck Phytoplankton (continued)

NP-4 102187

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	198
CRYPTOPHYTA	
Cryptomonas	46.8
Other cryptophytes	36
TOTAL	280.8
BACILLARIOPHYTA	198
CRYPTOPHYTA	82.8

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	396
CRYPTOPHYTA	
Cryptomonas	46.8
Other cryptophytes	36
TOTAL	478.8
BACILLARIOPHYTA	396
CRYPTOPHYTA	82.8

NP-5 102187

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	24.5
CHRYSOPHYTA	
Chromulina	77
CRYPTOPHYTA	
Cryptomonas	133
EUGLENOPHYTA	
Trachelomonas	7
TOTAL	241.5
BACILLARIOPHYTA	24.5
CHRYSOPHYTA	77
CRYPTOPHYTA	133
EUGLENOPHYTA	7

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	49
CHRYSOPHYTA	
Chromulina	15.4
CRYPTOPHYTA	
Cryptomonas	133
EUGLENOPHYTA	
Trachelomonas	7
TOTAL	204.4
BACILLARIOPHYTA	49
CHRYSOPHYTA	15.4
CRYPTOPHYTA	133
EUGLENOPHYTA	7

NP-4 111887

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	246.4
Synedra	8.8
CHLOROPHYTA	
Eudorina	70.4
CHRYSOPHYTA	
Chromulina	8.8
CRYPTOPHYTA	
Cryptomonas	8.9
TOTAL	343.2
BACILLARIOPHYTA	255.2
CHLOROPHYTA	70.4
CHRYSOPHYTA	8.8
CRYPTOPHYTA	8.8

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	492.8
Synedra	70.4
CHLOROPHYTA	
Eudorina	28.2
CHRYSOPHYTA	
Chromulina	1.7
CRYPTOPHYTA	
Cryptomonas	8.8
TOTAL	601.9
BACILLARIOPHYTA	563.2
CHLOROPHYTA	28.2
CHRYSOPHYTA	1.7
CRYPTOPHYTA	8.8

NP-5 111887

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	13.6
Cyclotella	1.7
Cymbella	1.7
Fragilaria	93.5
Melosira	5.1
CHLOROPHYTA	
Chlorella	18.7
CHRYSOPHYTA	
Chromulina	2065.5
CRYPTOPHYTA	
Cryptomonas	56.1
CYANOPHYTA	
Microcystis	110.5
TOTAL	2366.4
BACILLARIOPHYTA	115.6
CHLOROPHYTA	18.7
CHRYSOPHYTA	2065.5
CRYPTOPHYTA	56.1
CYANOPHYTA	110.5

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	9.5
Cyclotella	4.2
Cymbella	2.5
Fragilaria	187
Melosira	12.2
CHLOROPHYTA	
Chlorella	7.4
CHRYSOPHYTA	
Chromulina	413.1
CRYPTOPHYTA	
Cryptomonas	56.1
CYANOPHYTA	
Microcystis	3.3
TOTAL	695.5
BACILLARIOPHYTA	215.5
CHLOROPHYTA	7.4
CHRYSOPHYTA	413.1
CRYPTOPHYTA	56.1
CYANOPHYTA	3.3

Nashawannuck Phytoplankton (continued)

NP-4 121687

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	121
Melosira	6.6
Tabellaria	44
CHLOROPHYTA	
Staurastrum	2.2
CHRYSOPHYTA	
Chromulina	2.2
Dinobryon	57.2
Synura	473
CYANOPHYTA	
Anabaena	286
Coelosphaerium	165
PYRRHOPHYTA	
Ceratium	30.8
TOTAL	1188
BACILLARIOPHYTA	171.6
CHLOROPHYTA	2.2
CHRYSOPHYTA	532.4
CYANOPHYTA	451
PYRRHOPHYTA	30.8

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	242
Melosira	1.9
Tabellaria	792
CHLOROPHYTA	
Staurastrum	26.4
CHRYSOPHYTA	
Chromulina	2.2
Dinobryon	171.6
Synura	378.4
CYANOPHYTA	
Anabaena	886.6
Coelosphaerium	33
PYRRHOPHYTA	
Ceratium	7392
TOTAL	9926.1
BACILLARIOPHYTA	1035.9
CHLOROPHYTA	26.4
CHRYSOPHYTA	552.2
CYANOPHYTA	919.6
PYRRHOPHYTA	7392

NP-5 121687

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	87
CHRYSOPHYTA	
Chromulina	34.8
CRYPTOPHYTA	
Cryptomonas	14.5
Other cryptophytes	46.4
TOTAL	182.7
BACILLARIOPHYTA	87
CHRYSOPHYTA	34.8
CRYPTOPHYTA	60.9

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	174
CHRYSOPHYTA	
Chromulina	6.9
CRYPTOPHYTA	
Cryptomonas	14.5
Other cryptophytes	46.4
TOTAL	241.8
BACILLARIOPHYTA	174
CHRYSOPHYTA	6.9
CRYPTOPHYTA	60.9

NP-4 012088

TAXON	CELLS/ML
BACILLARIOPHYTA	
Cocconeis	3.1
Fragilaria	40.3
CHRYSOPHYTA	
Chromulina	6.2
CRYPTOPHYTA	
Cryptomonas	6.2
TOTAL	55.8
BACILLARIOPHYTA	43.4
CHRYSOPHYTA	6.2
CRYPTOPHYTA	6.2

TAXON	UG/L
BACILLARIOPHYTA	
Cocconeis	3.1
Fragilaria	12.0
CHRYSOPHYTA	
Chromulina	1.2
CRYPTOPHYTA	
Cryptomonas	6.2
TOTAL	22.6
BACILLARIOPHYTA	15.1
CHRYSOPHYTA	1.2
CRYPTOPHYTA	6.2

NP-5 012088

TAXON	CELLS/ML
CHLOROPHYTA	
Chlorella	5.4
CHRYSOPHYTA	
Chromulina	37.8
CRYPTOPHYTA	
Cryptomonas	13.5
TOTAL	56.7
CHLOROPHYTA	5.4
CHRYSOPHYTA	37.8
CRYPTOPHYTA	13.5

TAXON	UG/L
CHLOROPHYTA	
Chlorella	2.1
CHRYSOPHYTA	
Chromulina	7.5
CRYPTOPHYTA	
Cryptomonas	13.5
TOTAL	23.2
CHLOROPHYTA	2.1
CHRYSOPHYTA	7.5
CRYPTOPHYTA	13.5

Nashawannuck Phytoplankton (continued)

NP-4 022388

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	39
CHLOROPHYTA	
Tetraedron	33
CRYPTOPHYTA	
Cryptomonas	6
EUGLENOPHYTA	
Trachelomonas	6
PYRRHOPHYTA	
Ceratium	3
TOTAL	87
BACILLARIOPHYTA	39
CHLOROPHYTA	33
CRYPTOPHYTA	6
EUGLENOPHYTA	6
PYRRHOPHYTA	3

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	78
CHLOROPHYTA	
Tetraedron	82.5
CRYPTOPHYTA	
Cryptomonas	6
EUGLENOPHYTA	
Trachelomonas	6
PYRRHOPHYTA	
Ceratium	720
TOTAL	892.5
BACILLARIOPHYTA	78
CHLOROPHYTA	82.5
CRYPTOPHYTA	6
EUGLENOPHYTA	6
PYRRHOPHYTA	720

NP-5 022398

TAXON	CELLS/ML
BACILLARIOPHYTA	
Diatoma	2.7
CHLOROPHYTA	
Ankistrodesmus	5.4
CHRYSOPHYTA	
Chromulina	2.7
CYANOPHYTA	
Schizothrix	54
TOTAL	64.8
BACILLARIOPHYTA	2.7
CHLOROPHYTA	5.4
CHRYSOPHYTA	2.7
CYANOPHYTA	54

TAXON	UG/L
BACILLARIOPHYTA	
Diatoma	.8
CHLOROPHYTA	
Ankistrodesmus	2.7
CHRYSOPHYTA	
Chromulina	.5
CYANOPHYTA	
Schizothrix	.5
TOTAL	4.5
BACILLARIOPHYTA	.8
CHLOROPHYTA	2.7
CHRYSOPHYTA	.5
CYANOPHYTA	.5

CHLOROPHYLL (UG/L) IN THE NASHAWANNUCK POND

STATION DATE	NP-4	NP-5
04/16/87	.7	.7
04/30/87	5.0	4.9
05/14/87	2.2	5.0
05/28/87	9.0	5.3
06/09/87	4.5	16.7
07/08/87	3.5	12.0
07/22/87	6.0	19.3
08/06/87	16.6	18.7
08/20/87	9.1	5.2
09/03/87	5.9	10.1
06/25/87	2.7	4.5
09/24/87	1.1	1.7
10/21/87	.7	2.5
11/18/87	1.4	16.8
12/16/87	2.6	1.3
1/20/88	1.7	.5
2/23/88	0.0	.7
MAXIMUM	16.6	19.3
MINIMUM	0.0	.5
MEAN	4.3	7.8

NASHAWANNUCK POND 043087

TAXON	#/L
PROTOZOA	
Ciliophora	8.8
ROTIFERA	
Asplanchna	1.3
COPEPODA	
Nauplii	.8
CLADOCERA	
Bosmina	.3
Chydorus	1.3
OTHER ZOOPLANKTON	
Ostracoda	.2
TOTAL	12.7
PROTOZOA	8.8
ROTIFERA	1.3
COPEPODA	.8
CLADOCERA	1.6
OTHER ZOOPLANKTON	.2

TAXON	UG/L
PROTOZOA	
Ciliophora	.2
ROTIFERA	
Asplanchna	1.3
COPEPODA	
Nauplii	2.1
CLADOCERA	
Bosmina	.3
Chydorus	1.3
OTHER ZOOPLANKTON	
Ostracoda	2
TOTAL	7.2
PROTOZOA	.2
ROTIFERA	1.3
COPEPODA	2.1
CLADOCERA	1.6
OTHER ZOOPLANKTON	2
MEAN LENGTH (MM)	0.35

NASHAWANNUCK POND 090387

TAXON	#/L
ROTIFERA	
Asplanchna	.5
Brachionus	1.9
Kellicottia	.2
COPEPODA	
Mesocyclops	2.4
Diaptomus	1.3
Nauplii	.6
CLADOCERA	
Ceriodaphnia	1
Daphnia catawba	.3
Sida	.3
TOTAL	8.5
ROTIFERA	2.6
COPEPODA	4.3
CLADOCERA	1.6

TAXON	UG/L
ROTIFERA	
Asplanchna	.5
Brachionus	.4
Kellicottia	.1
COPEPODA	
Mesocyclops	3
Diaptomus	.6
Nauplii	1.6
CLADOCERA	
Ceriodaphnia	2.6
Daphnia catawba	1
Sida	1.7
TOTAL	11.5
ROTIFERA	.9
COPEPODA	5.2
CLADOCERA	5.3
MEAN LENGTH (MM)	0.51

3. Calculations Sheets and Useful Conversions.

HYDROLOGIC CALCULATIONS FOR NASHAWANNUCK POND

1.) Unit Watershed Area Method.

a.) Watershed Areas (ha) :

Broad Brook	1,771.2
White Brook	564.5
Wilton Brook	261.6
Direct drainage to Pond	76.2
Nashawannuck Pond	12.7
	2,686.2 ha

= 10.35 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 10.35 sq. mi. = 17.6 cu. m/min.
High estimate = 2.55 x 10.35 sq. mi. = 26.4 cu. m/min.

Range of flow estimates = 17.6 - 26.4 cu. m/min.

2.) Runoff Estimate Method.

a.) Assume that certain portion of the precipitation (study year ppt = 1.225 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 2,673.5 ha = 1.631 10^7 m^3/yr.

Low runoff range = 0.51 m/yr x 2,673.5 ha = 1.363 10^7 m^3/yr.

c.) Direct precipitation on Nashwannuck Pond (4/87-3/88):

1.225 m/yr x 12.7 ha = 1.556 10^5 m^3/yr.

d.) Evaporation losses from Nashawannuck Pond :

0.71 m/yr x 12.7 ha = 0.904 10^5 m^3/yr.

e.) Calculations :

16,310,000 + 155,600 - 90,400 = 16,375,200 m^3/yr.

13,630,000 + 155,600 - 90,400 = 13,695,200 m^3/yr.

f.) Range of flow estimates = 26.1 - 31.2 cu. m/min.

TABLE

Land Use in the Nashawannuck Pond Watershed with breakdown by sub-drainage basins.

Sub-drainage description.	Area (ac)	Land Use Types	Percent of Watershed.
Broad Bk. Watershed	4381	F	70.1
		LR	12.0
		MR	1.9
		AP	7.3
		AT	1.9
		AO	0.4
		AB	0.1
		O	3.9
		W	2.1
		R	0.3
White Bk. Watershed	1394	F	23.3
		LR	13.3
		MR	21.9
		AP	3.9
		AT	12.8
		AB	1.2
		O	13.1
		W	3.0
		R	2.3
		Sc	2.5
		C	1.8
		I	0.9
Wilton Bk.Watershed	664	F	35.0
		LR	21.9
		MR	5.8
		HR	3.6
		AP	4.6
		AT	4.4
		O	7.9
		W	4.7
		R	1.8
		Sc	4.4
		C	1.3
		I	4.6
Direct drainage to Nashawannuck Pond.	199	F	26.0
		MR	49.0
		O	8.0
		R	12.0
		C	5.0

LAND USES FOR TOTAL NASHAWANNUCK POND WATERSHED.

Symbol	Land Use	Percent
F =	Forested.	56.3
LR =	Low. Residential	13.1
MR =	Med. Residential.	7.9
HR =	High. Residential.	0.3
AP =	Pasturage.	5.7
AT =	Till fields.	4.4
AO =	Orchards.	0.3
AB =	Farm buildings.	0.3
O =	Open space.	7.1
W =	Wetlands	1.8
R =	Recreation/Park.	1.2
Sc =	Schools.	0.6
C =	Commercial.	0.5
I =	Industrial	0.5

Total Watershed = 6,638 ac.		100.0

Nashawannuck Pond Detention Time

Assume that outflow equals flow through the system = 23.4 cu.m/min (Table 8)

Assume lake volume equals 234,890 cu.m (Table 1)

Mean annual output = 12,299,040 cu.m/yr

$$\frac{234{,}890 \text{ cu.m}}{12{,}299{,}040 \text{ cu.m/yr}} = 0.019 \text{ yr} \times 365 \text{ day/yr} = \underline{7 \text{ days}}$$

Nashawannuck 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 Nashawannuck Pond.
T = lake residence time (yr)
Z = average lake depth (m)

$$t\ 1/2 = \frac{0.6931}{\frac{1}{0.019} + \frac{10}{1.5}} = 0.012 \text{ yr}$$

The lake's response time is estimated at 3x-5x the concentration half life of Nashawannuck Pond or (0.012 x 3 or 5 = 0.036 or 0.060 yr) 13 - 22 days.

Calculation of Phosphorus Loading by Atmospheric Deposition and Wildlife

Atmospheric Deposition

An atmospheric deposition factor of 0.43 kg P/ha/yr was used (1), due to the combination of forested, agricultural and residential land use in the watershed. The area of the lake is equal to 12.7 hectares. Thus, direct atmospheric deposition = 0.43 kg P/ha/yr x 12.7 ha = 5.5 kg P/yr.

Wildlife Deposition

The prevailing wildlife in the lake is likely to be waterfowl. Observations during the study year noted several resident flocks, especially Canadian geese in the winter months. Assume a yearly density of 3 birds per hectare over the year, or 38 birds. Using a mean value of 0.2 kg P/bird/yr (1), the wildlife input = 38 birds x 0.2 kg P/bird/yr = 7.6 kg P/yr.

(1) Source : Reckhow et. al, 1980.

Nashawannuck Pond Determination of Permissible and Critical Loading

Phosphorus Vollenweider Loading Analysis :

$$\frac{Z}{td} = \frac{1.6}{0.019} = 84.2$$ where: Z = mean depth (m)
td = detention time (yr)

Area of Nashawannuck Pond = 12.7 ha = 127,000 sq.m

for permissible (oligotrophic) loading (1):

0.92 g P/sq.m/yr x 127,000 sq.m = 117 kg P/yr

for critical (eutrophic) loading (1) :

1.83 g P/sq.m/yr x 127,000 sq.m = 232 kg P/yr

(1) Source : Vollenweider, 1968.

Nashawannuck Pond Phosphorus/Chlorophyll/Secchi disk transparency

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

$$[chl] = .28\ [TP]^{0.96}$$ in-lake (NP-4,5) TP = 48 ug/l (range = 21-120)

for TP = 48; chl a = 11.5 ug/l
TP = 21; chl a = 5.2 ug/l
TP = 120; chl a = 27.7 ug/l

Compare with actual Nashawannuck Pond mean chlorophyll value of 6.1 ug/l and a range of 0.0 - 19.3 ug/l

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

$$[\overline{Secchi}] = 9.33\ [\overline{chl}]^{-0.51}$$ in-lake [chl a] = 6.1 ug/l
range = 0.0 - 19.3 ug/l

with chl a = 6.1; SDT = 3.7 m
chl a = 19.3; SDT = 2.1 m

Compare with actual Nashawannuck Pond mean Secchi disk transparency of 2.2 m and a range of 1.2 - 3.1 m. The lower actual values are probably due to the shallowness of the lake at NP-4; many measurements are "to the bottom", which means that they would go further had they not be intercepted by the bottom.

Calculation of Internal Phosphorus Load from Bottom Sediments

1. From information from dissolved oxygen profiles (Figure 8); anoxia (assume for DO concentrations of 2.0 mg/l or less) persists at or below 3.5 m of depth between May 28 and September 24 (121 days). Assume anoxia at depths at or below 3.5 m for this period.

2. From hypsographic chart (Figure 4), estimate the area of Nashawannuck Pond affected ($\geq$ 3.5 m) as 15% of surface area:

0.15 x 12.7 ha x 10,000 sq. m ha + 19,050 sq. m

3. Range of measured benthic release rates for phosphorus are 6.0 to 28.0 mg P/sq. m/day

An empirical determination of phosphorus release from anoxic sediments in Nashawannuck Pond was made using a period (July 9 - August 6; August 20 - September 3, 1987) when water column is very stable. Assumptions are that no diffusion, mixing or uptake is occurring. Total phosphorus values in hypolimnion increased from 66 to 208 ug P/l over 28 days and 66 to 140 ug P/l over 14 days. Over a square meter of deep water you have 1200 l of hypolimnion. Totaling increases in phosphorus gives you 170 mg P/sq. m/28 days or 89 mg P/sq. m/14 days. These values translate to 6.1 to 6.3 mg P/sq. m/day. A remineralization release rate of 6.2 mg P/sq. m/day is assumed.

4. Total phosphorus load from bottom sediments is:

19,050 sq. m x 6.2 mg P/sq. m/day x 1 kg/1,000,000 mg x 121 days = 14.3 kg/yr.

GROUNDWATER CALCULATIONS FOR NASHAWANNUCK POND 1987

Tran sect	Mtr	SHORELINE LENGTH(M)	DIST. TO MUCK (M)	AREA (SQ. M)	AVERAGE SEEPAGE (L/SQ.M/D)	SHORELINE CONTRIB.(L/DY)
A	1	601	10	6010	7.0	42190
B	2	504	10	5040	7.7	38556
C	3	756	10	7560	2.1	16027
D	4	648	10	6480	5.7	37066
E	5	578	10	5780	3.6	20924
F	6	396	10	3960	1.5	5900
	TOTAL	3483		34830		160663
	MEAN		10		4.6	

TOTAL SEEPAGE (CU M./MIN.) .112

Stormwater Calculations for the Nashawannuck Pond Watershed.
Data from 10/21/87; Composite samples

Station	Flow	Total P Conc.	Product	Loading For 2 hr.	Percent Total flow	Percent Tot. P
NPS-1	.17	140	23.8	.00286	.14	.04
NPS-2	.46	550	253.0	.03036	.38	.45
NPS-3	.1	500	50.0	.00600	.08	.09
NPS-4	.16	810	129.6	.01555	.13	.23
NPS-6	.17	350	59.5	.00714	.14	.11
NPS-7	.16	260	41.6	.00499	.13	.07

Means : 1.22 557.5
P Loading in Kilograms : .06690
Flow-weighted [TP] : 457.0

Storm event rainfall = 0.43 cm.
Study year precipitation total = 122.5 cm.
Amount of yearly volume that produces runoff = 0.90 (Schueler, 1987)

Percentage of yearly ppt = 0.43 /(122.5 x .90) = 0.39%

P Loading (Kg) as yearly total = 0.0069 Kg / .0039 = 17.7 Kg P

Stormwater Calculations for the Nashawannuck Pond Watershed.
Data from 10/21/87; Composite samples

Station	Flow	Total N Conc.	Product	Loading For 2 hr.	Percent Total flow	Percent Tot. N
NPS-1	.17	2.40	.4	.04896	.14	.10
NPS-2	.46	2.96	1.4	.16339	.38	.34
NPS-3	.1	3.12	.3	.03744	.08	.08
NPS-4	.16	3.20	.5	.06144	.13	.13
NPS-6	.17	5.86	1.0	.11954	.14	.25
NPS-7	.16	2.80	.4	.05376	.13	.11

Means : 1.22 4.04
TN loading in kilograms : .48454
Flow-weighted [TN] : 3.3

Storm event rainfall = 0.43 cm.
Study year precipitation total = 122.5 cm.
Amount of yearly volume that produces runoff = 0.90 (Schueler, 1987)

Percentage of yearly ppt = 0.43 /(122.5 x .90) = 0.39%

TN loading as yearly total = 0.4845 kgg / .0039 = 124.2 kg TN

Data from 5/24/88; Time Series. Station NPS-2.

Time	%flow	Flow	Product 1	[TP]	Product 2	Loadings For 2 hr
10	.083	2.5	.208	779	161.6	.01940
20	.083	4.9	.407	540	219.6	.02635
30	.083	2.5	.208	305	63.3	.00759
45	.125	1	.125	350	43.8	.00525
60	.125	.3	.037	230	8.6	.00104
75	.125	.8	.100	600	60.0	.00720
90	.125	3.1	.388	303	117.4	.01409
105	.125	1.6	.200	250	50.0	.00600
120	.125	.6	.075	266	19.9	.00239

Mean Flow (cu. m/min) : 1.75 744.3

P Loading in Kilograms : .08931

Flow-weighted [TP] : 426.1

Data from 5/24/88; Time Series. Station NPS-4.

Time	%flow	Flow	Product 1	[TP]	Product 2	Loadings For 2 hr
10	.083	.3	.025	660	16.4	.00197
20	.083	1.4	.116	1100	127.8	.01534
30	.083	.9	.075	754	56.3	.00676
45	.125	.4	.050	515	25.8	.00309
60	.125	.2	.025	310	7.8	.00093
75	.125	.2	.025	280	7.0	.00084
90	.125	.6	.075	647	48.5	.00582
105	.125	.4	.050	400	20.0	.00240
120	.125	.3	.037	374	14.0	.00168

Mean flow (cu. m/min.) .48 323.6

P loading in Kilograms : .03884

Flow-weighted [TP] : 676.6

Storm event rainfall = 1.12 cm
Percentage of yearly ppt = 1.12/(122.5 x 0.90) = 1.02%

Percentage NPS-2 + NPS-4 flows / all flows = .38 + .13 = 0.51

P loading(Kg) as yearly total = [(0.0893 + 0.0388)/0.0102]/0.51 = 24.6 kg P

Data from 5/24/88; Time Series. Station NPS-2.

Time	%flow	Flow	Product 1	[TN]	Product 2	Loadings For 2 hr
10	.083	2.5	.208	4.95	1.0	.12326
20	.083	4.9	.407	3.56	1.4	.17374
30	.083	2.5	.208	2.88	.6	.07171
45	.125	1	.125	2.19	.3	.03285
60	.125	.3	.037	3.13	.1	.01408
75	.125	.8	.100	3.39	.3	.04068
90	.125	3.1	.388	3.36	1.3	.15624
105	.125	1.6	.200	2.08	.4	.04992
120	.125	.6	.075	2.4	.2	.02160

Mean Flow (cu. m/min) : 1.75 5.7

TN loading in kilograms : .68408

Flow-weighted [TN] : 3.3

Data from 5/24/88; Time Series. Station NPS-4.

Time	%flow	Flow	Product 1	[TN]	Product 2	Loadings For 2 hr
10	.083	.3	.025	6.27	.2	.01873
20	.083	1.4	.116	6.05	.7	.08436
30	.083	.9	.075	3.64	.3	.03263
45	.125	.4	.050	4	.2	.02400
60	.125	.2	.025	2.61	.1	.00783
75	.125	.2	.025	2.17	.1	.00651
90	.125	.6	.075	3.51	.3	.03159
105	.125	.4	.050	1.62	.1	.00972
120	.125	.3	.037	2.43	.1	.01093

Mean flow (cu. m/min.) .48 1.9

TN loading in kilograms : .22631

Flow-weighted [TN] : 3.9

Storm event rainfall = 1.12 cm
Percentage of yearly ppt = 1.12/(122.5 x 0.90) = 1.02%

Percentage NPS-2 + NPS-4 flows / all flows = .38 + .13 = 0.51

TN loading (kg) as yearly total =[(0.22631 + 0.68408)/0.0102]/ 0.51 = 175 kg TN

Data from 6/30/88; Time Series. Station NPS-2.

Time	%flow	Flow	Product 1	[TP]	Product 2	Loadings for 2 hr
10	.083	2.6	.216	130	28.1	.00337
20	.083	3.1	.257	780	200.7	.02408
30	.083	3.4	.282	480	135.5	.01625
45	.125	3.2	.400	280	112.0	.01344
60	.125	2.6	.325	200	65.0	.00780
75	.125	1.7	.212	150	31.9	.00383
90	.125	1.5	.188	100	18.8	.00225
105	.125	1.2	.150	130	19.5	.00234
120	.125	.9	.113	160	18.0	.00216

Mean flow (cu. m/min) : 2.14 629.3

P loading in Kilograms : .07552

Flow-weighted [TP] : 293.7

Data from 6/30/88; Time Series. Station NPS-4.

Time	%flow	Flow	Product 1	[TP]	Product 2	Loadings for 45 min.
0	.1	1.4	.14	520	72.8	.00364
10	.2	.9	.18	200	36.0	.00180
20	.2	.9	.18	190	34.2	.00171
30	.2	.4	.08	390	31.2	.00156
45	.3	.2	.06	380	22.8	.00114

Mean flow (cu. m/min) : .64 197

P loading in Kilograms : .00985

Flow-weighted [TP] : 307.8

Storm event rainfall = 0.51 cm
Percentage of yearly ppt. = 0.51/(122.5 x 0.90) = 0.46%

P loading(kg) as yearly total = [(0.0755 + 0.0099)/0.0046]/0.51 = 36.4 kg P

Data from 6/30/88; Time Series. Station NPS-2.

Time	%flow	Flow	Product 1	[TN]	Product 2	Loadings for 2 hr
10	.083	2.6	.216	1.7	.4	.04402
20	.083	3.1	.257	6.52	1.7	.20131
30	.083	3.4	.282	4.54	1.3	.15374
45	.125	3.2	.400	3.01	1.2	.14448
60	.125	2.6	.325	2.04	.7	.07956
75	.125	1.7	.212	2.04	.4	.05202
90	.125	1.5	.188	1.51	.3	.03397
105	.125	1.2	.150	1.54	.2	.02772
120	.125	.9	.113	1.54	.2	.02079

Mean flow (cu. m/min) : 2.14 6.3

TN loadings in kilograms : .75762

Flow-weighted [TN] : 2.9

Data from 6/30/88; Time Series. Station NPS-4.

Time	%flow	Flow	Product 1	[TN]	Product 2	Loadings for 45 min.
0	.1	1.4	.14	4.52	.6	.03164
10	.2	.9	.18	2.03	.4	.01827
20	.2	.9	.18	2.02	.4	.01818
30	.2	.4	.08	4.03	.3	.01612
45	.3	.2	.06	4.03	.2	.01209

Mean flow (cu. m/min) : .64 1.926

TN loading in kilograms : .0963

Flow-weighted [TN] : 3.0

Storm event rainfall = 0.51 cm
Percentage of yearly ppt. = 0.51/(122.5 x 0.90) = 0.46%

TN loading (kg) as yearly total = [(0.75762 + 0.0963)/0.0046]/0.51 = 364.0 kg TN

Nashawannuck Pond Calculations

Soft Sediment Depth of Nashawannuck Pond.

Area (ha)	Depth Range (m)	Z	m^2	m^3
2.66	0-0.5	0.25	26,600	6,650
3.28	0.5-1.0	0.75	32,800	24,600
1.90	1.0-1.5	1.25	19,000	22,750
0.02	>1.5	1.5	200	300
7.86				55,300 m^3 = 72,300 CY

Sediment type is very organic muck, rich in nutrients.

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)

APPENDIX E

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 $44.5^{\circ}C \pm 0.2^{\circ}C$ on M-FC medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 ml of sample.

Fecal Streptococci Bacteria - Bacteria of the Streptococci group found in intestines of warm-blooded animals. Their presence in water is considered to verify fecal pollution. They are characterized as gram positive, cocciod bacteria which are capable of growth in brain-heart infusion broth. In the laboratory they are defined as all the organisms which produce red or pink colonies within 48 hours at 35°C± 1.0°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.