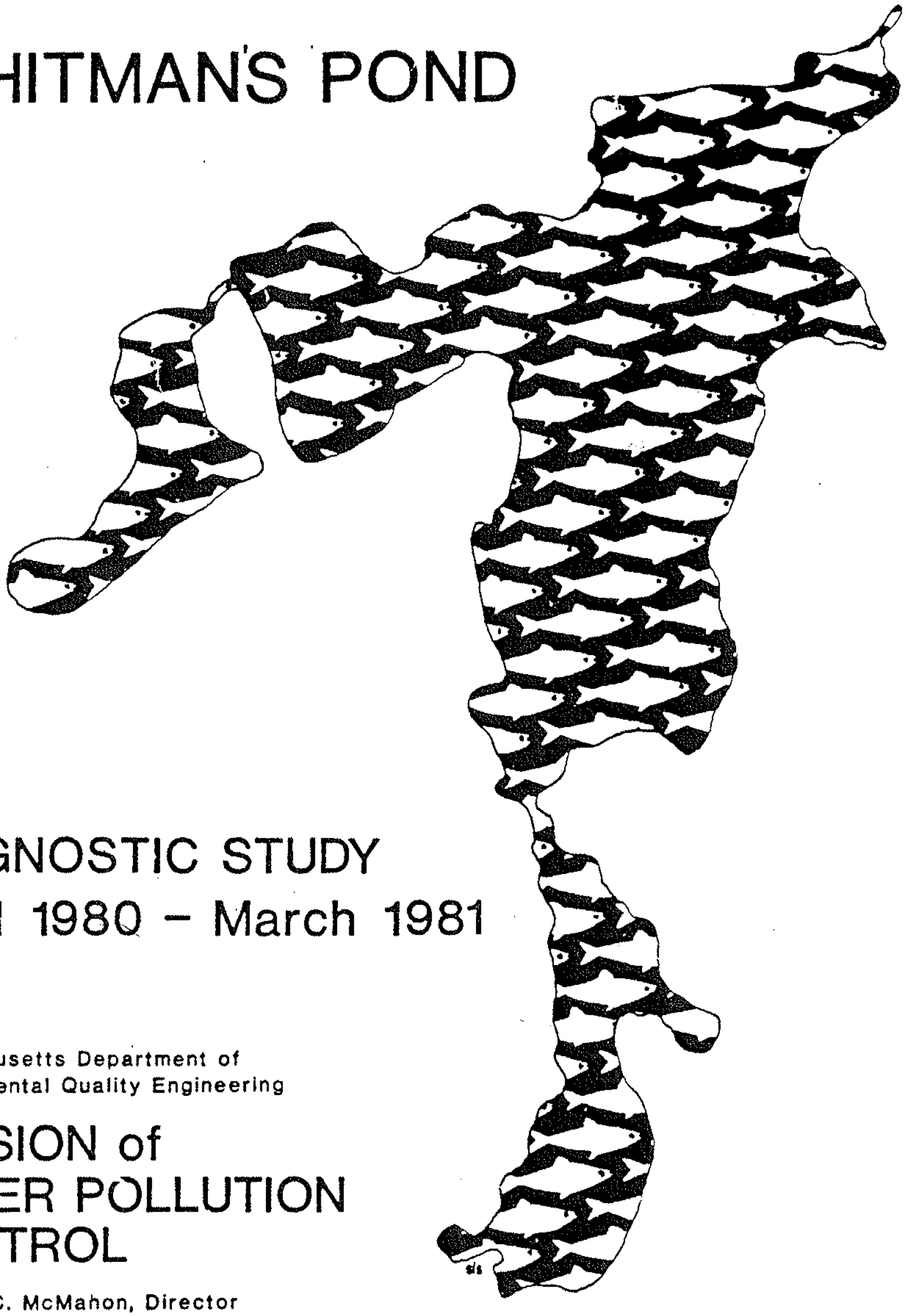
Conservation

WHITMAN'S POND



DIAGNOSTIC STUDY
April 1980 - March 1981

Massachusetts Department of
Environmental Quality Engineering

DIVISION of WATER POLLUTION CONTROL

Thomas C. McMahon, Director

Clean Lakes
now Liminology
Bob Haynes
1-508-792-7470

WHITMAN'S POND

DIAGNOSTIC STUDY

APRIL 1980 - MARCH 1981

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WESTBOROUGH, MASSACHUSETTS

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<u>Cover</u>

Graphic Design by Sharon L. Stacey

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INTRODUCTION

There are many lakes and ponds within the Commonwealth which exhibit the characteristics of advanced eutrophication. The intensity and extent of eutrophication in these lakes and ponds vary according to the natural and cultural factors which influence this process. In response to the growing concern over the consequences of extensive eutrophication problems in the Commonwealth, the Massachusetts Department of Environmental Quality Engineering, Division of Water Pollution Control (through its Technical Services Branch) has developed a program of monitoring and assessing the water quality of Massachusetts' lakes and ponds. Preliminary assessments of trophic status and more detailed limnological studies of the causes of eutrophication are routinely carried out. This report summarizes the information obtained during a one-year study of Whitman's Pond from April 1980 through March 1981 to determine the cause of nuisance aquatic plant growths, algal blooms, and other manifestations of accelerated eutrophication. The purposes of this study were as follows:

1. To partially fulfill the requirements of a Diagnostic/Feasibility study under Section 314 (Clean Lakes Program) of the 1977 Amendments to the Federal Water Pollution Control Act (PL95-217);

2. To characterize the limnology and estimate the trophic condition of Whitman's Pond;

3. To provide useful and authoritative limnological data on Whitman's Pond from which management decisions concerning the pond and its watershed can be made;

4. To provide a data base so that future limnological changes in Whitman's Pond can be compared to it;

5. To develop and evaluate new techniques of lake water quality sampling technology;

6. To satisfy the request made by the Town of Weymouth.

WATERSHED CHARACTERISTICS

Physical Description

Size and Location

Whitman's Pond watershed is located in the Massachusetts Division of Water Pollution Control's Boston Harbor Drainage Area, and more specifically located in the Weymouth and Weir River Basin and Coastal Drainage Area (Figure 1). The watershed encompasses 12.6 square miles with 9.4 square miles, or approximately 75 percent, located in Weymouth, Massachusetts (Figure 2). Smaller regions of the drainage basin are located in the other towns of Braintree, Holbrook, Abington, Rockland and Hingham. Great Pond is also located in Weymouth and is part of the Whitman's Pond watershed.

Climatology

The climate of the area is typically that of a north temperate zone, but experiencing cooling effects from sea breezes. The average annual temperature is approximately 50°F (10°C) but monthly averages range from 30°F (-1.1°C) in January to 71°F (21.8°C) in July (USDA, 1978). The average annual temperature measured by National Oceanic Atmospheric Administration (1980-1981) at Blue Hills Observatory (about 8.75 miles (14.1 km) west of Whitman's Pond) was 48.2°F (9°C) for the study period.

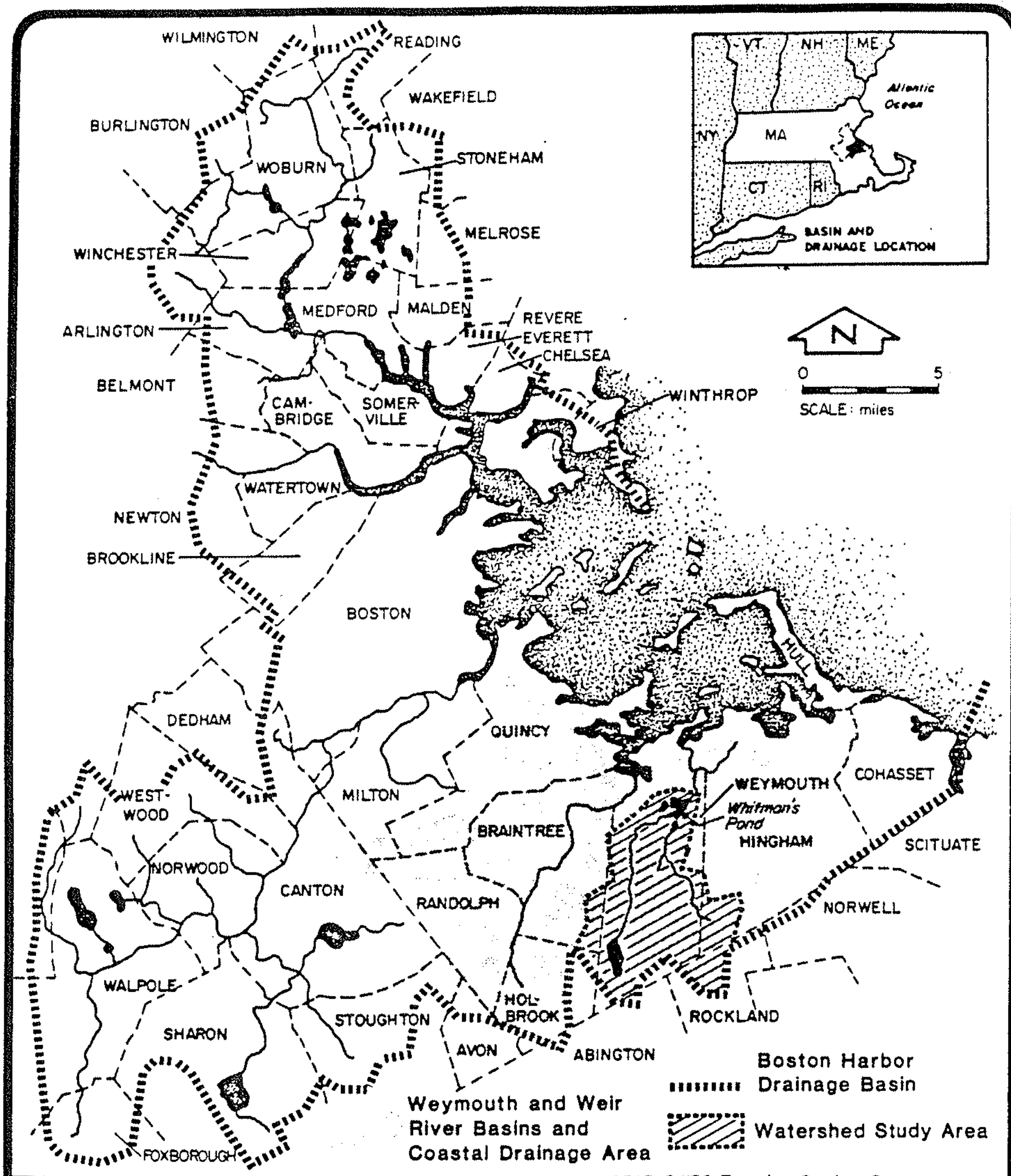
According to the United States Department of Agriculture (1978), the average annual precipitation for this region is about 44" (112 cm). The total precipitation recorded at Blue Hills Observatory by NOAA (1980,1981) for this study period was 34.69" (88.1 cm). During the study period, rainfall was below average in May, August, September, November and December of 1980. In 1981, below average rainfall occurred in January and March. Dry periods did occur at irregular intervals over the entire study period and represent the major type of climate during that time. The remaining months during the study experienced above normal precipitation with the highest being 7.93" (20.1 cm) in February, 1981. U.S.D.A. (1978) indicates that snowfall depths range from 30-70 inches per year with an average of about 50 inches (127 cm). The growing season varies from 160-180 days in close proximity to Whitman's Pond and up to 200 days at the immediate coast.

Topography

The Whitman's Pond watershed has a gently rolling topography with scattered hills. The watershed elevations range from 130-200 feet above mean sea level. Whitman's Pond is located at 66 feet above sea level and Great Pond has an elevation of 159 feet.

Geology

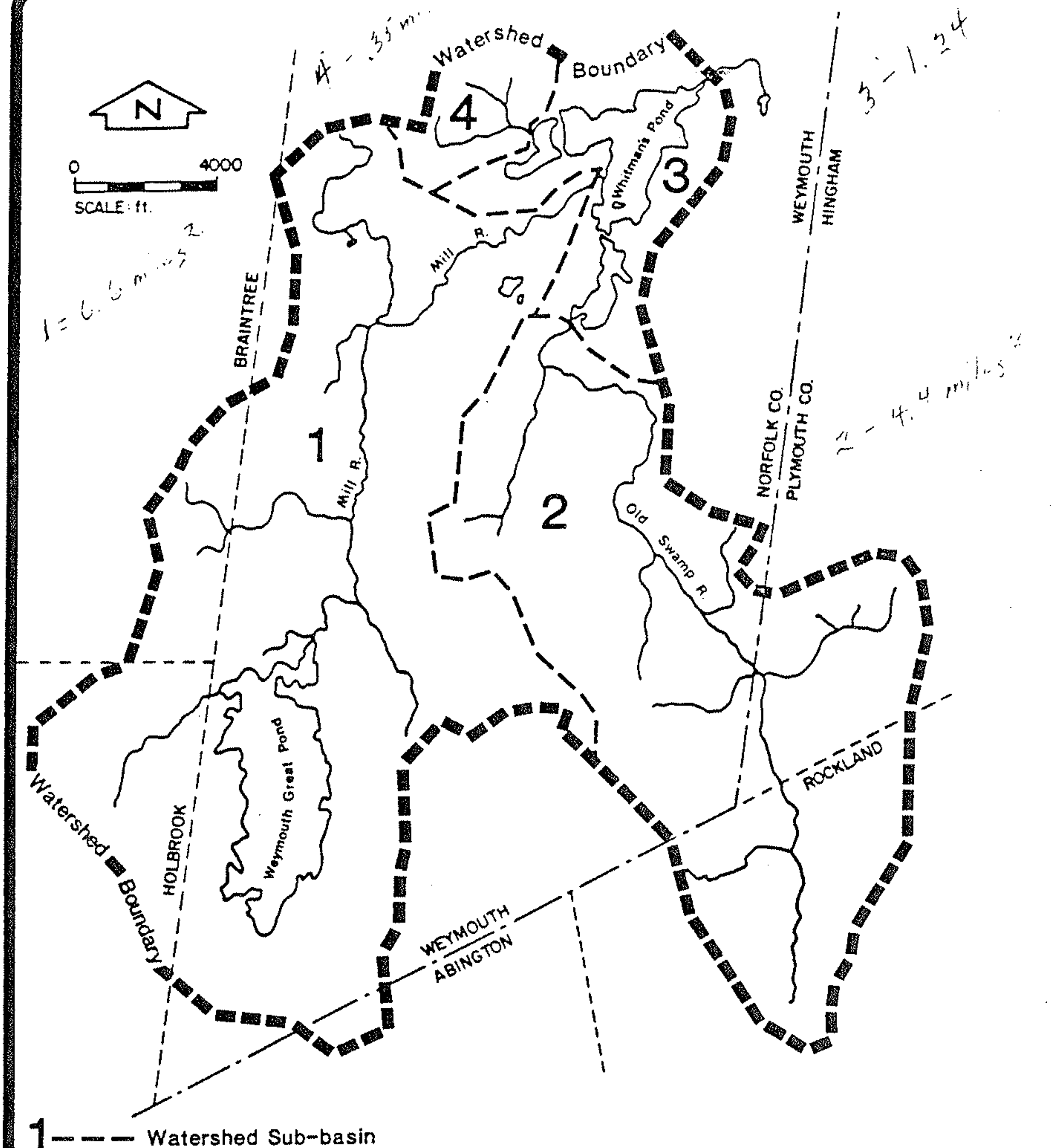
The Whitman's Pond watershed lies within the coastal lowland section of the New England physiographic province (U.S.D.A., 1978). The coastal region includes all the coastal watersheds and offshore islands from the Parker



WHITMAN'S POND

Figure 1

BOSTON HARBOR BASIN PLANNING AREA



WHITMAN'S POND

Figure 2 WATERSHED and SUB-BASIN LOCATION MAP

River in Newbury, Massachusetts in the north to Buzzards Bay and Narragansett Bay drainage in the southeast portion of Massachusetts. The western boundary is the Merrimack and Blackstone River Basins and the Atlantic Ocean serves as the eastern boundary. On the average, igneous, metamorphic and sedimentary bedrock types are ten feet below the surface, but rock outcrops are common. Surficial geology can be described as unconsolidated geological material that was deposited by glacial movements during the last ice age. The drainage pattern that developed in this area consists of a series of wetlands interconnected by a system of rivers and streams. Streams from melting glaciers deposited sediments in broad, flat outwash plains.

Soils

The soils of the coastal region formed in glacial deposits and vary greatly with sand or sand and gravel substrata. The major types in the Whitman's Pond watershed are Paxton, Hollis and Canton (Hill, 1979) (Figure 3). Descriptions of these soils and others in the watershed are listed in Appendix A.

Soil characteristics can greatly influence septic system effectiveness and their failure rate. Of the types associated with the Whitman's Pond watershed, Hollis and Paxton types have severe limitations for the construction of leaching fields. Soil limitations are based on such internal characteristics as texture, structure, drainage and depth to bedrock. External characteristics include surface stoniness, rockiness, slope and flood hazard. The more severe the limitations, the more complex the engineering design and the higher the cost of overcoming the limitation. However, the potential of the soil indicates the types of available management to overcome the limitations. According to Hill, Hollis and Paxton soil types have medium to low potential which, at best, indicates continuous limitations and poor economic feasibility. The limitations and associated potential for Paxton and Hollis soils support the reasons to sewer the area.

Canton soils which constitute about 10% of the Paxton, Hollis, Canton association, have moderate limitations for septic tanks coupled with a high potential to overcome the limitations. Management practices such as enlarging the leaching area and avoiding construction when moisture content is high may increase the life expectancy of a properly operating septic system. Canton soil characteristics also support the possibility of the installation of a subsurface sewerage disposal system.

Hydrology

The Whitman's Pond watershed area measures 12.6 $miles^2$ (32.8 km^2). Whitman's Pond encompasses an area of 0.29 $mile^2$ (.75 km^2) or 2.3 percent of the total watershed area. Old Swamp River and Mill River are the two major tributaries that drain into Whitman's Pond. A small stream in the northwest corner of Whitman's Pond along with the run off from the surrounding urban area contribute to the pond's watershed. Groundwater also contributes to the pond; an observation well located 0.8 miles (1.3 km) south of Route 18 is maintained by the U. S. Geological Survey in cooperation with the Massachusetts Department of Public Works.

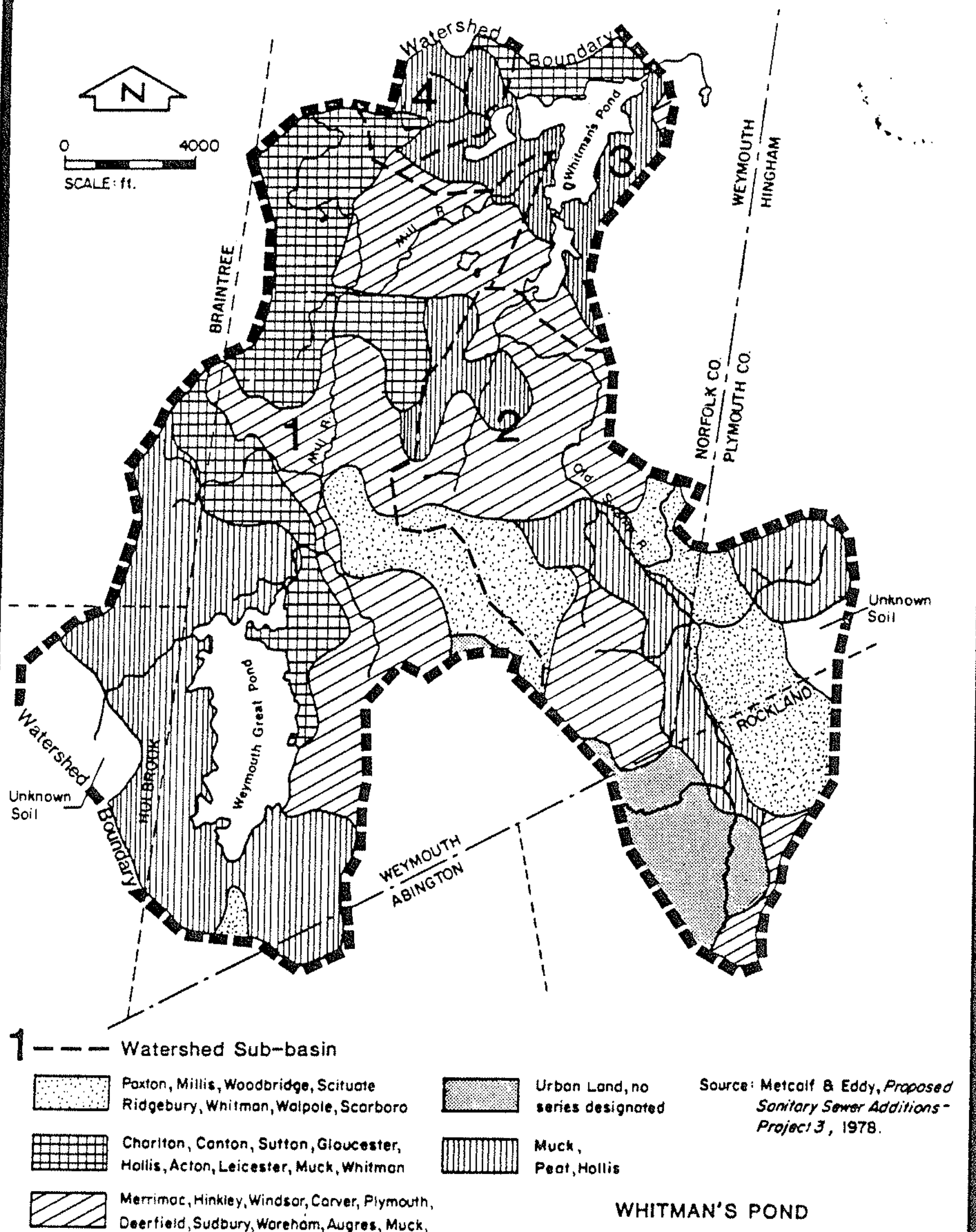


Figure 3 GENERAL SOILS MAP

1- 6.6
2- 4.4
4- .3
3 1.2
12.5

Whitman's Pond watershed was divided into four sub-basins to delineate the watershed into its major drainage areas (Figure 2). The largest sub-basin (#1) is the Mill River sub-basin which represents 6.6 miles^2 (17.2 km^2) and includes Great Pond and its watershed. Sub-basin #2 drains the Old Swamp River sub-basin and represents 4.4 miles (11.4 km^2). A stream located in the northwest corner of Whitman's Pond drains a relatively small area of 0.35 miles (0.81 km^2) and is denoted sub-basin #4. Sub-basin #3 represents the direct drainage into Whitman's Pond and encompasses 1.24 miles^2 (3.2 km^2). Water flowing from Whitman's Pond exits in the northeast corner of the pond through a sediment control structure, town constructed fish passage facilities and Iron Hill Reservoir eventually flowing into the Back River.

DEVELOPMENT

Population

The latest census report from the Metropolitan Area Planning Commission (1980) indicates the population of Weymouth is 55,601 persons. This value represents a 6.8% decrease from an estimated projection for 1980 of 59,000 persons calculated by the Massachuetts Department of Commerce and Development. The population is expected to reach 62,500 within the next two decades which represents a 12.4% increase.

The potential user population for Whitman's Pond exceeds three million people. An 80 km radius includes towns of the Boston Standard Metropolitan Statistical Area (SMSA) which accounts for 2,763,357 persons to date (1980) and suburbs of Worcester and Providence to the west and south, respectively. Route 3 bisects the watershed in close proximity to Whitman's Pond and offers easy access to Boston Metropolitan residents.

Land Use

General land use for Whitman's Pond watershed (Figure 4) was determined using the MacConnell Map Down Series (1971) and from a USGS topographic map (Weymouth, Massachusetts quadrangle, 7.5 minute series, 1971). Percentages of land uses for each sub-basin were determined using a planimeter (Table 1).

The majority of land use is forest land which covers an area of 48.4% of the watershed or 6.1 miles^2 (15.9 km^2). The forests are mainly hardwood with a mixing of softwoods and are concentrated in the southern half of the watershed and surround Great Pond as well.

Urban areas cover 36.3% of the watershed or 4.5 miles^2 (11.9 km^2) and constitute the second largest land use. Urban areas include land use types such as commercial, residential, industrial and transportation. The percentage of urban land use with respect to other land uses is greatest in sub-basin #3. Fifty-two percent of the land use in sub-basin #3 is urban which represents the area of direct drainage of the periphery of the pond into Whitman's Pond.

Wetlands and open waters cover 8.3% or 1 mile^2 (2.72 km^2) of the watershed and include the surface waters of Whitman's and Great Ponds. The

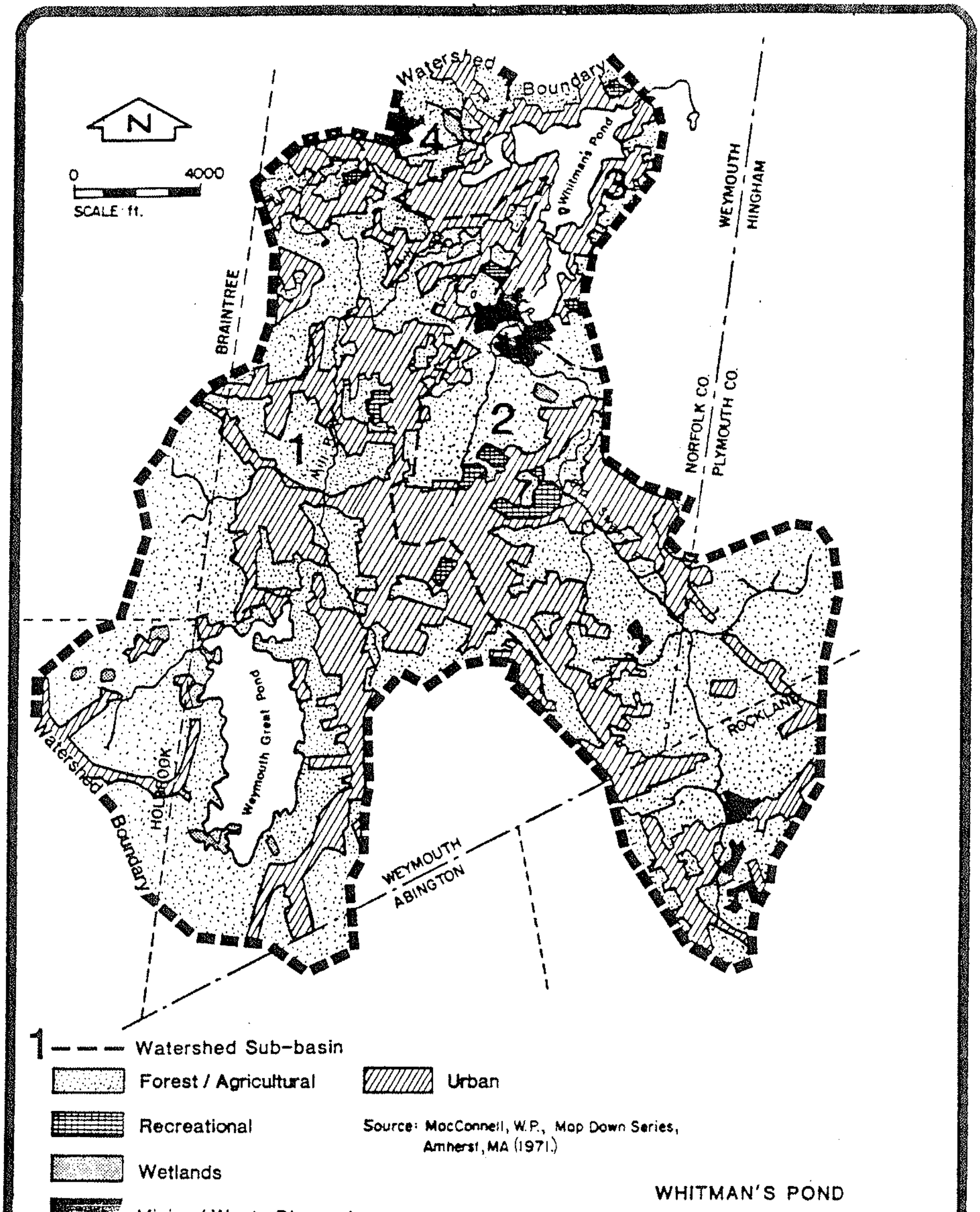


Figure 4 LAND USE MAP

TABLE 1

LAND USE PERCENTAGES

	TYPE	SUB-BASIN #1 (km^2)	SUB-BASIN #2 (km^2)	SUB-BASIN #3 (km^2)	SUB-BASIN #4 (km^2)	PERCENTAGES OF TOTAL
1.	Forest	8.9	5.8	0.63	0.49	48.4
2.	Urban	5.5	4.4	1.7	0.32	36.3
3.	Wetland*	1.9	0.01	0.75	0.08	8.3
4.	Agriculture	0.45	0.69			3.5
5.	Mining & Waste	0.07	0.28	0.14	0.03	1.6
6.	Highway	0.23	0.12			1.0
7.	Outdoor Recreation	0.08	0.15	0.03		0.8

* Includes surface waters of Whitman's and Great Ponds.

freshwater wetlands in the watershed are located in close proximity to either Whitman's Pond or Great Pond.

Other minor land uses include 3.5% agriculture (0.42 $miles^2$ or 1.14 km^2), 1.6% mining and waste (0.2 $miles^2$ or 0.52 km^2), 1.0% highway (0.1 $mile^2$ or 0.34 km^2) and 0.8% outdoor recreation (0.1 $mile^2$ or 0.26 km^2).

Libbey Industrial Park, located near the southern border of Whitman's Pond was developed after 1971 and encompasses 0.25 $miles^2$ (0.65 km^2) and is not reflected in land use percentages. Such a reflection would manifest an increase of 0.25 $miles^2$ (0.65 km^2) in the urban land use category and a corresponding decrease in the forest land use area in the watershed and more specifically in sub-basin #2.

LAKE CHARACTERISTICS

Physical Description

Location

Whitman's Pond, an enhanced "Great Pond", is located in the northern central region of Weymouth.* The approximate center of the pond is located at latitude 42° 12'15" N. and longitude 70° 56'15" W.

Lake Formation

The original lake basin was formed during the last ice age (10,000 years ago) when receding glaciers carved out deep depressions (Crosby 1893). Melt-water formed a huge lake known as Lake Bouve which covered large portions of Plymouth and Norfolk Counties. Whitman's Pond lies in that portion of Lake Bouve's bed known as Whitman's Plain. The original pond size is not available.

The pond was first dammed to provide power for an iron foundry operation, the owners of which built the dam and controlled the water rights (Belding, 1905). The lake level was raised 4 feet in 1836 by increasing the dam height. The Wool Scouring Mill eventually bought the privilege to draw water by buying out the iron foundry. The Mill Company was under obligations to carry up a certain number of herring each year for spawning. On September 13, 1905 the pond was drawn down 5 feet to facilitate examination of the alluvial land which at the time consisted of brown mud resting on stones or gravel.

Presently the town of Weymouth Highway Department maintains the dam structure and the town owns the dam and the water rights.

Morphometry

Whitman's Pond has a surface area of 72 ha (177.9 acres) and a total volume of 1,537,422m^3 (1246 acre - feet). It is sub-divided into three

* Great Ponds are defined by The Commonwealth of Massachusetts General Laws as naturally occurring ponds over 10 acres in size, except regarding fishing where rights exist in ponds over 20 acres.

basins (Fig. 5). Ancillary basins are shallow; the western sub-basin has a maximum depth of 3 feet and the southern basin maximum depth is 5 feet. The main basin has a mean depth of 2.1m (6.9 feet) and a maximum depth of 7.9m (26 feet). The development of the shoreline has a value of 3.173. This characteristic represents the quantity that can be regarded as a measure of the potential effect of shoreline processes such as wave action or currents on the lake. A value of 1 would be assigned to a lake that is a perfect circle. The value for Whitman's Pond may be attributed to its elongate shape and its connecting sub-basins. Table 2 presents a complete list of morphometric data for Whitman's Pond.

Lake Uses

Whitman's Pond is classified as a class B water according to the Massachusetts Water Quality Standards 1978 Water Resources Commission (DWPC). These waters are thus suitable for bathing and recreational purposes. It is also acceptable to use class B waters for public water supply provided there is treatment and disinfection. The town of Weymouth uses water from Whitman's Pond as a secondary source of drinking water. Water is first pumped to Great Pond, then through a treatment facility and ultimately made available for public drinking water. In addition to supplying town water, other public uses include boating, ice-skating and fishing. A public beach is located off Lake Street on the north shore of Whitman's Pond. Boat launching was possible at a public ramp off of Middle Street, but has been prohibited by the Selectmen due to vandalism.

Whitman's Pond provides a major spawning ground for a species of herring known as *Alosa pseudoharengus* or more commonly called alewives. Historically they were important as a source of food and fertilizer. Alewives migrate from Hingham Bay into Whitman's Pond via Weymouth's Back River during April and May. Construction of fish ladders, modified culverts and additional shoring of the river banks by the town has facilitated this migration and allowed for their survival (Edward Owens, communication by letter 1979).

No industrial uses of the pond are currently reported. Quincy Steel, an iron foundry that is in operation is located on Old Swamp River.*

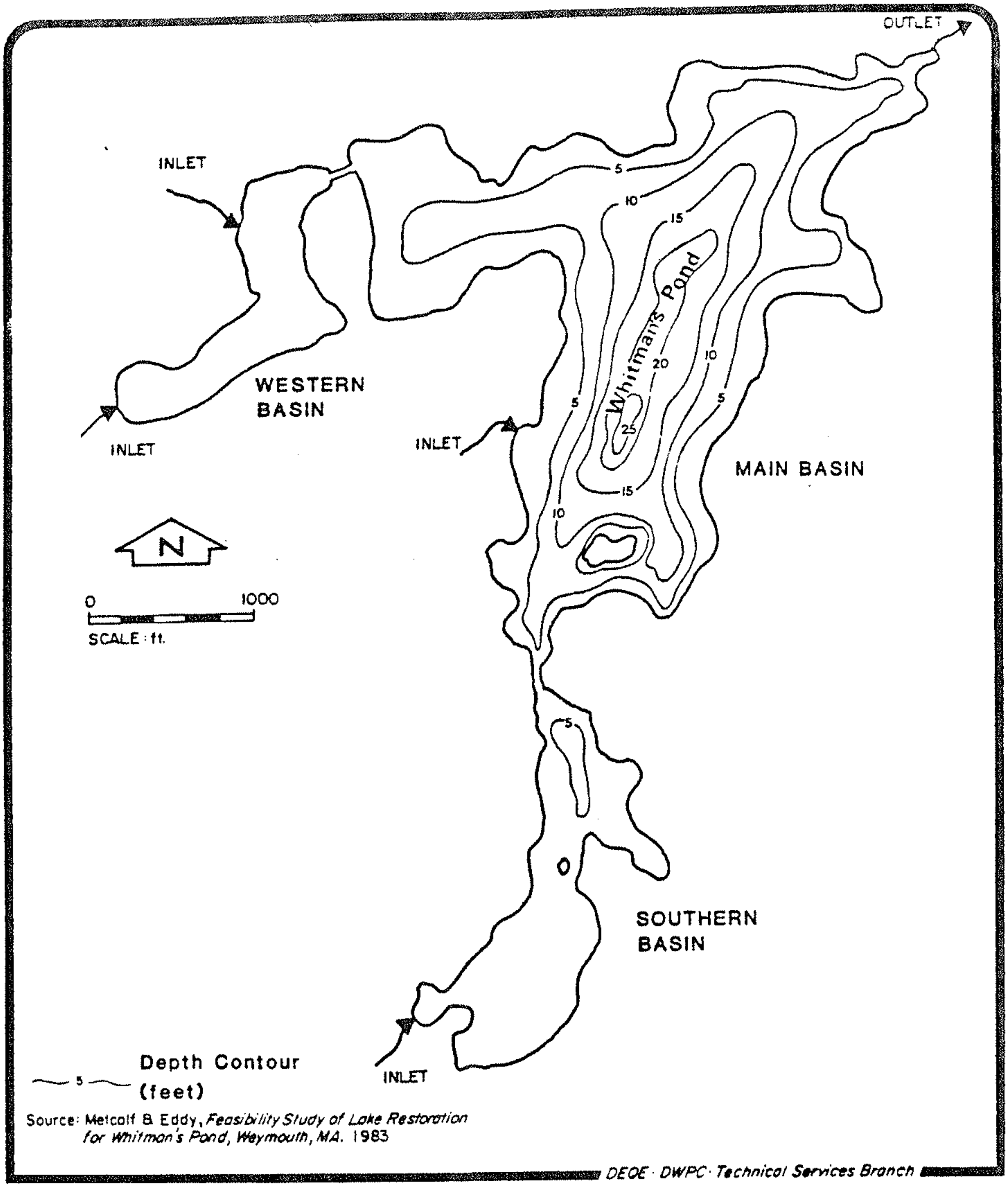
The town of Weymouth is serviced by public transportation in the form of buses which are not available directly to Whitman's Pond but are franchised by the State to serve the town. There is also a commuter boat available at the Back River for transporting passengers to and from Boston.

PROBLEMS AND MANAGEMENT PRACTICES

Watershed

The principle problems associated with the watershed of Whitman's Pond seems to include urban stormwater runoff and leachate from subsurface disposal systems.

* During the storm drain survey a 4" cast iron pipe, identified number 24, was noted in close proximity to Quincy Steel (Figure 8). Testing for phenols was conducted and results were negative.



WHITMAN'S POND

Figure 5

BATHYMETRIC MAP

TABLE 2

WHITMAN'S POND

WEYMOUTH, MASSACHUSETTS

MORPHOMETRIC DATA

Area (Total Pond)	72.0 hectares (177.9 acres)
Basin 1 - Main basin	51.8 hectares (128.0 acres)
Basin 3 - Southern basin	12.1 hectares (29.9 acres)
Basin 8 - Western basin	8.1 hectares (20.0 acres)
Volume (Total Pond)	1,537,422 m^3 (1246 acre-feet)
Basin 1 - Main basin	1,424,931 m^3 (1155 acre-feet)
Basin 3 - Southern basin	72,671 m^3 (60 acre-feet)
Basin 8 - Western basin	39,820 m^3 (32 acre-feet)
Maximum Depth (Zm)	7.9 m (26.0 feet)
Mean Depth ($\overline{Z}$)	2.1 m (6.9 feet)
Maximum Length	1443.0 m (4734.0 feet)
Maximum Effective Length	1443.0 m (4734.0 feet)
Maximum Width	888.0 m (271.0 feet)
Maximum Effective Width	888.0 m (271.0 feet)
Shoreline Length	9.546 km (5.932 miles)
Development of Shoreline	3.173
Development of Volume	0.797
Mean to Maximum Depth Ratio	0.266
Elevation Above Mean Sea Level	20.0 m (66 feet)
Latitude	42^0 12' 15" N
Longitude	70^0 56' 15" W

Since 36.3% of the watershed is classified as an urban setting (industrial, commercial, residential) most precipitation runs off impervious surfaces carrying pollutants into proximate storm drains or a surface watercourse. The feasibility study conducted by Metcalf and Eddy (1983) includes a comprehensive stormwater run off investigation. The storm water drainage from sub-basin #3 (Figure 2) exerts the most impact from direct drainage as opposed to the other sub-basins.

Another reason for the degradation of Whitman's Pond water quality is septic system leachate. Although nearly 70% of Weymouth's population is now served by sewers, about 5,000 septic systems are still in operation.* Three areas in particular are experiencing persistent problems. They include the hilly area east of Whitman's Pond, regions adjacent to the Naval Air Station and the area off of White Street and the southern end of Union Street.

Problems associated with these areas that may cause septic system failures include bedrock that is visibly close to the surface and the poorly drained soils of muck and peat. Plans to sewer the entire town have been developed and will be completed in phases. Owners of septic systems that are experiencing problems should have their systems pumped frequently until sewering is complete.

Lake

The immediate problem in Whitman's Pond is the very dense aquatic macrophytes which impede the pump station from operating properly. Water is pumped from Whitman's Pond to supplement the water level at Great Pond which is used as a primary water supply by the town of Weymouth. The station is located on Washington Street near the south basin and must be continually cleared and maintained during the summer months when aquatic vegetation is very dense to avoid clogging problems. Dense macrophyte growth may also prohibit such recreational activities as swimming and boating. Spot treatments and partial treatments to control macrophyte growth were conducted in 1976, 1977 and 1978 using Silvex. Treatments successfully abated macrophytes for that year but did not qualify as a long-term solution.

Another problem that is experienced at Whitman's Pond is the occurrence of an anoxic hypolimnion during the summer months. The pond stratifies during this time and diffusion of oxygen from the upper layer to the hypolimnion is slow or non-existent. The density gradient that develops as a result of stratification prohibits the water from mixing and causes stagnation. Flow pumped from the Washington Street station does not contribute to pond flushing, since the withdrawal point is near the major inflow to the pond.

The public beach was closed for several days (June 25 - July 1) in 1979 due to excessively high coliform counts (Owens, Edward. Communication by letter, 1979). The town responded by adding chlorine to the waters in the immediate vicinity of the beach. Bacterial pollution does not appear to be

* Information furnished via telecom with Weymouth Water Department, Nov. 1982.

a significant problem of Whitman's Pond under dry weather conditions. However, after storms high bacterial counts are a problem in localized areas near storm drain outfalls.

LIMNOLOGICAL DATA

Methods

Morphology

A bathymetric map of Whitman's Pond provided by the Weymouth Department of Public Works was refined in the field with a fathometer (Ray Jefferson Model 6000). Morphometric parameters were measured with a planimeter and rotometer according to Hutchinson (1957) and Welch (1948). Other pertinent map data (drainage basin area) were derived from a U.S. Geological Survey topographic map (Weymouth, Massachusetts quadrangle, 7.5 minute series, 1971).

Physical and Chemical

Temperature profiles were made in the field with a Tele-Thermometer (YSI Model 425C). Transparency measurements were made with a standard 20 cm Secchi disk following standard procedures (Hutchinson, 1957). Field pH tests were taken with a Hach Model 17N wide range pH test kit. Surface collection of chemical, bacteriological, and dissolved oxygen samples were done by hand. Depth sampling was conducted using a 2-liter brass Kemmerer sampler. Chemical samples were collected in pre-rinsed glass bottles and stored on ice for transport. Bacteriological samples were collected in sterilized bottles and also stored on ice for transport.

The following analyses were conducted on each water sample: pH, total alkalinity, total hardness, conductivity, suspended solids, total solids, total Kjeldahl nitrogen, ammonia-nitrogen, nitrate-nitrogen, total phosphorous, choride, iron, manganese, total and fecal coliform bacteria, and fecal streptococcus bacteria.

Dissolved oxygen concentrations were measured by the azide modification of the Winkler technique; both chemical and bacteriological samples were analyzed at the Lawrence Experiment Station of the Department of Environmental Quality Engineering, Division of Laboratories according to Standard Methods, 14th ed. (APHA, 1976), and Methods for Chemical Analysis of Water and Wastes (U.S. EPA, 1979).

Phytoplankton and Chlorophyll *a*

Samples were collected by a standard procedure described by the Maine Department of Environmental Protection, Division of Lakes and Biological Studies (1974). When the lake was unstratified, samples were collected by holding a clean and rinsed sample bottle several inches under the surface of the water. If stratification was evident, a composite sample of the water column above the thermocline was taken. Each sample consisted of a composite core taken with 1/4 inch I. D. plastic tube with a weight attached to one end. The tube was lowered at the deep station to an appropriate point above the thermocline, pinched below the meniscus, and raised into the boat. The sample was allowed to drain into a clean and rinsed sample bottle. This procedure was repeated until approximately 500 ml. of sample was collected.

The phytoplankton counts were made on the day of collection using a Whipple micrometer and Sedgewick-Rafter (Standard Methods, 14th ed. (APHA, 1976) and reported in cells/ml. Chlorophyll a analysis (Appendix B) was modified from a U.S. EPA fluormetric procedure developed by The Division of Water Pollution Control at Westborough, Massachusetts (Kimball, 1979).

Aquatic Macrophyton

The aquatic macrophyton community in Whitman's Pond was located and mapped by slowly examining the entire littoral zone and cove areas. All habitats were generally sampled and the relative abundance of each plant type noted. In deeper water, plant sampling was facilitated by dragging a grappling hook along the substrate. Most of the identification was done in the field except for a few samples that were taken back to the laboratory to examine. In such cases, entire plants were generally taken for analysis, including flowers, fruits, and if present, the roots, rhizomes, or tubers. Identification of the plant specimens were made using a stereoscopic microscope and various taxonomic keys (Fassett, 1972; Hotchkiss, 1972; and Prescott, 1969).

Bottom Sediment Sample

See Table 21 Page 67

Representative sediment samples were collected from Stations 1, 2 and 3, using a standard 23 x 23 cm Ekman dredge (Figure 6). Homogenous samples were placed in separate plastic containers, packed in ice, and transported to the Lawrence Experiment Station for analysis. The following analyses were performed on each sample utilizing the methods described in Standard Methods (APHA, 1976): total Kjeldahl-nitrogen, total phosphorous, arsenic, cadmium, chromium, copper, iron, lead, manganese, nickel, zinc.

SURFACE WATER FLOW MEASUREMENTS

Measurements of surface water flow were taken during the study period and methodology was adapted to the particular situation encountered.

Station #4 - color-velocity method, total of 3 culverts
Station #7 - pygmy meter
Station #9 - color-velocity method through a box culvert
Station #10 - pygmy meter

The color-velicity method entails measuring the velocity of rhodamine dye between 2 points in the channel. This velocity multiplied by the cross-sectional area of the channel gave the discharge.

The pygmy meter was specifically designed for use in shallow water. The meter consists of a cup-type bucket wheel mounted on a vertical shaft. The rotation speed of the bucket varies with the velocity of the flow.

These methodologies were adapted from the following sources: Ohio River Valley Water Sanitation Commission, 1952; U.S.E.P.A., 1973 and U. S. Department of the Interior, 1967.

Sampling Station Description and Location

The following stations were sampled. The location of the in-lake stations are indicated in Fig. 6. Refer to Fig. 7 for the location of tributary sample stations.

In-lake:

1. Maximum depth (6.5m) located in the main basin of the pond.

1A. Deep water station (6.5m) at another deep hole, main basin.

2. Surface water station in the main basin.

3. Surface water station in the center of the southern basin.

4. Old Swamp River inlet station taken from middle culvert under the dirt road.

5. Washington Street culvert connecting southern basin to the main basin.

6. Middle Street culvert connecting western sub-basin with the main basin.

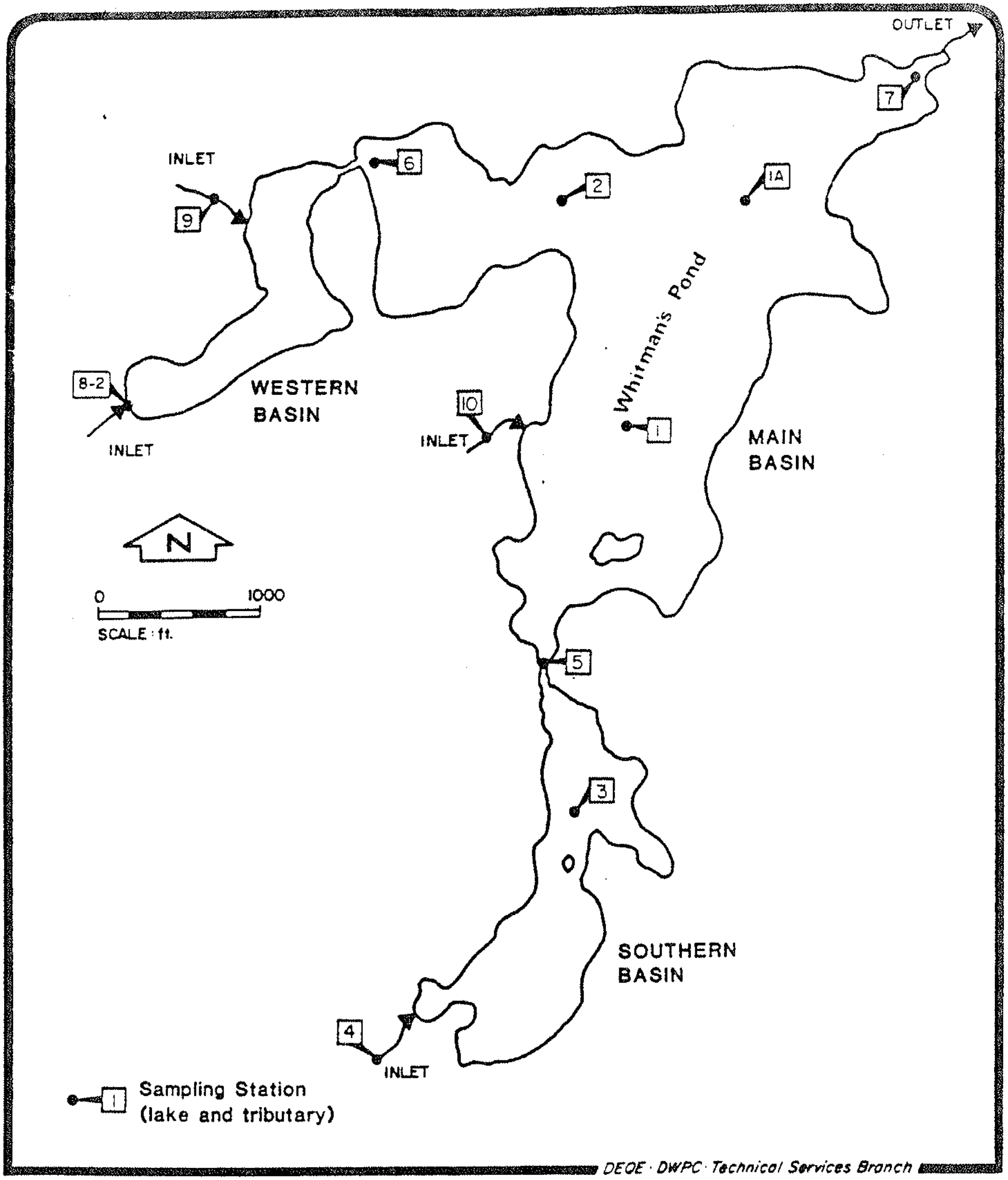
7. Outlet station downstream from fish passage facilities and dam.

8-2. Inlet station taken from a culvert rear of the trailer park (storm drain #49, Figure 8).

9. Culvert upstream of the unnamed tributary in the northwest corner of the western sub-basin located off Greenwood Avenue.

10. Mill River inlet station upstream of confluence with the main basin.

Storm drains around the periphery of Whitman's Pond were also sampled at various times over the study period. Refer to Fig. 8 and Table 3 for locations and descriptions, respectively.



WHITMAN'S POND

Figure 6

SAMPLING STATION LOCATION MAP

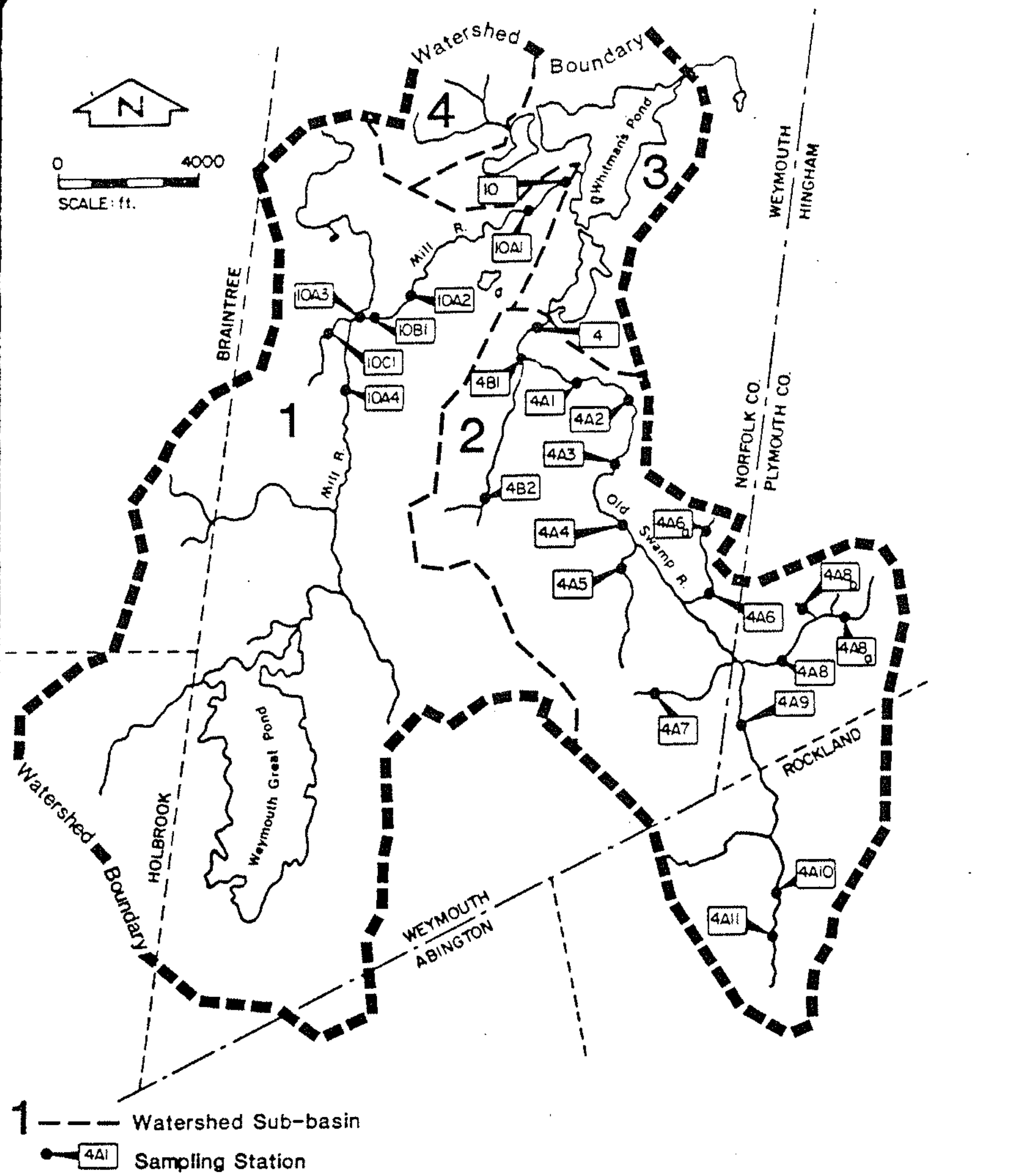


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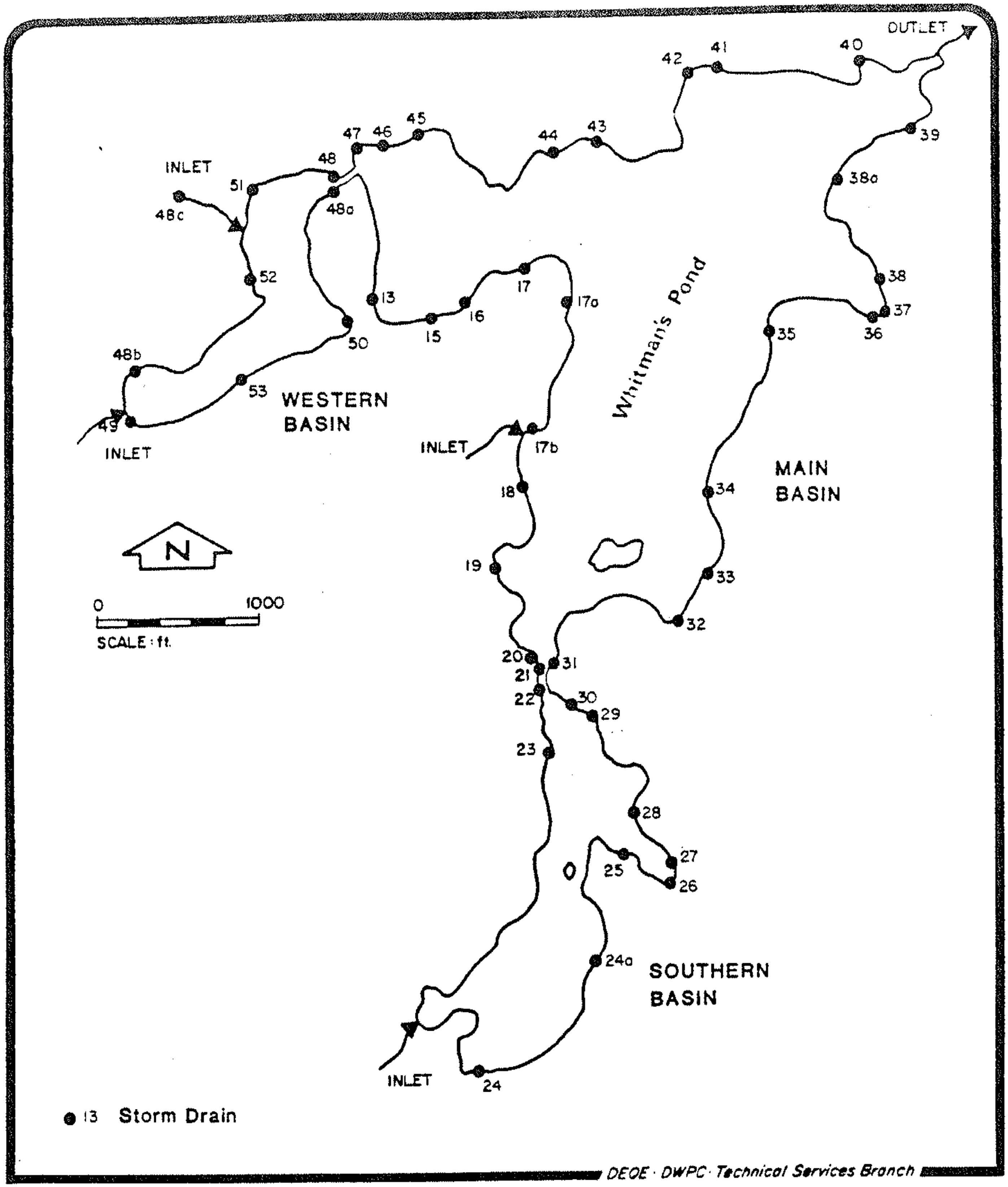
Figure 7 TRIBUTARY SAMPLING STATION LOCATION MAP



WHITMAN'S POND

Figure 8

STORM DRAIN LOCATION MAP

TABLE 3

STORM DRAIN DESCRIPTIONS

The following storm drains empty into the main basin:

NUMBER	TYPE AND SIZE OF PIPE	DRAINAGE AREA
13	12" reinforced concrete	300' of Middle Street, 3 C.B.*, 1-M.H.**
15	12" concrete	600' Lakeshore Drive, SE to Intervale then S. to Glen Road, 5-C.B., 1-M.H.
16	10" concrete	75' of Lakeshore Drive, 1-C.B.
17	8" concrete	150' of Lakeshore Drive, 2-C.B.
17A	Not visible, buried under rock headworks	150' of Lakeshore Drive, 2-C.B.
17B	10" concrete	300' from Lakeshore Drive, 2-C.B.
18	8" concrete with headwork broken up	75' of Lakeview Road, 2-C.B.
19	10" corrugated metal	75' of Seaver Street, 1-C.B.
20	15" concrete in headwork	600' of Route 53 and Lane Avenue and Joan Terrace, 8-C.B., 3-M.H.
21	12" clay in headwork	75' of Route 53, 1-C.B.
31	10" clay	75' of Route 53, 1-C.B.
32	15" concrete	Woodbine Road, 5-C.B.
33	12" concrete	600' from Overlook Road and Oak Cliff 10-C.B., 4-M.H.
34	12" concrete	300' E. across Alpine Road to Birch path, 4-C.B.
35	10" concrete	75' from Alpine Road, 1-C.B.
36	10" concrete	750' S. on Cross Street including Mountain View Road, 11-C.B., 4-M.H.
37	10" concrete	300' on Lamber Avenue, 2-C.B.
38	10" concrete	300' of Lamber Avenue, 3-C.B.

NUMBER	TYPED AND SIZE OF PIPE	DRAINAGE AREA
38A	Unable to locate - buried under riprap	75' of Revere Road, 2-C.B.
39	10" concrete	75' of Revere Road, 2-C.B.
40	12" concrete	750' N. across Lake Street, 8-C.B. Includes Skyview Avenue and Humphrey School parking lot.
41	8" concrete	75' of Lake Street, 2-C.B.
42	12" concrete	450' of Lake Street, 3-C.B.
43	12" clay in concrete headwork	450' E. end of Memorial Drive, 7-C.B.
44	24" clay in concrete headwork	1200' N. across Memorial Drive and Lake Street. Includes Joseph Fern Court and Carroll Street, 20-C.B., 14-M.H.
45	10" concrete	300' of Lake Street, 2-C.B.
46	10" concrete	300' of Castle Road, 2-C.B..
47	10" corrugated metal	Drain Nos. 47, 48, 48A all drain from 2400' of Middle Street, and Essex Street, 13-C.B., 12-M.H.

The following storm drains empty into the west basin:

48	12" concrete	See Drain number 47.
48A	12" concrete	See Drain number 47.
48B	12" concrete	300' of W. Lake Drive, 4-C.B., 4-M.H.
48C		Discharges into stream in the NW corner - not a pond discharge.
49	24" concrete headwork	900' of Rt. 53 and wetland area SW. thereof, rear of trailer park, 12-C.B., 4-M.H.
50	12" concrete	1350' of Middle Street, 9-C.B., 4-M.H.
51	10" concrete	From Greenwood Avenue
52	10" concrete	From S. end of Greenvale Avenue

NUMBER	TYPE AND SIZE OF PIPE	DRAINAGE AREA
53	12" concrete	From Cranch Street

The following storm drains empty into the south basin:

22	6" cast iron	
23	12" concrete with stone and concrete headwork	150' of St. Margaret Street, 3-C.B.
24	4" cast iron	Rear of Quincy Steel operation
24A	10" concrete	From Bridle Path
25	10" concrete	150' of Patterson Beach Avenue, 2-C.B., 1-M.H
26	10" concrete stonework	150' of Patterson Beach Avenue, 1-C.B., 1-M.H
27	12" corrugated metal	200' - Lakehurst Avenue, 2-C.B.
28	8" clay	300' of Lakehurst Avenue, 1-C.B.
29	18" concrete	1500' of Washington Street and 300' of Pine Cliff, 13-C.B., 10-M.H.
30	10" concrete	75' of Washington Street, 1-C.B.

* C.B. = Catch Basin
** M.H. = Manhole

11 out flow 9

2750' of streets - drain into 19 C.B.

19 C.B

Results

Physical Data

Temperature

Temperature profiles for Whitman's Pond were established during the study period (Table 4 , Figure 9). Temperatures varied as much as 13°C with depth as evidenced at Station 1 and 1A from May through October. This is characteristic of stratified lakes and ponds. Stratification during the summer months creates a density difference and prohibits the warmer epilimnion from mixing with the cooler hypolimnion. At or near the time of fall turnover, the water column mixes and the water temperatures become constant. From November 1980 through March 1981, the temperatures were generally constant with depth. The temperature range of this lake system varied from a low of 1°C at Station 9 on February 9, 1981 to a high of 30°C at Station 2 on July 21, 1980.

Transparency

The Secchi disk is a simple test for measuring transparency depth. Factors affecting transparency include the absorption characteristic of the water, its dissolved and suspended matter, the surface and weather conditions, and observer bias. Values at Whitman's Pond ranged from 1.2m to 2.6m (Table 5). According to the Massachusetts Lakes Classification Program (DWPC, 1982), these values indicate a slight problem and are considered to be potentially degrading. Seasonal variations were not discernible from the data. At no time did the values fall below the minimum transparency required for a bathing beach (1.2m) set by the Massachusetts Department of Public Health (Article 7, Regulation 102B of the state Sanitary Code, Commonwealth of Massachusetts, Department of Public Health, 1969).

Flow

The flow data for Whitman's Pond as recorded by the Division can be found in Appendix C. Station #4, the Old Swamp River inlet exhibited the greatest discharge and ranged from $0.0m^3$/sec (0.0 cfs) to $0.769m^3$/sec (27.46 cfs) during the course of the study. The Mill River inlet was dry from June 1980 to November 1980. Flow values that were measured ranged from 0.0^3/sec (0.0 cfs) to $391m^3$/sec (13.97 cfs). An unnamed tributary to the Northwest of Whitman's Pond was also measured for flow. It was dry during most of the study period (June 1980 - February 1981) and the heaviest flow was recorded in April 1980 and measured $0.058m^3$/sec (2.07 cfs). The heaviest flow recorded of all the inlets occurred in April and May of 1980. The outlet (Station #7) flow ranged from $0.0m^3$/sec (0.0 cfs) to $0.521m^3$/sec (18.62 cfs). During September and October of 1980, there was no flow at any of the inlets or the outlet.

Chemical Data

Dissolved Oxygen

Because it is essential to the metabolism of all living aquatic organisms, dissolved oxygen is one of the fundamental parameters of a water quality study.

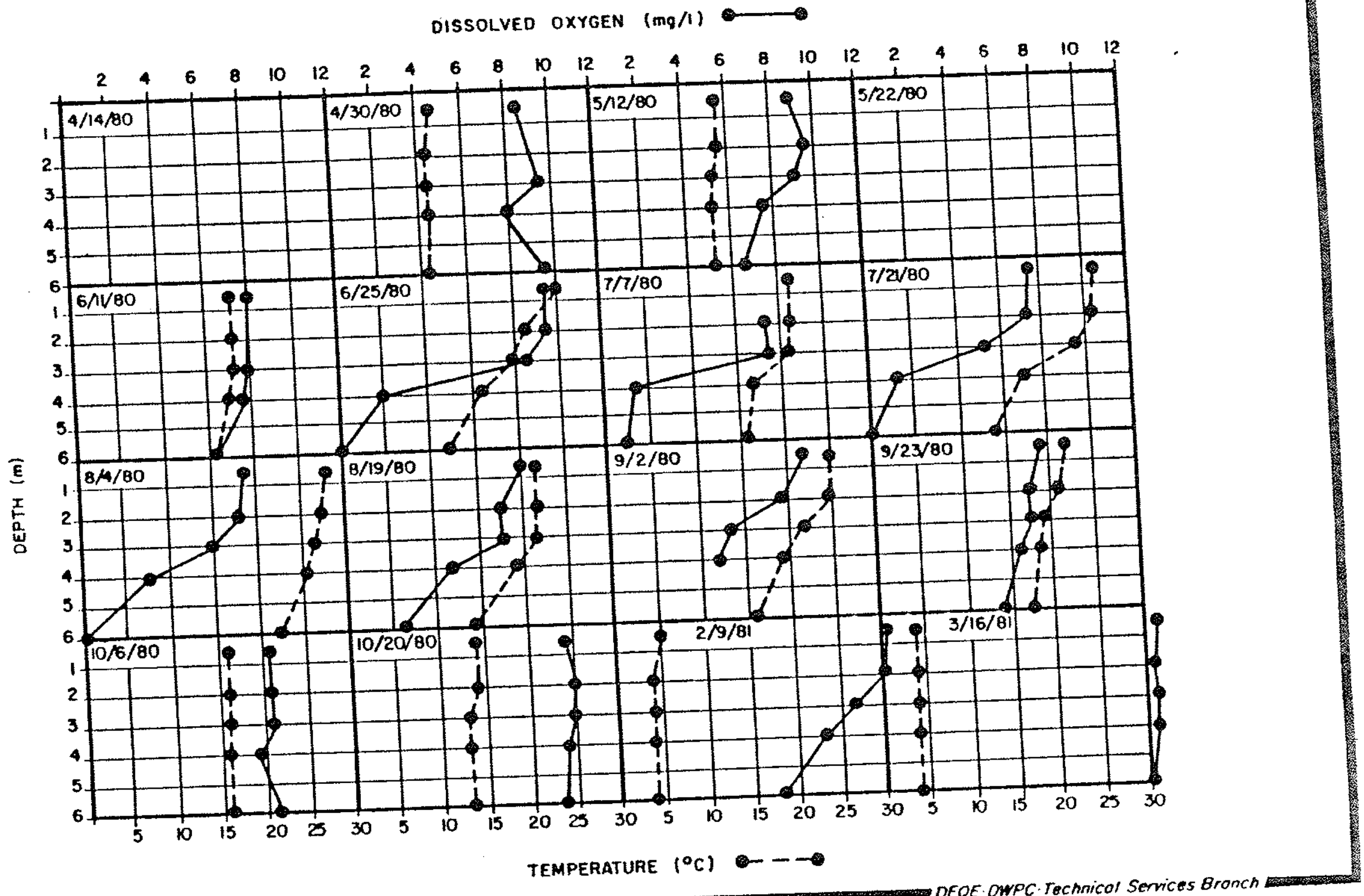
TABLE 4

WHITMAN'S POND

TEMPERATURE (^{o}C)

1980

DATE OF COLLECTION STATION NUMBER	DEPTH	14 Apr	30 Apr	12 May	22 May	11 Jun	25 Jun	7 Jul	21 Jul	4 Aug	19 Aug	2 Sept
1 - Top	(0.5 m)	--	12.0	14.0	--	18.0	25.0	22.7	27.0	28.9	22.0	25.0
	(2 m)	--	11.5	14.0	--	18.0	22.0	22.7	26.5	28.6	22.0	25.0
1 - Middle	(3-3.5 m)	--	11.5	13.5	--	18.0	20.0	22.5	24.0	26.4	22.0	22.5
	(4-5 m)	--	11.5	13.5	--	17.5	16.5	17.8	18.0	25.3	19.0	19.0
1 - Bottom	(5.5-6.5 m)	--	11.0	13.0	--	15.5	13.5	17.2	14.0	23.1	14.5	16.5
1A - Top	(0.5 m)	--	12.0	14.0	--	18.0	24.5	23.3	28.0	28.9	--	--
1A - Middle	(3-4 m)	--	11.5	13.5	--	18.0	21.0	21.1	25.0	26.9	--	--
1A - Bottom	(4.5-6.5 m)	--	11.0	13.0	--	17.5	15.0	15.6	17.5	25.8	--	--
2		--	11.1	13.3	--	16.0	25.0	23.3	30.0	27.8	22.8	25.0
3		--	11.7	13.3	--	18.0	29.5	24.4	28.9	--	21.1	--
4		8.9	11.1	12.5	15.0	13.0	20.0	15.6	--	22.2	18.9	21.7
5		11.1	10.0	13.9	18.0	18.0	27.5	23.9	28.9	27.2	22.2	25.0
6		12.2	12.2	15.0	20.0	11.0	18.9	19.4	28.0	25.6	21.1	25.0
7		10.6	12.8	15.5	19.0	17.0	18.3	20.6	--	--	--	--
8·2		--	--	--	--	--	--	--	--	--	--	--
9		10.6	11.1	15.0	18.0	--	--	16.7	--	--	--	--
10		10.0	11.1	15.5	20.0	16.0	--	23.9	--	--	--	--



WHITMAN'S POND

Figure 9

TEMPERATURE (°C) and DISSOLVED OXYGEN (mg/l) STATION 1

TABLE 4 (CONTINUED)

		1980					1981			
DATE OF COLLECTION		23 Sept	6 Oct	20 Oct	19 Nov	15 Dec	12 Jan	9 Feb	16 Mar	30 Mar
STATION NUMBER	DEPTH									
1 - Top	(0.5 m)	22.5	16.0	14.0	--	--	--	5.0	4.0	7.5
	(2 m)	21.0	16.0	14.0	--	--	--	4.5	4.0	7.0
1 - Middle	(3.5 m)	19.0	16.0	13.5	--	--	--	4.5	4.0	7.0
	(5 m)	19.0	16.0	13.0	--	--	--	4.0	4.0	7.0
1 - Bottom	(5.5-6.5 m)	18.5	16.0	13.0	--	--	--	4.0	4.0	7.0
1A - Top	(0.5 m)	--	--	--	--	--	--	--	--	--
1A - Middle	(3.5 m)	--	--	--	--	--	--	--	--	--
1A - Bottom	(4.5-6.5 m)	--	--	--	--	--	--	--	--	--
2		23.9	13.3	14.4	--	--	--	3.0	5.0	9.0
3		--	--	--	--	--	--	3.0	5.0	11.0
4		20.0	12.2	12.2	3.3	1.7	3.9	0.0	5.0	12.0
5		23.9	13.3	15.6	1.7	3.3	2.2	--	5.0	10.0
6		--	--	--	4.4	3.3	--	3.0	4.0	13.0
7		--	--	--	--	--	--	1.0	5.0	10.5
8-2		--	--	--	--	--	--	--	9.0	9.0
9		--	--	--	--	--	--	1.0	5.0	12.0
10		--	--	--	3.3	--	--	2.0	5.0	13.0

TABLE 5

Results of SECCHI DISK
WHITMAN'S POND

April 1980 - March 1981

DATE	STATION	DEPTH	TIME	WEATHER	WATER COLOR
04/30/80	Sta 3	1.1m	10:30 am	overcast	yellow
	Sta 1	1.8m	N/A	overcast	yellow
	Sta 1A	1.8m	11:45 am	overcast	yellow
05/12/80	Sta 1	1.7m	11:50 am	hazy	orange-brown
05/12/80	Sta 1A	1.6m	11:05 am	hazy	orange-brown
06/11/80	Sta 1	1.9m	N/A	--	orange-red
	Sta 1A	1.6m	N/A	--	orange-red
06/25/80	Sta 3	Weeds to Surface		hazy	
	Sta 1A	1.4m	AM	hazy	red-brown
	Sta 1	2.5m	AM	hazy	red-brown
07/07/80	Sta 1	2.0m	11:10 am	--	yellow
	Sta 1A	2.0m	10:30 am	--	yellow
07/21/80	Sta 1	1.2m	11:00 am	--	brown-green
07/21/80	Sta 1A	1.2m	12:00 noon	--	brown-green
08/04/80	Sta 1	1.6m	12:04 pm	hazy	brown
	Sta 1A	1.2m	12:01 pm	hazy	brown
08/19/80	Sta 1	1.4m	11:08 am	Lt. rain	brown
09/02/80	Sta 1	1.2m	10:45 am	mod. clouds	yellow-brown
09/23/80	Sta 1	1.6m	10:15 am	hazy	brown
10/06/80	Sta 1	2.0m	12:08 pm	dense clouds	brown
10/20/80	Sta 1	2.6m	12:47 pm	mod. clouds	brown-green
02/09/81	Sta 1	--	--	clear	ice cover
03/16/81	Sta 1	2.0m	10:47 am	cloudy	brown
03/30/81	Sta 1	1.6m	11:30 am	hazy	brown-green

The distribution of dissolved oxygen throughout the water column is a basis for understanding the behavior, distribution and physiciogical growth of aquatic life. The sources of dissolved oxygen within a lake system include the process of photosynthesis and as the result of diffusion from the atmosphere, coupled with hydromechanical mixing. Both are counter balanced by consumptive processes such as respiration and decomposition, which exert biological and chemical oxygen demand on the system. The rate of oxygen synthesis relative to utilization is a standard parameter for evaluating the productivity of a lake system as a whole (Wetzel, 1975).

The dissolved oxygen profiles are presented in conjunction with the temperature data in Figure 9 and Table 6. The surface water (0-2m) dissolved oxygen values ranged from 7.0 mg/l to 12.2 mg/l. The percentage of saturation is a value used to describe the ratio between the observed dissolved oxygen and the saturated dissolved oxygen value. The saturated dissolved oxygen value is a constant based on the observed temperature. Epilimnetic saturation values ranged from 80-90%. Hypolimnetic (5.5-6.5m) dissolved oxygen values ranged from 0.0 to 12.3 mg/l and saturation values varied from 0-93%. The broad range of hypolimnetic values can be attributed to the stratification of the pond and high oxygen demand in summer coupled with little or no activity during the colder months. The diffusion of oxygen from the overlying water is very slow due to the stratification in summer. Whitman's Pond did exhibit a hypolimnetic anoxic period from June-August (1980) which may be partially attributed to bacterial respiration in decomposition of the sediment. When unstratified conditions returned in October, the observed dissolved oxygen was equally consistent throughout the water column. Generally, the dissolved oxygen values in the water column followed seasonal variations, that is, warmer water contained less dissolved oxygen than colder winter water.

pH

The pH of Whitman's Pond ranged from 5.6 (logarithmic units) on February 9, 1981 Station 3 to 7.8 on March 16, 1981 Station 8-2 (Table 7). The range in pH of a majority of open lakes is between 6 and 9, but may extend between the extremes of 2 and 12 (Wetzel, 1975). The inlet stations exhibited a pH range that fell within the range of in-lake stations. Seasonal variations were expressed. That is, higher values (6.9-7.4) occurred more frequently in the warmer months. These higher values can be partially attributed to a decrease in the concentration of CO_2 (Wetzel, 1975). The photosynthetic process causes a decrease in the concentration of CO_2 which would be at a peak during the warmer months.

The pH of storm drain sampling ranged from 5.9 to 7.8 (Table 8). This range exemplifies the variety of storm drain locations and their respective sources. All storm drain sampling was done in the winter so no seasonal variation could be determined.

Tributary investigative surveys demonstrated a pH range of between 6.1 and 7.3 (Table 9). Seasonal variations were expressed here also, that is, lower pH values occurred in the colder months. Both storm drain and tributary pH ranges were within the range exhibited by the pond proper.

TABLE 6

WHITMAN'S POND

DISSOLVED OXYGEN (mg/1)

DATE OF COLLECTION		14 Apr 1980	30 Apr	12 May	22 May	11 Jun	25 Jun	7 Jul	21 Jul	4 Aug	19 Aug	2 Sept
STATION NUMBER	DEPTH											
1 - Top	(0.5 m)	--	8.5	9.0	--	8.0	9.6	--	7.8	7.6	8.0	8.8
	(2m)	--	--	9.7	--	--	9.2	7.6	7.6	7.3	7.0	7.9
1 - Middle	(3-3.5 m)	--	9.5	9.0	--	7.8	8.2	7.6	5.1	6.0	7.0	5.7
	(4.5-5.0 m)	--	8.0	7.8	--	7.6	2.0	1.6	1.3	3.1	4.4	4.7
1 - Bottom	(5.5-6.5 m)	--	9.6	6.5	--	6.2	0.0	1.0	0.0	0.0	2.6	--
1A - Top	(0.5 m)	--	6.6	9.8	--	8.4	8.2	7.5	7.5	7.7	--	--
1A - Middle	(3.0-4.0 m)	--	11.4	9.2	--	--	9.2	6.9	6.4	6.5	--	--
1A - Bottom	(4.5-6.5 m)	--	9.7	9.0	--	8.0	1.1	0.0	1.5	2.4	--	--
2		--	6.8	9.0	--	8.3	9.1	8.1	8.8	7.0	7.6	8.3
3		--	9.3	9.6	--	8.9	7.9	8.6	6.5	--	6.5	--
4		9.8	10.5	--	10.5	10.0	6.5	7.2	6.1	5.7	8.8	8.2
5		9.5	10.1	--	8.1	8.8	8.9	8.0	7.7	7.2	5.1	8.3
6		9.3	9.4	--	8.1	7.6	4.3	3.0	3.8	--	3.9	5.2
7		10.4	10.9	--	8.6	9.4	7.7	8.0	7.2	--	--	--
8-2		--	--	--	--	--	--	--	--	--	--	--
9		6.3	4.0	--	1.4	--	--	1.0	--	--	--	--
10		9.2	10.0	--	8.6	7.0	--	7.5	--	--	--	--

TABLE 6 (CONTINUED)

DATE OF COLLECTION		1980					1981			
		23 Sept	6 Oct	20 Oct	19 Nov	15 Dec	12 Jan	9 Feb	16 Mar	30 Mar
STATION NUMBER	DEPTH									
1 - Top	(0.5 m)	7.9	8.2	9.9	--	--	--	12.2	12.3	12.1
	(2.0 m)	7.3	8.2	10.0	--	--	--	12.1	12.2	12.0
1 - Middle	(3.0-3.5 m)	7.4	8.2	10.0	--	--	--	10.6	12.3	12.0
	(4.0-5.0 m)	6.4	7.9	9.6	--	--	--	9.3	12.3	--
1 - Bottom	(5.5-6.5 m)	5.9	8.2	9.2	--	--	--	7.3	12.2	12.1
1A - Top	(0.5 m)	--	--	--	--	--	--	--	--	--
1A - Middle	(3.0-4.0 m)	--	--	--	--	--	--	--	--	--
1A - Bottom	(4.5-6.5 m)	--	--	--	--	--	--	--	--	--
2		7.4	8.2	9.8	--	--	--	12.8	12.4	--
3		--	--	--	--	--	--	11.2	12.1	--
4		7.5	7.4	6.4	--	--	--	--	--	--
5		6.5	8.3	9.3	--	--	--	--	--	--
6		--	--	--	--	--	--	--	--	--
7		--	--	--	--	--	--	--	--	--
8-2		--	--	--	--	--	--	--	--	--
9		--	--	--	--	--	--	--	--	--
10		--	--	--	--	--	--	--	--	--

TABLE 7

WHITMAN'S POND

pH (Logarithmic Units)

1980

DATE OF COLLECTION STATION NUMBER	DEPTH	14 Apr	30 Apr	12 May	22 May	11 Jun	25 Jun	7 Jul	21 Jul	4 Aug	19 Aug	2 Sept
1 - Top	(0.5 m)	--	6.9	7.2	--	7.2	7.4	7.1	7.0	6.8	6.5	7.0
	(2 m)	--	--	--	--	--	7.1	--	7.1	6.5	6.9	7.0
1 - Middle	(3-3.5 m)	--	--	7.1	--	7.2	7.4	7.4	7.1	6.7	7.0	6.8
	(4-5 m)	--	--	--	--	7.3	6.9	7.0	7.2	6.8	7.6	6.6
1 - Bottom	(5.5-6.5 m)	--	6.2	6.8	--	7.2	6.9	7.1	7.4	6.7	7.2	--
1A - Top	(0.5 m)	--	7.0	7.1	--	7.2	7.1	7.2	7.3	7.0	--	--
1A - Middle	(3-4 m)	--	7.0	--	--	--	7.1	7.5	7.1	--	--	--
1A - Bottom	(4.5-6.5 m)	--	7.0	7.1	--	7.5	7.2	7.0	7.3	6.7	--	--
2		--	7.0	7.2	--	7.2	7.3	7.3	7.2	6.9	7.4	7.0
3		--	6.9	7.1	--	7.2	7.4	7.4	7.3	--	7.1	--
4		6.8	6.6	7.0	7.2	7.1	7.3	7.1	6.8	6.6	7.5	6.8
5		6.7	6.9	7.1	7.3	7.3	7.3	7.2	7.4	7.0	7.1	7.0
6		6.9	7.3	7.5	7.3	7.5	7.3	7.2	7.1	6.9	7.0	7.0
7		7.0	7.2	7.2	7.3	7.4	7.4	7.2	7.4	--	--	--
8-2		--	--	--	--	--	--	--	--	--	--	--
9		6.3	6.3	6.7	7.2	--	--	6.7	--	--	--	6.4
10		6.6	6.9	7.1	7.5	7.3	--	7.1	--	--	--	--

TABLE 7 (CONTINUED)

DATE OF COLLECTION		1980					1981			
STATION NUMBER	DEPTH	23 Sept	6 Oct	20 Oct	19 Nov	15 Dec	12 Jan	9 Feb	16 Mar	30 Mar
1 - Top	(0.5 m)	6.9	6.9	6.7	--	--	--	6.3	6.3	6.4
	(2 m)	7.0	6.9	6.8	--	--	--	6.7	6.4	6.6
1 - Middle	(3-3.5 m)	7.0	7.0	6.9	--	--	--	6.7	6.6	6.6
	(4-5 m)	6.9	7.0	6.9	--	--	--	6.5	6.9	6.6
1 - Bottom	(5.5-6.5 m)	6.9	7.0	7.0	--	--	--	6.7	6.9	6.6
1A - Top	(0.5 m)	--	--	--	--	--	--	--	--	--
1A - Middle	((3-4 m)	--	--	--	--	--	--	--	--	--
1A - Bottom	(4.5-6.5 M)	--	--	--	--	--	--	--	--	--
2		7.1	7.3	7.1	--	--	--	6.5	6.8	6.7
3		--	--	--	--	--	--	5.6	6.7	6.6
4		6.8	6.8	6.8	6.5	5.7	6.6	5.6	7.0	6.5
5		7.3	7.3	7.2	6.5	5.9	--	--	6.9	6.6
6		--	--	--	6.9	5.9	--	7.1	6.8	6.9
7		--	--	--	--	--	--	6.4	6.6	6.7
8-2		--	--	--	--	--	--	--	7.8	6.7
9		--	--	--	--	--	--	6.2	6.5	6.3
10		--	--	--	6.7	--	--	6.5	6.9	6.6

TABLE 8

WHITMAN'S POND

STORM DRAIN SAMPLING

(Results in mg/l)

	11 February 1981									16 March 1981	
DRAIN NUMBER	13	20	29	33	34	36	37	42	49	44	49
PARAMETER											
pH (Standard Units)	6.6	6.6	6.8	6.1	5.9	5.9	6.2	6.5	6.4	6.8	7.8
Total Alkalinity	8	12	20	12	5	10	12	11	42	20	24
Total Hardness	28	35	35	19	37	36	33	26	82	58	--
Conductivity (umhos/cm)	400	1,000	1,350	170	155	230	225	610	510	225	660
Suspended Solids	556	194	135	574	5	97	73	63	20	1	6
Total Solids	838	844	974	798	144	268	292	488	270	136	--
Total Kjeldahl-Nitrogen	3.10	2.70	3.70	3.90	1.10	2.70	3.10	2.90	1.30	0.38	1.00
Ammonia-Nitrogen	0.36	0.39	0.43	0.46	0.38	0.37	0.48	0.27	0.50	0.07	0.73
Nitrate-Nitrogen	0.8	0.5	0.6	1.2	1.9	0.5	0.8	0.8	0.8	3.9	1.8
Total Phosphorus	0.82	0.60	0.65	1.2	0.12	0.57	0.55	0.40	0.07	0.05	0.04
Chloride	110	310	415	40	18	42	46	165	125	22	69
Manganese	3.50	0.33	0.54	0.28	0.08	0.23	0.46	0.25	1.30	0.08	--
Iron	1.20	0.50	0.47	0.86	0.10	0.22	0.21	0.59	5.60	0.01	--
Total Coliform (#/100 ml)	730	4,600	4,600	75,000	430	4,600	930	24,000	91	1,400	40
Fecal Coliform (#/100 ml)	<36	230	430	24,000	36	430	230	11,000	36	160	<5
Fecal Streptococcus (#/100 ml)	10,000	8,000	28,000	67,000	3,600	40,000	112,000	14,000	100	--	--

TABLE 9

WHITMAN'S POND

TRIBUTARY INVESTIGATIVE SURVEYS

(Results in mg/1)

DATE OF COLLECTION:	4 August 1980		19 August 1980		2 September 1980		6 October 1980	
STATION NUMBER:	4A2	4B2	4A2	4B2	4A2	4B2	4A2	4B2
PARAMETER								
pH (Standard Units)	7.3	7.0	7.2	7.3	6.9	6.8	6.9	7.0
Total Alkalinity	21	25	27	18	27	29	15	32
Total Hardness	45	72	49	33	50	77	--	--
Conductivity (umhos/cm)	190	360	210	130	210	380	235	370
Suspended Solids	0.0	1.0	4.0	3.0	0.5	8.0	0.5	0.5
Total Solids	88	162	156	116	126	232	--	--
Total Kjeldahl-Nitrogen	0.44	0.18	0.24	0.57	0.56	0.69	0.58	0.69
Ammonia-Nitrogen	0.02	0.07	0.01	0.01	0.08	0.06	0.02	0.03
Nitrate-Nitrogen	0.4	1.8	0.7	0.9	0.0	0.1	0.8	1.5
Total Phosphorus	0.06	0.04	0.03	0.01	0.03	0.04	0.06	0.06
Chloride	30	67	33	17	32	72	32	71
Iron	0.15	0.17	0.07	0.21	0.05	0.38	--	--
Manganese	0.03	0.24	0.02	0.05	0.02	0.10	--	--
Total Coliform (#/100 ml)	4,000	3,000	1,300	19,000	1,100	160	1,100	1,200
Fecal Coliform (#/100 ml)	350	150	230	2,000	20	30	190	100
Fecal Streptococcus (#/100 ml)	--	--	--	--	30	10	--	--

TABLE 9 (CONTINUED)

DATE OF COLLECTION:	19 November 1980			2 December 1980							
STATION NUMBER:	4A2	4A3	4B2	4A1	4A4	4A5	4A6	4A8	4A9	4A10	4A11
PARAMETER											
pH (Standard Units)	6.3	6.0	6.5	6.1	6.2	6.5	6.6	6.6	6.1	6.7	6.3
Total Alkalinity	8	7	26	18	8	21	26	28	9	20	18
Total Hardness	--	--	--	86	84	89	86	86	86	86	86
Conductivity (µmhos/cm)	240	240	330	140	230	200	390	240	230	370	340
Suspended Solids	3.0	1.0	0	0	1	0	2	3	0	0	0
Total Solids	--	--	--	--	--	--	--	--	--	--	--
Total Kjeldahl-Nitrogen	0.59	0.53	0.70	0.50	0.59	0.45	0.92	0.92	0.51	0.51	0.44
Ammonia-Nitrogen	0.01	0.02	0.02	0.06	0.07	0.02	0.64	0.29	0.02	0.09	0.08
Nitrate-Nitrogen	0.5	0.4	0.0	0.6	0.4	0.0	1.6	0.4	0.0	2.9	1.9
Total Phosphorus	0.03	0.03	0.03	0.05	0.06	0.05	0.04	0.15	0.04	0.07	0.03
Chloride	30	29	52	19	30	27	65	30	72	60	61
Iron	--	--	--	--	--	--	--	--	--	--	--
Manganese	--	--	--	--	--	--	--	--	--	--	--
Total Coliform (#/100 m)	420	360	5,000	80	130	100	20	420	60	400	250
Fecal Coliform (#/100 ml)	30	50	120	5	5	<5	<5	<5	<5	50	30
Fecal Streptococcus (#/100 ml)	--	--	--	--	--	--	--	--	--	--	--

TABLE 9 (CONTINUED)

DATE OF COLLECTION:	14 April 1981					22 April 1981					
STATION NUMBER:	10A1	10A2	10A3	10A4	10B1	4A6	4A6a	4A8a	4A8b	4B1	4B2
PARAMETER											
pH (Standard Units)	6.2	6.5	6.5	6.3	6.6	7.2	6.8	6.9	7.1	7.0	6.8
Total Alkalinity	15	14	13	14	10	29	19	17	19	14	29
Total Hardness	47	47	44	45	35	78	72	51	63	56	94
Conductivity (µmhos/cm)	230	210	200	210	260	530	600	325	310	300	570
Suspended Solids	5	2	0	1	1	0	7	1	0	0	0
Total Solids	160	142	136	148	160	332	374	200	194	168	348
Total Kjeldahl-Nitrogen	0.65	0.32	0.38	0.42	0.46	0.89	1.00	0.28	1.70	0.17	0.31
Ammonia-Nitrogen	0.17	0.02	0.07	0.01	0.38	0.63	1.00	0.09	1.60	0.14	0.11
Nitrate-Nitrogen	0.3	0.6	0.5	0.4	0.2	1.9	2.7	0.4	1.0	0.7	3.1
Total Phosphorus	0.06	0.03	0.03	0.04	0.06	0.14	0.13	0.09	0.03	0.04	0.21
Chloride	43	38	33	35	56	110	140	68	52	56	100
Iron	--	--	--	--	--	--	--	--	--	--	--
Manganese	--	--	--	--	--	--	--	--	--	--	--
Total Coliform (#/100 ml)	40	440	30	80	600	295	615	5	5	30	185
Fecal Coliform (#/100 ml)	10	140	<5	<5	120	40	70	<5	<5	5	20
Fecal Streptococcus (#/100 ml)	<5	<5	<5	<5	<5	5	5	<5	<5	<5	20

Total Alkalinity

Total alkalinity refers to the kinds of compounds present in natural waters that shift the pH towards the alkaline side of neutrality. It can also be a means of determining the buffer capacity of a particular lake or pond. Buffer capacity refers to the ability of a lake or pond to respond to acidic input, such as acid rain. The more alkaline a system is, the better its buffering ability. The Massachusetts Division of Fisheries and Wildlife has developed the following criteria to assess a pond's vulnerability to the effects of acid deposition:

Vulnerable	-	6-10 mg/l
Endangered	-	3-5 mg/l
Critical	-	<2 mg/l

The total alkalinity range for Whitman's Pond was from 8.0 mg/l on March 16, 1981 (Stations 1, 2, 3, 5) to 80 mg/l on February 9, 1981, Station 6 (Table 10). All total alkalinity values were high on February 9, 1981 with respect to observed values on other sampling days. This phenomenon is most likely due to road de-icing operations that were conducted on or prior to February 9, 1981. Inlet stations values were within the range of in-lake stations values except on two occasions where the value was 7 mg/l (Table 10).

Storm drain and tributary total alkalinity values were in the same range as that of the in-lake measurements (Table 8 and Table 9). Only on one occasion, February 11, 1981, storm drain #34 was the observed reading (5.0 mg/l) outside of this range. This value is on the border between endangered and vulnerable values according to Massachusetts Fish and Wildlife Division. The effects of this value were not manifested in the pond as evidenced by values observed at a later date on February 16, 1981 (Table 10).

Total Hardness

The hardness of a water supply is a quantitative term used to describe the concentration of calcium and magnesium salts combined with other ions (Wetzel, 1975). Hardness values reported as mg/l of $CaCO_3$ are an expression of the calcium hardness. The difference between total and calcium hardness is magnesium hardness.

Total hardness values observed at Whitman's Pond are presented in Table 11. They are reported as mg/l of $CaCO_3$ because of the methodology but actually represent the total hardness. In-lake values range from 27 mg/l on April 30, 1980 Station 3 to one extreme measurement of 107 mg/l on March 30, 1981, Station 8-2. An average value of 37.8 mg/l was determined by averaging all in-lake values. According to Sawyer (1960) this value characterizes the pond as a soft water system. Soft waters refers to waters derived from the drainage of acidic igneous rock which is included in the types of bedrock surrounding Whitman's Pond.

Storm drain and tributary hardness values were generally within the range of 27-107 mg/l, exhibited by the pond proper (Tables 8 and 9). Tributary seasonal variations were expressed, that is, higher values were evident during the winter months, which may be a result of road salting operations discussed earlier.

TABLE 10

WHITMAN'S POND

TOTAL ALKALINITY (mg/1 as $CaCO_3$)

1980

DATE OF COLLECTION		14 Apr	30 Apr	11 Jun	25 Jun	21 Jul	4 Aug	19 Aug	2 Sept
STATION NUMBER	DEPTH								
1 - Top	(0.5 m)	--	13	18	--	18	16	22	19
	(2 m)	--	--	--	14	18	15	16	18
1 - Middle	(3-3.5 m)	--	--	19	19	19	18	19	19
	(4-5 m)	--	--	23	17	27	24	26	22
1 - Bottom	(5.5-6.5 m)	--	16	17	26	34	37	32	--
1A - Top	(0.5 m)	--	12	15	15	20	18	--	--
1A - Middle	(3-4 m)	--	13	--	16	18	--	--	--
1A - Bottom	(4.5-6.5 m)	--	12	12	16	35	22	--	--
2		--	12	16	18	19	18	18	19
3		--	12	15	20	26	--	22	--
4		11	9	16	21	26	21	21	27
5		10	13	20	19	19	17	16	19
6		18	23	26	20	33	35	15	32
7		11	12	14	16	27	--	--	--
8-2		--	--	--	--	--	--	--	--
9		10	8	--	--	--	--	--	46
10		13	14	20	--	--	--	--	--

TABLE 10 (CONTINUED)

DATE OF COLLECTION		1980 23 Sept	6 Oct	20 Oct	19 Nov	15 Dec	1981 12 Jan	9 Feb	16 Mar	30 Mar
STATION NUMBER	DEPTH									
1 - Top	(0.5 m)	21	19	18	--	--	--	19	8	10
	(2 m)	21	19	18	--	--	--	22	8	9
1 - Middle	(3-3.5 m)	24	19	19	--	--	--	23	9	9
	(4-5 m)	21	20	19	--	--	--	20	8	9
1 - Bottom	(5.5-6.5 m)	21	19	19	--	--	--	20	8	9
1A - Top	(0.5 m)	--	--	--	--	--	--	--	--	--
1A - Middle	(3-4 m)	--	--	--	--	--	--	--	--	--
1A - Bottom	(4.5-6.5 m)	--	--	--	--	--	--	--	--	--
2		21	19	19	--	--	--	15	8	9
3		--	--	--	--	--	--	26	8	10
4		28	15	24	7	11	20	37	8	9
5		23	19	19	13	13	--	--	8	10
6		--	--	--	51	28	--	80	15	19
7		--	--	--	--	--	--	69	9	10
8-2		--	--	--	--	--	--	--	24	48
9		--	--	--	--	--	--	35	7	18
10		--	--	--	14	--	--	32	8	11

TABLE 11

WHITMAN'S POND

TOTAL HARDNESS (mg/1 as $CaCO_3$)

DATE OF COLLECTION		1980					1981	
STATION NUMBER	DEPTH	14 Apr	30 Apr	11 Jun	19 Aug	2 Sept	9 Feb	30 Mar
1 - Top	(0.5 m)	--	30	30	34	35	36	38
	(2 m)	--	--	--	34	33	36	32
1 - Middle	(3-3.5 m)	--	--	30	35	33	29	38
	(4.5-5 m)	--	--	30	36	33	39	38
1 - Bottom	(6-6.5 m)	--	31	29	39	--	37	37
1A - Top	(0.5 m)	--	31	29	--	--	--	--
1A - Middle	(3 m)	--	30	--	--	--	--	--
1A - Bottom	(6 m)	--	31	31	--	--	--	--
2		--	30	29	33	29	31	38
3		--	27	34	41	--	38	44
4		29	26	36	48	50	34	44
5		27	32	33	34	32	--	42
6		36	41	41	41	45	60	63
7		27	30	33	--	--	56	41
8-2		--	--	--	--	--	--	107
9		34	29	--	--	--	52	65
10		29	26	41	--	63	58	52

Phosphorous

Phosphorous is one of the essential elements necessary for plant metabolism. In relation to other elements of the biosphere, it is the least abundant and so most commonly limits biological productivity in ecosystems. Sources in lakes and pond vary from naturally occurring, such as from rocks, soils and organic decomposition to being introduced to the environment culturally.

Total phosphorous values for Whitman's Pond are presented in Table 12. Surface values of in-lake stations range from 0.01 mg/l at Station 2 on July 7, 1980 to 0.11 mg/l on August 4, 1980 at Station 6. This wide range includes values expected from oligotrophic to eutrophic ponds according to the Massachusetts Lake Classification Program, 1982. Variations with depth were expressed at Stations 1 and 1A, however, no pattern was discernible. Inlet station values exceeded the upper range of the pond (0.11 mg/l) on two occasions; Station 4 on June 11, 1980 was 0.14 mg/l and Station 9 on May 22, 1980 was 0.13 mg/l. These values may be attributed to the wet weather conditions which increase flows and associated nutrients.

Stormwater values were excessive; the range includes values from 0.04 mg/l on March 16, 1981 to 1.2 mg/l on February 11, 1981 compared to the U. S. EPA criteria (0.05 mg/l) for streams entering a lake. Tributary sample values range from 0.01 mg/l at Station 4B2 on August 19, 1980 to 0.21 mg/l at the same station on April 22, 1981. Higher values are expessed in the spring, which may be attributed to wet weather conditions. Both storm drains and tributaries demonstrate a wider range of values than the pond proper and may indicate a cultural source of influent phosphorous.

Specific Conductance

The specific conductance of a water body is a measure of the quantity of various ions that may be present. Conductivity values increase with a corresponding increase in the concentration of ions and is temperature dependent. In general, conductivity is increased 2.5% for every $1^{o}C$ increase (Wetzel, 1975).

In-lake station conductivity values range from 140 µmhos/cm at Station 5 on April 14, 1980 to 380 µmhos/cm at Station 6 on March 30, 1981 (Table 13). Inlet station ranges were 117 µmhos/cm at Station 9 on April 30, 1980 to 600 µmhos/cm at Station 8-2 on March 16, 1981.

Conductivity values increased with warmer temperatures. Higher temperatures increase ionic velocities which in turn increase conductivity values. The highest conductivity values were recorded in early spring (March 16 and 30, 1981). These spring time high values corresponded accordingly with high chloride readings (Table 14) observed at the same time which are probably a result of road and pavement salting operations that caused an increase in ion concentrations.

Stormwater values exceeded those of the pond with a range of 155-1350 µmhos/cm (Table 8). These values likely represent the effects of road salting since sampling was conducted only in February - March, 1981 and storm drains are a direct source of road runoff.

Tributary investigations shows a conductivity range of 130-600 µmhos/cm (Table 9) and fall within the range of the lake and inlet values. Highest

TABLE 12

WHITMAN'S POND

TOTAL PHOSPHORUS (mg/1)

1980

DATE OF COLLECTION		14 Apr	30 Apr	12 May	22 May	11 Jun	25 Jun	7 Jul	21 Jul	4 Aug	19 Aug	2 Sept
STATION NUMBER	DEPTH											
1 - Top	(0.5 m)	--	0.07	0.02	--	0.05	0.05	0.04	0.07	0.06	0.04	0.04
	(2 m)	--	--	--	--	--	0.11	--	0.08	0.05	0.03	0.04
1 - Middle	(3-3.5 m)	--	--	0.03	--	0.45	0.08	0.02	0.04	0.03	0.02	0.04
	(4-5 m)	--	--	--	--	0.11	0.05	0.03	0.04	0.02	0.03	0.02
1 - Bottom	(5.5-6.5 m)	--	0.04	0.01	--	0.10	0.04	0.04	0.04	0.03	0.05	--
1A - Top	(0.5 m)	--	0.08	0.06	--	0.09	0.05	0.03	0.03	0.02	--	--
1A - Middle	(3-4 m)	--	0.11	--	--	--	0.05	0.03	0.02	--	--	--
1A - Bottom	(4.5-6.5 m)	--	0.04	0.04	--	0.09	0.06	0.05	0.01	0.03	--	--
2		--	0.04	0.03	--	0.09	0.03	0.01	0.07	0.05	0.03	0.03
3		--	0.03	0.04	--	0.07	0.03	0.06	0.03	--	0.03	--
4		0.04	0.03	0.03	0.05	0.14	0.05	0.08	0.04	0.05	0.02	0.03
5		0.05	0.03	0.03	0.06	0.09	0.06	0.03	0.04	0.05	0.01	0.03
6		0.05	0.07	0.05	0.07	0.09	0.07	0.1	0.06	0.11	0.08	0.06
7		0.05	0.02	0.05	0.04	0.08	0.05	0.04	0.02	--	--	--
8-2		--	--	--	--	--	--	--	--	--	--	--
9		0.04	0.04	0.04	0.13	--	--	0.5	--	--	--	0.07
10		0.03	0.05	0.06	0.06	0.07	--	0.1	--	--	--	--

TABLE 12 (CONTINUED)

DATE OF COLLECTION		1980					1981			
STATION NUMBER	DEPTH	23 Sept	6 Oct	20 Oct	19 Nov	15 Dec	12 Jan	9 Feb	16 Mar	30 Mar
1 - Top	(0.5 m)	0.03	0.03	0.05	--	--	--	0.07	0.07	0.06
	(2 m)	0.03	0.05	0.05	--	--	--	0.07	0.09	0.05
1 - Middle	(3-3.5 m)	0.03	0.05	0.04	--	--	--	0.08	0.07	0.05
	(4-5 m)	0.03	0.05	0.04	--	--	--	0.09	0.04	0.05
1 - Bottom	(5.5-6.5 m)	0.06	0.04	0.03	--	--	--	0.10	0.05	0.04
1A - Top	(0.5 m)	--	--	--	--	--	--	--	--	--
1A - Middle	(3-4 m)	--	--	--	--	--	--	--	--	--
1A - Bottom	(4.5-6.5 m)	--	--	--	--	--	--	--	--	--
2		0.03	0.05	0.05	--	--	--	0.09	0.05	0.05
3		--	--	--	--	--	--	0.11	0.05	0.06
4		0.04	0.06	0.03	0.02	0.08	0.04	0.07	0.05	0.07
5		0.03	0.05	0.04	0.02	0.08	--	--	0.06	0.08
6		--	--	--	0.01	0.05	--	0.10	0.05	0.09
7		--	--	--	--	--	--	0.09	0.04	0.06
8-2		--	--	--	--	--	--	--	0.04	0.03
9		--	--	--	--	--	--	0.08	0.04	0.05
10		--	--	--	0.01	--	--	0.06	0.03	0.03

TABLE 13

WHITMAN'S POND

SPECIFIC CONDUCTANCE (µmhos/cm)

1980

DATE OF COLLECTION STATION NUMBER	DEPTH	14 Apr	30 Apr	11 Jun	25 Jun	7 Jul	21 Jul	4 Aug	19 Aug	2 Sept
1 - Top	(0.5 m)	--	153	190	170	167	180	170	170	180
	(2 m)	--	--	--	170	--	170	170	170	170
1 - Middle		--	--	190	160	170	170	165	170	170
	(4-5 m)	--	--	190	170	173	170	180	170	170
1 - Bottom	(5.5-6.5 m)	--	156	190	170	180	175	180	180	--
1A - Top	(0.5 m)	--	157	180	170	174	170	170	--	--
1A - Middle	(3-4 m)	--	161	--	170	175	180	--	--	--
1A - Bottom	(4.5-6.5 m)	--	156	190	170	177	180	170	--	--
2		--	155	180	180	174	180	170	170	170
3		--	148	190	200	177	180	--	180	--
4		165	141	210	170	210	220	--	220	240
5		140	160	200	170	165	170	170	170	170
6		190	220	240	240	212	250	225	210	250
7		150	160	180	180	191	210	--	--	--
8-2		--	--	--	--	--	--	--	--	--
9		170	117	--	--	176	--	--	--	
10		150	130	200	--	272	--	--	--	250

TABLE 13 (CONTINUED)

DATE OF COLLECTION		1980					1981			
		23 Sept	6 Oct	20 Oct	19 Nov	15 Dec	12 Jan	9 Feb	16 Mar	30 Mar
STATION NUMBER	DEPTH									
1 - Top	(0.5 m)	170	190	175	--	--	--	185	195	215
	(2 m)	180	190	175	--	--	--	185	195	215
1 - Middle	(3-3.5 m)	170	185	175	--	--	--	200	195	215
	(4-5 m)	175	185	165	--	--	--	210	195	215
1 - Bottom	(5.5-6,5 m)	170	185	175	--	--	--	260	195	210
1A - Top	(0.5 m)	--	--	--	--	--	--	--	--	--
1A - Middle	(3-4 m)	--	--	--	--	--	--	--	--	--
1A - Bottom	(4.5-6.5 m)	--	--	--	--	--	--	--	--	--
2		180	190	170	--	--	--	160	195	215
3		--	--	--	--	--	--	185	225	240
4		240	235	220	250	280	280	185	225	240
5		180	190	190	300	230	--	--	215	230
6		--	--	--	260	240	--	370	340	380
7		--	--	--	--	--	--	260	205	220
8-2		--	--	--	--	--	--	--	660	620
9		--	--	--	--	--	--	370	300	340
10		--	--	--	300	--	--	440	250	270

readings were again observed in the spring and represent the effects of road de-icing operations.

Chlorides

Most chlorides found in natural water bodies originate from oceanic sources via the atmosphere or through man's activities such as road de-icing operations (Hem, 1975). Whitman's Pond being close to the oceanic shoreline probably receives some of its chloride input from the ocean.

Oligotrophic fresh waters exhibit a chloride level in the range of 1-10 mg/l while wastewater polluted bodies that have been chlorinated for sanitary purposes can express levels between 10-100 mg/l (Faust, 1981).

Whitman's Pond in-lake station chloride values ranged from 6 mg/l on June 25, 1980 at Station 1 (surface) to 76 mg/l on March 16, 1981 at Station 6 (Table 14). Inlet station values were within this range except on March 16, 1981, Station 8-2 where the observed value was 145 mg/l. Higher values noted in early spring could be due to road and sidewalk salting as discussed in the specific conductivity section. No consistent variation with depth was discernible from these data.

Stormwater sampling yielded chloride values ranging from 18-415 mg/l (Table 8). These data exceed those of the pond proper as do most of the other chemical parameters discussed. Since storm drain sampling was conducted only during February and March of 1981, it is reasonable to expect elevated chloride values due to the probability of road and sidewalk de-icing operations.

Tributary chloride results ranged from 17-140 mg/l and were within the range exhibited by the pond and inlet stations (Table 9).

Mean values were computed for the pond, storm drains and tributaries. Since the storm drain average (124 mg/l) and the tributary average value (52 mg/l) exceed the pond average value (36 mg/l), the major contributing source of chloride seems to be from road runoff via storm drains. This source may be detrimental should the amount significantly increase in the near future.

Nitrogen

Nitrogen is an essential element to plant metabolism which occasionally limits plant and algal growth. Sources to a lake include fixed nitrogen from the atmosphere, precipitation and inputs from surface and groundwater. Nitrogen occurs in freshwater in numerous forms: dissolved N_2; organic compounds; ammonia (NH_4); nitrite (NO_2); and nitrate (NO_3).

The nitrogen parameters used to assess Whitman's Pond include nitrate-nitrogen (Table 15), ammonia-nitrogen (Table 16) and total nitrogen (Table 17). Nitrate-nitrogen readings range from 0.0 mg/l in many instances to 2.9 mg/l on March 30, 1981 at Station 1 (2m). A seasonal variation exists with respect to nitrate concentrations, that is colder waters contain more nitrate than warmer waters. One reason for this variation is that metabolic processes during spring and summer deplete nitrate concentrations. Nitrate is removed from the water column by plant and algal metabolism, thus decreasing the concentration during the warmer months. Another reason may be that hypolimnetic anoxic conditions that occurred in the summer prohibited the nitrification

TABLE 14

WHITMAN'S POND

CHLORIDE (mg/1)

DATE OF COLLECTION		1980 14 Apr	30 Apr	12 May	22 May	11 Jun	25 Jun	7 Jul	21 Jul	4 Aug	19 Aug	2 Sept
STATION NUMBER	DEPTH											
1 - Top	(0.5 m)	--	26	25	--	25	6	28	35	31	30	31
	(2 m)	--	--	--	--	--	32	--	32	30	31	31
1 - Middle	(3-3.5 m)	--	--	27	--	25	32	29	32	31	31	32
	(4-5 m)	--	--	--	--	26	31	29	28	29	30	31
1 - Bottom	(5.5-6.5 m)	--	26	26	--	26	31	27	28	29	28	--
1A - Top	(0.5 m)	--	26	27	--	27	28	27	32	31	--	--
1A - Middle	(3-4 m)	--	26	--	--	--	31	28	31	--	--	--
1A - Bottom	(4.5-6.5 m)	--	26	27	--	27	29	27	29	31	--	--
2		--	26	27	--	27	30	28	31	32	32	32
3 Middle S. Cove		--	25	30	--	31	31	30	34	--	30	--
4 Swamp River		27	23	33	33	33	35	36	39	35	38	40
5 Wash ST		22	26	30	35	32	38	29	31	36	30	32
6		37	36	37	38	38	32	42	48	39	42	49
7		26	25	27	30	28	33	30	34	--	--	--
8-2		--	--	--	--	--	--	--	--	--	--	--
9		37	19	35	37	--	--	29	--	--	--	32
10		25	19	29	31	31	--	51	--	--	--	--

TABLE 14 (CONTINUED)

DATE OF COLLECTION		1980					1981			
STATION NUMBER	DEPTH	23 Sept	6 Oct	20 Oct	19 Nov	15 Dec	12 Jan	9 Feb	16 Mar	30 Mar
1 - Top	(0.5 m)	32	31	32	--	--	--	40	39	38
	(2 m)	32	33	32	--	--	--	34	36	38
1 - Middle	(3-3.5 m)	32	32	32	--	--	--	35	36	37
	(4-5 m)	32	32	32	--	--	--	37	36	39
1 - Bottom	(5.5-6.5 m)	32	32	31	--	--	--	42	35	37
1A - Top	(0.5 m)	--	--	--	--	--	--	--	--	--
1A - Middle	(3-4 m)	--	--	--	--	--	--	--	--	--
1A - Bottom	(4.5-6.5 m)	--	--	--	--	--	--	--	--	--
2		32	33	32	--	--	--	55	35	37
3		--	--	--	--	--	--	30	42	45
4		42	32	36	35	45	51	35	45	44
5		33	33	33	57	37	--	--	41	41
6		--	--	--	31	46	--	35	76	75
7		--	--	--	--	--	--	75	37	38
8-2		--	--	--	--	--	--	69	145	
9		--	--	--	--	--	--	38	51	46
10		--	--	--	59	--	--	79	44	44

of NH_4 (ammonia-nitrogen) to NO_3 (nitrate-nitrogen). Therefore, nitrate concentrations would decrease while ammonia concentrations would increase (Table 16) during the summer months in the hypolimnion.

Ammonia-nitrogen concentrations ranged from 0.0 mg/l on June 25, 1980 (Station 1 - surface and middle layer) to 0.97 mg/l on August 19, 1980 (Station 1 - 6.5m). Seasonal and spatial variations existed. These variations were that an increase of hypolimnetic ammonia-nitrogen occurred in the warmer months. This event can be attributed to a number of reasons, one was discussed earlier with respect to nitrate concentrations. Anoxic conditions also cause increased ammonia concentrations in the hypolimnion by 1) a release of NH_4 from the sediments as a result of the reduced adsorption capacity, and 2) an increase in NH_4 concentrations due to the decomposition process in which NH_4 is the primary end-product.

Total nitrogen values represent the sum of organic nitrogen, ammonia-nitrogen and nitrate-nitrogen. The organic nitrogen fraction of Whitman's Pond may thus be determined by simple mathematics. Whitman's Pond total nitrogen values range from 0.36 mg/l on August 19, 1980 to 6.4 mg/l on March 30, 1981. Total nitrogen values follow the seasonal variations of the other nitrogen parameters, that is higher values were observed in the colder months, with the exception of hypolimnetic values. This seasonal variation is partially attributed to the variations of the other two parameters as discussed earlier. Another reason may be that the organic fraction would be taken up during the spring and summer by metabolic processes and cause a decrease in total nitrogen values. The values observed in the colder months would contain more of the organic fraction thus increasing the total nitrogen values during those months.

Stormwater sampling included testing for total Kjeldahl nitrogen, ammonia-nitrogen and nitrate-nitrogen (Table 8). Total Kjeldahl values represent the sum of organic nitrogen and ammonia-nitrogen present in the sample. The total nitrogen value can thus be determined by combining the total Kjeldahl value with the nitrate-nitrogen value. The total nitrogen values of stormwater have been determined to range from 2.1 to 5.1 mg/l. This range falls within the total nitrogen value range exhibited by the pond proper.

Tributary surveys included testing for Kjeldahl nitrogen, ammonia-nitrogen and nitrate-nitrogen (Table 9). Total Kjeldahl values range from 0.18 mg/l on August 4, 1980 to 1.70 mg/l on April 27, 1981. The values appear to be a function of wet weather conditions, that is higher values are observed in the spring and lowest values were observed in the summer.

Ammonia-nitrogen values range from 0.01 mg/l to 1.60 mg/l. These values exceeded those of the pond ammonia-nitrogen values and may represent the high affinity of ammonia to particulate and colloidal particles which travel via tributaries and streams.

Nitrate-nitrogen values from the tributaries range from 0.0 mg/l to 3.1 mg/l. No seasonal variation was discernible from the data. Tributary nitrate-nitrogen values also exceed those of the pond proper.

TABLE 15

WHITMAN'S POND

NITRATE-NITROGEN (mg/1)

DATE OF COLLECTION		1980										
STATION NUMBER	DEPTH	14 Apr	30 Apr	12 May	22 May	11 Jun	25 Jun	7 Jul	21 Jul	4 Aug	19 Aug	2 Sept
1 - Top	(0.5 m)	--	0.4	0.3	--	0.2	0.0	0.0	0.0	0.0	0.1	0.1
	(2 m)	--	--	--	--	--	0.1	--	0.0	0.0	0.0	0.2
1 - Middle	(3-3.5 m)	--	--	0.3	--	0.2	0.0	0.0	0.1	0.0	0.0	0.1
	(4-5 m)	--	--	--	--	0.2	0.0	0.0	0.0	0.0	0.0	0.1
1 - Bottom	(5.5-6.5 m)	--	0.3	0.3	--	0.2	0.0	0.0	0.0	0.0	0.2	--
1A - Top	(0.5 m)	--	0.3	0.3	--	0.2	0.0	0.0	0.0	0.0	--	--
1A - Middle	(3-4 m)	--	0.3	--	--	--	0.0	0.1	0.0	--	--	--
1A - Bottom	(4.5-6 m)	--	0.3	0.3	--	0.2	0.0	0.0	0.0	0.0	--	--
2		--	0.3	0.3	--	0.3	0.0	0.0	0.0	0.1	0.0	0.0
3		--	0.3	0.3	--	0.2	0.0	0.0	0.0	--	0.0	--
4		0.4	0.3	0.4	0.4	0.6	0.6	0.4	0.2	0.3	0.2	0.0
5		0.4	0.3	0.3	0.2	0.2	0.0	0.1	0.1	0.2	0.0	0.2
6		0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.4	0.4
7		0.5	0.4	0.3	0.3	0.3	0.2	0.5	0.6	--	--	--
8-2		--	--	--	--	--	--	--	--	--	--	--
9		0.1	0.0	0.0	0.0	--	--	0.0	--	--	--	0.1
10		0.2	0.1	0.1	0.2	0.2	--	0.3	--	--	--	--

TABLE 15 (CONTINUED)

DATE OF COLLECTION		1980					1981			
STATION NUMBER	DEPTH	23 Sept	6 Oct	20 Oct	19 Nov	15 Dec	12 Jan	9 Feb	16 Mar	30 Mar
1 - Top	(0.5 m)	0.1	0.0	0.0	-	--	--	0.2	0.7	0.7
	(2 m)	0.0	--	0.0	--	--	--	0.1	0.7	2.9
1 - Middle	(3-3.5 m)	0.1	0.0	0.0	--	--	--	0.1	0.7	0.7
	(4-5 m)	0.0	0.0	0.0	--	--	--	0.2	0.7	0.6
1 - Bottom	(4.5-6.5 m)	0.0	0.0	0.0	--	--	--	0.2	0.7	0.7
1A - Top	(0.5 m)	--	--	--	--	--	--	--	--	--
1A - Middle	(3-4 m)	--	--	--	--	--	--	--	--	--
1A - Bottom	(4.5-6 m)	--	--	--	--	--	--	--	--	--
2		0.0	0.0	0.0	--	--	--	0.2	0.7	0.6
3		--	--	--	--	--	--	0.5	0.7	5.9
4		0.2	0.8	0.2	0.6	0.5	0.6	0.6	0.6	1.4
5		0.0	0.0	0.1	0.3	0.4	--	--	0.8	1.4
6		--	--	--	1.3	0.0	--	0.2	0.5	0.2
7		--	--	--	--	--	--	3.0	1.0	0.9
8-2		--	--	--	--	--	--	--	1.8	1.3
9		--	--	--	--	--	--	1.1	0.3	0.2
10		--	--	--	0.9	--	--	1.6	0.6	0.3

TABLE 16

WHITMAN'S POND

AMMONIA-NITROGEN (mg/l)

DATE OF COLLECTION		1980 14 Apr	30 Apr	12 May	22 May	11 Jun	25 Jun	7 Jul	21 Jul	4 Aug	19 Aug	2 Sept
STATION NUMBER	DEPTH											
1 - Top	(0.5 m)	--	0.04	0.02	--	0.03	0.00	0.06	0.05	0.02	0.07	0.05
	(2 m)	--	--	--	--	--	0.00	--	0.07	0.02	0.06	0.04
1 - Middle	(3-3.5 m)	--	--	0.02	--	0.04	0.00	0.06	0.08	0.07	0.07	0.11
	4-5 m)	--	--	--	--	0.04	0.00	0.12	0.31	0.26	0.26	0.13
1 - Bottom	(5.5-6.5 m)	--	0.05	0.03	--	0.15	0.34	0.32	0.64	0.79	0.97	--
1A - Top	(0.5 m)	--	0.04	0.03	--	0.03	0.00	0.06	0.05	0.03	--	--
1A - Middle	(3-4 m)	--	0.05	--	--	--	0.00	0.06	0.08	--	--	--
1A - Bottom	(4.5-6.5 m)	--	0.04	0.02	--	0.03	0.12	0.26	0.46	0.19	--	--
2		--	0.03	0.03	--	0.02	0.00	0.06	0.07	0.05	0.05	0.13
3		--	0.05	0.05	--	0.05	0.00	0.02	0.03	--	0.03	--
4		0.06	0.04	0.04	0.12	0.06	0.07	0.06	0.06	0.05	0.01	0.17
5		0.03	0.07	0.05	0.11	0.03	0.01	0.05	0.06	0.10	0.07	0.05
6		0.04	0.21	0.09	0.13	0.02	0.08	0.09	0.09	0.22	0.12	0.11
7		0.05	0.05	0.04	0.09	0.04	0.04	0.05	0.04	--	--	--
8-2		--	--	--	--	--	--	--	--	--	--	--
9		0.03	0.03	0.04	0.11	--	--	0.36	--	--	--	0.07
10		0.04	0.03	0.03	0.13	0.21	--	0.13	--	--	--	--

TABLE 16 (CONTINUED)

DATE OF COLLECTION		1980					1981			
STATION NUMBER	DEPTH	23 Sept	6 Oct	20 Oct	19 Nov	15 Dec	12 Jan	9 Feb	16 Mar	30 Mar
1 - Top	(0.5 m)	0.03	0.04	0.02	--	--	--	0.06	0.02	0.17
	(2 m)	0.04	0.03	0.02	--	--	--	0.07	0.01	0.17
1 - Middle	(3-3.5 m)	0.05	0.03	0.02	--	--	--	0.05	0.03	0.26
	(4-5 m)	0.06	0.03	0.04	--	--	--	0.08	0.02	0.04
1 - Bottom	(5.5-6.5 m)	0.07	0.02	0.04	--	--	--	0.16	0.02	0.08
1A - Top	(0.5 m)	--	--	--	--	--	--	--	--	--
1A - Middle	(3-4 m)	--	--	--	--	--	--	--	--	--
1A - Bottom	(4.5-6.5 m)	--	--	--	--	--	--	--	--	--
2		0.03	0.02	0.02	--	--	--	0.04	0.01	0.18
3		--	--	--	--	--	--	0.07	0.07	0.44
4		0.08	0.02	0.01	0.01	0.04	0.19	0.07	0.07	0.28
5		0.05	0.03	0.05	0.08	0.04	--	--	0.05	0.20
6		--	--	--	0.86	0.01	--	0.28	0.02	0.07
7		--	--	--	--	--	--	0.31	0.06	0.02
8-2		--	--	--	--	--	--	--	0.73	0.64
9		--	--	--	--	--	--	0.16	0.03	0.08
10		--	--	--	0.04	--	--	0.28	0.03	0.07

TABLE 17

WHITMAN'S POND

TOTAL NITROGEN (mg/l)

1980

DATE OF COLLECTION		14 Apr	30 Apr	12 May	22 May	11 Jun	25 Jun	7 Jul	21 Jul	4 Aug	19 Aug	2 Sept
STATION NUMBER	DEPTH											
1 - Top	(0.5 m)	--	1.21	1.17	--	0.58	0.88	0.76	0.80	0.70	0.49	0.57
	(2 m)	--	--	--	--	--	1.17	--	0.73	0.65	0.36	1.50
1 - Middle	(3-3.5)	--	--	0.84	--	0.68	0.68	0.56	0.84	0.38	0.38	0.99
	(4-5 m)	--	--	--	--	0.61	0.56	0.64	0.84	0.48	0.61	0.90
1 - Bottom	(5.5-6.5 m)	--	1.22	0.93	--	0.68	1.20	0.79	1.20	1.20	1.40	--
1A - Top	(0.5 m)	--	1.16	0.96	--	0.64	0.83	0.48	0.67	0.40	--	--
1A - Middle	(3-4 m)	--	1.13	--	--	--	0.99	0.82	0.64	--	--	--
1A - Bottom	(4.5-6.5)	--	1.17	1.05	--	0.67	1.30	0.77	1.18	0.51	--	--
2		--	1.13	0.82	--	0.72	1.30	0.45	0.76	0.65	0.38	0.74
3		--	1.17	1.00	--	0.86	0.89	0.68	0.64	--	0.40	--
4		1.10	1.15	0.94	0.95	1.17	1.45	1.00	0.87	0.67	0.36	0.64
5		1.27	1.11	1.00	0.75	0.66	0.98	0.85	0.86	0.75	0.41	0.91
6		1.08	1.50	0.78	0.80	0.57	1.20	1.10	1.16	1.20	1.18	1.50
7		1.44	1.17	0.93	0.72	0.81	0.95	1.17	1.23	--	--	--
8-2		--	--	--	--	--	--	--	--	--	--	--
9		0.98	1.00	0.59	0.88	--	--	3.40	--	--	--	1.50
10		1.10	1.10	1.06	0.83	0.86	--	1.19	--	--	--	--

TABLE 17 (CONTINUED)

DATE OF COLLECTION		1980 25 Sept	6 Oct	20 Oct	19 Nov	15 Dec	1981 12 Jan	9 Feb	16 Mar	30 Mar
STATION NUMBER	DEPTH									
1 - Top	(0.5 m)	0.63	0.79	0.86	--	--	--	1.13	1.17	1.37
	(2 m)	0.53	0.67	0.83	--	--	--	0.76	1.09	3.43
1 - Middle	(3-3.5 m)	0.72	0.90	0.55	--	--	--	0.93	1.13	1.23
	(4-5 m)	0.60	0.72	0.64	--	--	--	1.17	1.13	1.12
1 - Bottom	(5.5-6.5 m)	0.71	0.62	0.60	--	--	--	1.30	1.70	1.20
1A - Top	(0.5 m)	--	--	--	--	--	--	--	--	--
1A - Middle	(3-4 m)	--	--	--	--	--	--	--	--	--
1A - Bottom	(4.5-6.5 m)	--	--	--	--	--	--	--	--	--
2		0.76	0.73	0.73	--	--	--	0.78	1.37	1.11
3		--	--	--	--	--	--	1.38	1.10	6.40
4		0.71	1.41	0.70	1.35	1.02	1.14	1.70	1.03	1.80
5		0.61	0.92	0.77	0.72	1.22	--	--	1.34	1.96
6		--	--	--	2.23	0.59	--	1.50	0.99	0.93
7		--	--	--	--	--	--	4.20	1.45	1.49
8-2		--	--	--	--	--	--	--	2.80	2.40
9		--	--	--	--	--	--	2.20	0.83	0.76
10		--	--	--	1.34	--	--	1.42	1.05	0.86

Total nitrogen values can be determined for the tributaries by combining the total Kjeldahl value with the nitrate-nitrogen value. This computation yields a total nitrogen value range from 0.45-3.51 mg/l. This range falls within the range exhibited by the pond proper for total nitrogen values.

Iron and Manganese

Iron and manganese are important as micronutrients to the metabolism of freshwater flora and fauna. Rarely are they limiting to growth in lakes because supply usually exceeds demand. In contrast, high concentrations of manganese (>1.0 mg/l) are inhibitory to blue-green algae production. Iron is necessary for chlorophyll and protein synthesis while manganese is an essential catalyst of numerous enzyme systems.

Sources of iron and manganese can include bottom sediments, leachate from soils and rocks, and particulates. Within Whitman's Pond these elements are most likely absorbed to organic or inorganic matter within the biota of the pond.

The results of iron analysis conducted on Whitman's Pond are presented in Table 18. The results in the pond range from 0.02 - 4.60 mg/l. The highest values were recorded in the hypolimnion at Station 1 during the summer stratification under anoxic conditions. One reading of 12.0 mg/l was observed at Station 9 on July 7, 1980. High concentrations of iron may be as a result of bacterial action on the wetland and bog biota located upstream of Whitman's Pond. Massachusetts Division of Water Supply (1970) reports an iron concentration of 1.9 mg/l at one of the wells nearby Whitman's Pond. The manganese values range from 0.0-4.50 mg/l (Table 19). Again the highest concentrations were observed at the hypolimnion where anoxic conditions would allow the release of manganous ions from the sediments (Wetzel, 1975). The inlet stations values were within the range of in-lake manganese values.

Tributary iron values range from 0.05-0.38 mg/l and were measured only in August and September of 1980 (Table 9). These values are lower than those observed within the pond and may reflect low flows that occurred at this time. The range of manganese values were also low (0.02-0.24 mg/l) with respect to in-lake concentrations and again were measured only during periods of low flow.

Stormwater values for manganese and iron are presented in Table 8. The range of manganese values falls within the range exhibited by the pond proper. Iron values range from 0.01-5.60 mg/l. The highest reading was observed from storm drain #49. Storm drain #49 is near inlet Station #9 which also exhibited a high iron concentration. As discussed earlier, these high values may be attributed to bacterial action on the nearby biota or as a result of leachate from soils and bedrock.

Total and Suspended Solids

Total and suspended solids data for Whitman's Pond are presented in Table 20. Total solids measurements represent the aggregate of suspended and dissolved solids. Most of the solids within Whitman's Pond are present as dissolved matter rather than suspended as evidenced in the data. Dissolved forms are typically composed of inorganic salts, small amounts of organic matter and dissolved gases (Sawyer, 1967).

TABLE 18

WHITMAN'S POND

IRON (mg/1)

DATE OF COLLECTION		1980					1981
		14 Apr	11 Jun	7 Jul	19 Aug	2 Sept	9 Feb
STATION NUMBER	DEPTH						
1 - Top	(0.5 m)	--	0.29	0.24	0.07	0.18	0.02
	(2 m)	--	--	--	0.07	0.18	0.05
1 - Middle	(3-3.5 m)	--	0.24	0.21	0.08	0.20	0.07
	(4-5 m)	--	0.23	0.19	0.28	0.40	0.06
1 - Bottom	(5.5-6.5 m)	--	0.34	1.60	4.60	--	0.10
1A - Top	(0.5 m)	--	0.22	0.25	--	--	--
1A - Middle	(4 m)	--	--	0.29	--	--	
1A - Bottom	(5.5-6.5 m)	--	0.29	0.94	--	--	--
2		--	0.26	0.25	0.12	0.30	0.06
3		--	0.95	0.91	0.25	0.20	
4		0.25	0.40	0.63	0.19	0.30	0.23
5		0.35	0.37	0.72	0.15	0.15	--
6		0.60	1.30	1.00	0.44	0.70	1.50
7		0.15	0.19	0.27	--	--	0.31
8-2		--	--	--	--	--	--
9		0.45	--	12.0	--	1.30	0.45
10		0.50	1.40	2.00	--	--	0.21

TABLE 19

WHITMAN'S POND

MANGANESE (mg/1)

DATE OF COLLECTION		1980				1981
		11 Jun	25 Jun	19 Aug	2 Sept	9 Feb
STATION NUMBER	DEPTH					
1 - Top	(0.5 m)	0.22	--	0.30	0.21	0.01
	(2 m)	--	0.02	0.28	0.21	0.00
1 - Middle	(3-3.5 m)	0.21	0.03	0.28	0.30	0.05
	(4.5-5 m)	0.22	1.00	2.40	0.92	0.12
1 - Bottom	(6 m)	1.00	2.00	4.50	--	0.34
1A - Top	(0.5 m)	0.22	0.04	--	--	--
1A - Middle	(4 m)	--	0.04	--	--	--
1A - Bottom	(5.5-6 m)	0.23	1.00	--	--	--
2		0.21	0.04	0.06	0.18	0.05
3		0.09	--	0.25	--	0.25
4		0.09	--	0.19	0.18	0.13
5		0.13	--	0.15	0.20	--
6		0.08	--	0.44	0.10	6.50
7		0.04	--	--	--	0.47
8-2		--	--	--	--	--
9		--	--	--	0.65	0.64
10		0.00	--	--	--	1.30

Within Whitman's Pond, total solids ranged from 96-202 mg/l and suspended solids ranged from 0.0-21.0 mg/l. No seasonal variation was evident from the data.

Tributary investigative surveys included an analysis of total and suspended solids. Total solids values ranged from 88-374 mg/l. Suspended solids values represent only a small percentage of the total values and ranged from 0-8 mg/l (Table 9).

Stormwater values ranged from 136-974 mg/l for total solids and 1-574 mg/l for suspended solids. These results indicate that a significant amount of the suspended solids may enter the pond via the storm drains. Suspended solids that settle in the pond may be detrimental. That is, they can block gravel spawning beds and, if organic, remove dissolved oxygen from overlying waters (U.S.EPA, 1976).

Sediment Analysis

The sediment analysis for Whitman's Pond is presented in Table 21. Included in this table for comparison is an average value from lakes previously studied by the Massachusetts Division of Water Pollution Control. This average value was determined from lakes that represent a wide range of sediment conditions. Stations 1 and 2 of the main basin and Station 3 in the southern basin were sampled on February 8, 1981.

As evidenced from the table, copper values at Whitman's are somewhat less than the average while chromium, lead and nickel values are elevated over the average value. The iron foundry that once existed near Whitman's Pond may account for the high concentrations of heavy metals within the sediments.

Total Kjeldahl-nitrogen and total phosphorous levels are high with respect to the other parameters and are probably as a result of organic decomposition from decayed plant and animal matter. Iron levels are also high and can be attributed to the resource of iron within the surrounding bogs and from soil leachate.

Storm Event Analysis

During the course of this study, storm events were sampled to estimate their effect on water quality. Two events, February 11, 1981 and March 16, 1981 were sampled and incorporated into the results (Table 8). Data from an event that occurred after the study period (July 21, 1981) are available in Table 22.

The storm drain results from the study period indicate that the storm drains could contribute significant amounts of nutrients into the pond. Especially high levels of bacteria are a public health concern and excess phosphorous and nitrogen levels can promote algae and aquatic vegetation growth.

The July 21, 1981 sampling depicts runoff conditions during warm weather conditions rather than those of winter storms as discussed earlier.

TABLE 20

WHITMAN'S POND

SUSPENDED SOLIDS/TOTAL SOLIDS (mg/1)

1980

DATE OF COLLECTION		14 Apr	30 Apr	11 Jun	25 Jun	7 Jul	21 Jul	4 Aug	19 Aug	2 Sept
STATION NUMBER	DEPTH									
1 - Top	(0.5 m)	--	1.0/116	0.5/108	1.0	3.0	1.5	2.0	14.0/108	2.0/110
	(2 m)	--	--	--	--	--	5.0	1.5	2.0/102	2.0/104
1 - Middle	(3-3.5 m)	--	--	1.0/110	--	1.0	2.0	--	3.0/106	1.0/106
	(4-5 m)	--	--	1.5/106	--	4.5	2.5	2.5	4.0/110	2.0/106
1 - Bottom	(5.5-6.5 m)	--	2.5/116	1.5/104	--	4.0	2.0	2.0	5.0/130	--
1A - Top	(0.5 m)	--	1.5/114	1.0/110	--	1.6	1.5	2.5	--	--
1A - Middle	(3-3.5 m)	--	1.0/116	--	--	2.5	3.0	--	--	--
1A - Bottom	(4.5-6.5)	--	2.5/120	1.5/112	--	3.5	2.5	1.5	--	--
2		--	0.0/110	1.0/110	--	3.5	3.5	2.0	1.0/106	2.5/106
3		--	1.0/120	0.0/124	5.0	--	1.0	--	2.0/112	--
4		3.0/104	0.5/110	0.5/126	2.0	--	2.0	--	1.0/140	0.5/138
5		3.5/96	2.5/122	1.5/112	1.5	--	4.0	0.0	2.5/110	0.5/116
6		4.0/124	5.0/160	4.5/146	3.0	--	0.0	--	8.0/164	3.5/202
7		1.0/100	1.0/116	2.0/108	0.5	--	1.0	--	--	--
8-2		--	--	--	--	--	--	--	--	--
9		0.5/112	0.0/122	--	--	--	--	--	--	--
10		1.5/100	2.0/108	2.0/138	--	--	--	--	--	21.0/168

Only one number indicates suspended solids value

TABLE 20 (CONTINUED)

DATE OF COLLECTION		1980				1981			
STATION NUMBER	DEPTH	6 Oct	20 Oct	19 Nov	15 Dec	12 Jan	9 Feb	16 Mar	30 Mar
1 - Top	(0.5 m)	0.5	1.0	--	--	--	2.0	3.0	3.0
	(2 m)	1.0	0.5	--	--	--	3.0	1.0	2.0
1 - Middle	(3-3.5 m)	1.5	0.0	--	--	--	1.0	1.0	3.0
	(4-5 m)	0.5	0.0	--	--	--	4.0	2.0	2.0
1 - Bottom	(5.5-6.5 m)	1.0	0.0	--	--	--	4.0	1.0	1.0
1A - Top	(0.5 m)	--	--	--	--	--	--	--	--
1A - Middle	(3-3.5 m)	--	--	--	--	--	--	--	--
1A - Bottom	(4.5-6.5)	--	--	--	--	--	--	--	--
2		0.5	0.0	--	--	--	3.0	1.0	3.0
3		--	--	--	--	--	3.0	2.0	1.0
4		0.5	0.0	0.0	0.0	1.0	6.0	1.0	0.0
5		0.5	0.0	0.0	7.0	--	--	1.0	4.0
6		--	--	0.0	4.0	--	8.0	2.0	7.0
7		--	--	--	--	--	3.0	1.0	3.0
8-2		--	--	--	--	--	--	6.0	12.0
9		--	--	--	--	--	4.0	4.0	9.0
10		--	--	1.0	--	--	0.0	1.0	1.0

Only one number indicates suspended solids value

TABLE 21

WHITMAN'S POND

SEDIMENT ANALYSIS (mg/kg dry wgt.)

South Cove

8 February 1981

STATION NUMBER:	1	2	3	AVERAGE*
PARAMETER				
Total Kjeldahl-Nitrogen	8,400	9,400	6,550	7,100
Total Phosphorus	2,000	1,475	1,400	1,300
Arsenic	13	17	9.2	16
Cadmium	3.7	5.5	3.7	--
Chromium	75	94	73	43
Copper	73	111	123	137
Iron	31,000	32,200	18,300	24,600
Lead	475	442	311	249
Manganese	913	2,760	568	624
Nickel	201	221	167	76
Zinc	438	700	293	285

*Average values from surveys conducted by the Massachusetts Division of Water Pollution Control on the following lakes and ponds: Attitash, Indian, Pearl, Upper Mystic, Pontoosuc, Waushacum, Mattawa, Quinsigamond, White Island, Boon, Fort, Eagle, Winthrop, Norton, Red Bridge, Wyman and East Lake Waushacum.

Changes in these data (lower chloride and conductivity values) can possibly be attributed to road de-icing operations conducted in the winter. Bacteria levels were higher in the warmer sampling period while total and suspended solids values were higher in the winter. Other parameters (pH, total Kjeldahl-nitrogen, phosphorous) were comparable.

BIOLOGICAL DATA

Bacteriological

Bacteriological analyses from Whitman's Pond are presented in Table 23. Total and fecal coliform bacteria were the standard parameters measured. Fecal streptococcus was analyzed as an indicator of recent fecal pollution from warm blooded animals. A fecal coliform to fecal streptococcus ratio (FC/FS) greater than 4.0 usually indicates that the pollution is human in origin (Gunner and Rho, 1977).

Generally the bacteria counts within the pond were low. Seasonal trends were evident; higher total bacteria counts occurred more often in spring and summer than in the winter months. There was a contamination problem on April 30 and June 11, 1980 when FC/FS ratios exceeded 4.0 at stations 3 through 9, which may be attributed to wet weather conditions.

Stormwater sampling results presented in Table 8 include total coliform, fecal coliform and fecal streptococcus. Stormwater contamination may include rubbish, litter and bacteria adsorbed onto soil particles as well as fecal matter. Stormwater bacteria values exceeded those values found within the pond. The FC/FS ratio was calculated and determined to be less than 4.0.

Storm drains #33 and #42 appear to contribute the most significant amounts of bacteria. High total coliform bacteria in conjunction with high fecal coliform bacteria counts indicate the probability of septage or sewage contamination. Both drains #33 and #42 originate from highly urbanized areas and indicate the possibility of failing subsurface septic systems.

Tributary data are presented in Table 9. Total coliform bacteria values exceeded those found in the pond, especially during the summer sampling. Total coliform bacteria may have originated from a variety of sources including soils. High total coliform counts and relatively low fecal counts indicate that soils are the primary source of bacteria within the tributaries (Hem, 1975).

Phytoplankton and chlorophyll a

Chlorophyll a data from Whitman's Pond are presented in Table 24 . The concentrations ranged from 1.66-27.07 mg/m^3. The maximum depth station ranged from 1.66-13.58 mg/m^3. The highest concentration of chlorophyll a (27.07 mg/m^3) was recorded on June 11, 1980 at Station 3 and high concentrations continued thru June 25, 1980. These conditions followed a similar increase in total phosphorous (Table 12) concentrations which may have stimulated bloom conditions.

TABLE 22

WHITMAN'S POND

STORM EVENT - 7/21/81

WATER QUALITY DATA (mg/1)

DRAIN NUMBER:	15	16	19	20	29	30	36
PARAMETER							
pH (Standard Units)	5.0	4.2	5.8	3.6	6.0	6.0	4.9
Total Alkalinity	1.	--	4	--	5	5	2
Specific Conductance(umhos/cm)	70	30	48	88	54	90	72
Suspended Solids	14	53	20	52	32	15	17
Hardness	19	8	15	20	13	15	17
Total Solids	100	76	78	130	102	108	114
Iron	0.40	0.19	0.15	0.95	0.46	1.1	.20
Manganese	0.2	0.1	0.08	0.36	0.18	0.45	0.20
Total Kjeldahl-Nitrogen	1.8	2.0	0.48	2.0	1.2	1.4	1.9
Ammonia-Nitrogen	0.70	0.38	0.15	0.68	0.21	0.82	0.69
Nitrate-Nitrogen	1.5	0.7	0.6	1.6	1.0	1.6	1.3
Total Phosphorus	0.35	0.45	0.22	0.28	0.22	0.15	0.40
Total Coliform/100ml	88,000	70,000	140,000	1,000	85,000	12,000	38,000
Fecal Coliform/100ml	20,000	12,300	15,000	400	8,700	1,400	4,100
Chloride	1	0	0	3	0	2	1
Fecal Streptococcus /100 ml.	1,200	4,000	600	200	2,300	200	900
Acidity	--	3	--	5	--	--	--

TABLE 22
WHITMAN'S POND
STORM EVENT - 7/21/81
WATER QUALITY DATA (mg/l)
(CONTINUED)

DRAIN NUMBER:	39	40	43	44	45	47	48
PARAMETER							
pH (Standard Units)	6.1	3.8	4.8	4.7	4.3	4.2	4.4
Total Alkalinity	6	--	2	2	1	1	1
Specific Conductance (υmhos/cm)	175	66	56	74	74	96	87
Suspended Solids	20	172	26	1.5	73	33	52
Hardness	46	18	12	22	19	17	25
Total Solids	178	256	84	86	130	126	150
Iron	0.23	2.7	0.65	0.26	1.1	1.0	1.3
Manganese	0.40	0.33	0.15	0.15	0.22	0.28	0.34
Total Kjeldahl-Nitrogen	1.4	1.6	1.3	0.62	1.9	1.6	1.5
Nitrate Nitrogen	0.68	0.61	0.59	0.46	0.69	0165	0.63
Nitrate-Nitrogen	5.6	1.5	1.2	1.6	1.3	1.5	1.6
Total Phosphorus	0.40	0.52	0.30	0.08	0.45	0.40	0.42
Total Coliform/100ml	240,000	45,000	6,600(3800)*	6,400	110,000	45,000	87,000
Fecal Coliform/100ml	30,000	1,000	300(400)*	1,100	3,100	200	2,200
Chloride	5	0	0	2	2	4	4
Fecal Streptococcus/100 ml.	6,000	1,600	100(500)*	900	800	50	200
Acidity	--	4	--	--	--	--	--

*Duplicate coliform samples taken

TABLE 23

WHITMAN'S POND

FECAL COLIFORM, FECAL STREPTOCOCCUS, TOTAL COLIFORM (#/100 ml)

1980

STATION NUMBER	DEPTH	14 Apr	30 Apr	12 May	22 May	11 Jun	25 Jun
1	Surface	--	5(<5)/30	<10/20 [2]	--	5(<5)/30	<5/10
1	Middle	--	--	--	--	--	--
1	Bottom	--	--	--	--	--	--
1A	Surface	--	--	5/70	--	5(5)/20	5/30
1A	Middle	--	--	--	--	--	--
1A	Bottom	--	--	--	--	--	--
2		--	50(<5)/80	5/100	--	5(<5)/10	<5/20
3		--	700(40)/1,300	15/60	--	10(<5)/40	5/10
4		50(40)/700 [1]	40(30)/200	100/1,600	160/1,200	120(10/)/600	180/700
5		<10(90)/200	120(40)/240	100/200	20/320	20(<5)/120	200/250
6		<10(80)/20	15(5)/80	100/200	70/520	70(<5)/1,000	<5/800
7		<10(60)/80	50(15)/90	10/110	300/3,400	300(<5)/1,500	80/160
8-2		--	--	--	--	--	--
9		<10(120)/40	60(5)/110	80/120	200/1,800	--	--
10		30(70)/120	150(40)/450	35/140	210/3,000	--	--

[1] Fecal coliform, fecal streptococcus, total coliform values indicated respectively.

[2] Two values indicate fecal coliform and total coliform values, respectively.

TABLE 23 (CONTINUED)

DATE OF COLLECTION		1980						
STATION NUMBER	DEPTH	7 Jul	21 Jul	4 Aug	19 Aug	2 Sept	23 Sept	6 Oct
1	Surface	5/25	20/40	15/60	<5/30	20(5)/20	30/40	110/200
1	Middle	--	--	--	--	--	--	--
1	Bottom	--	--	--	--	--	--	--
1A	Surface	5/10	--	10/00	--	--	--	--
1A	Middle	--	--	--	--	--		
							--	--
1A	Bottom	--	--	--	--	--	--	--
2		10/20	10/20	30/50	5/200	<5(<5)/40	50/220	120/300
3		10/20	<5/30	--	<5/20	--	--	--
4		150/450	50/680	150/1,800	60/500	50(40)/650	20/100	140/600
5		10/20	50/100	10/200	<5/100	10(<5)/100	50/80	320/500
6		120/400	20/120	1,500/20,000	10/300	30(10)/160	--	--
7		2,000/7,000	150/700	--	--	--	--	--
8-2		--	--	--	--	--	--	--
9		200/240	--	--	--	30(20)/1,000	--	--
10		600/1,300	--	--	--	--	--	--

TABLE 23 (CONTINUED)

DATE OF COLLECTION		1980 20 Oct	1980 19 Nov	1980 15 Dec	1981 12 Jan	1981 9 Feb	1981 16 Mar	1981 30 Mar
STATION NUMBER	DEPTH							
1	Surface	5/20	--	--	--	<10/<20	<5/10	10/20
1	Middle	--	--	--	--	--	--	--
1	Bottom	--	--	--	--	--	--	--
1A	Surface	--	--	--	--	--	--	--
1A	Middle	--	--	--	--	--	--	--
1A	Bottom	--	--	--	--	--	--	--
2		20/80	--	--	--	<10/<20	<5/<10	<5/5
3		--	--	--	--	--	<5/10	<5/5
4		10/340	60/580	10/180	<10/40	80/900	5/80	5/80
5		60/80	40/450	40/60	--	--	10/10	<5/10
6		--	5/230	40/140	--	60/100	5/10	300/360
7		--	--	--	--	4,000/18,000	5/150	85/1,500
8-2		--	--	--	--	--	<5/40	<5/5
9		--	--	--	--	50/520	<5/ 10	<5/5
10		--	90/350	--	--	40/380	<5/ 10	<5/10

Phytoplankton data are presented in Table 25. Results from the maximum depth station (#1) indicate seasonal variations, that is, dominant species were diatoms in May (Asterionella sp.) and a variety of flagellates during June. Green algae dominated in August and diatoms were predominant again during late October. Phytoplankton counts were highest in June, 1980 in conjunction with the high chlorophyll a concentrations discussed earlier.

Station #2 data reflects the same general types and concentrations of phytoplankton as were found at Station #1.

Station #3 exhibited high concentrations of the green alga , Spyrogyra in June which remained until late July. At other times during the study period, Station #3 reflected the same types and concentrations of phytoplankton as Station #1.

Station #5 was sampled and analyzed for phytoplankton once on June 25, 1980. The diatoms and green algae were dominant and reflect the same species that dominated the main and south basins at that time.

Aquatic Vegetation

An aquatic macrophyte survey and density analysis was originally conducted on Whitman's Pond on July 5, 1979. During the present study, the map was updated to denote changes in community structure. Density maps were also developed to describe the areal coverage and to semi-quantify the macrophytes (Fig. 13). Macrophytes are an important component of lake and pond ecosystems. They protect shores from wave erosion and can serve as soil stabilizers. They also provide a diverse food source for fish and wild fowl and a habitat for attached algae and other pond fauna.

Whitman's Pond identified macrophytes are presented in Figures 10, 11 and 12. Figure 10 represents the western basin in which Cabomba caroliniana covered the bottom of the pond. Nymphaea sp. and Pletandra virginica were also dense. The southern basin (Fig. 12) was also dense with Cabomba caroliniana and a variety of other macrophytes, The main basin of the pond (Fig. 11) had open water during the survey (Fig. 13) and was dominated by Potamogeton sp. which was restricted to the periphery of the pond.

Fish Populations

A survey conducted in 1905 by the Massachusetts Division of Fish and Game noted pickerel (Esox sp.) to be the most numerous followed by black bass (Micropterus dolomieui), yellow perch (Perca flavescens), white perch (Morone americana), horned pouts or catfish (Ictalurus punctatus) and herring (Alosa pseudoharengus).* At that time aquatic vegetation was scarce and a few lily pads were noted. Water quality was not noted. The pond was stocked through 1962 primarily with pan fish, pickerel, small mouth bass and yellow perch. In 1957, a partial poisoning with rotenone was used to estimate and sample the endemic population. The results indicated that a warm water population existed and that trout should be stocked every spring to stimulate fishing. Since 1966, 500 trout have been stocked annually by the Massachusetts Division of Fisheries and Wildlife.

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* Information furnished from the files of MDF & W, Field Headquarters, Westborough, Massachusetts.

TABLE 24

WHITMAN'S POND

CHLOROPHYLL a CONCENTRATIONS (mg/m^3)

STATION #	DATE	CHLOROPHYLL a (mg/m^3)
1	5/12/80	2.91
1	5/12/80	2.49
2	5/12/80	2.49
3	5/12/80	2.49
3	6/11/80	27.07
1	6/25/80	13.58
3	6/25/80	23.69
1	7/7/80	1.90
3	7/7/80	2.49
1	7/21/80	3.32
2	7/21/80	3.32
3	7/21/80	1.76
1	8/3/80	3.32
2	8/3/80	2.91
1	8/18/80	4.15
2	8/18/80	2.57
3	8/18/80	7.47
1	9/2/80	4.57
2	9/2/80	2.91
1	9/23/80	1.66
2	9/23/80	1.76
1	10/6/80	2.91
1	10/20/80	3.74
1	12/9/80	2.17

TABLE 25

WHITMAN'S POND

PHYTOPLANKTON (in cells/ml)

STATION #1

DATES:	1980 5/2	6/11	6/25	7/7	7/21	8/4	8/19	9/2	10/6	10/20	1981 2/9	3/16
Diatoms	1377	--	54	--	28	28	56	--	14	562	70	280
Blue-Green	--	--	56	--	--	28	--	--	--	--	--	--
Green	--	56	140	14	84	420	168	84	14	112	28	--
Flagellates	253	112	954	154	196	28	197	421	--	--	56	196
Total	1630	168	1234	168	308	504	421	505	28	674	154	476

STATION #2

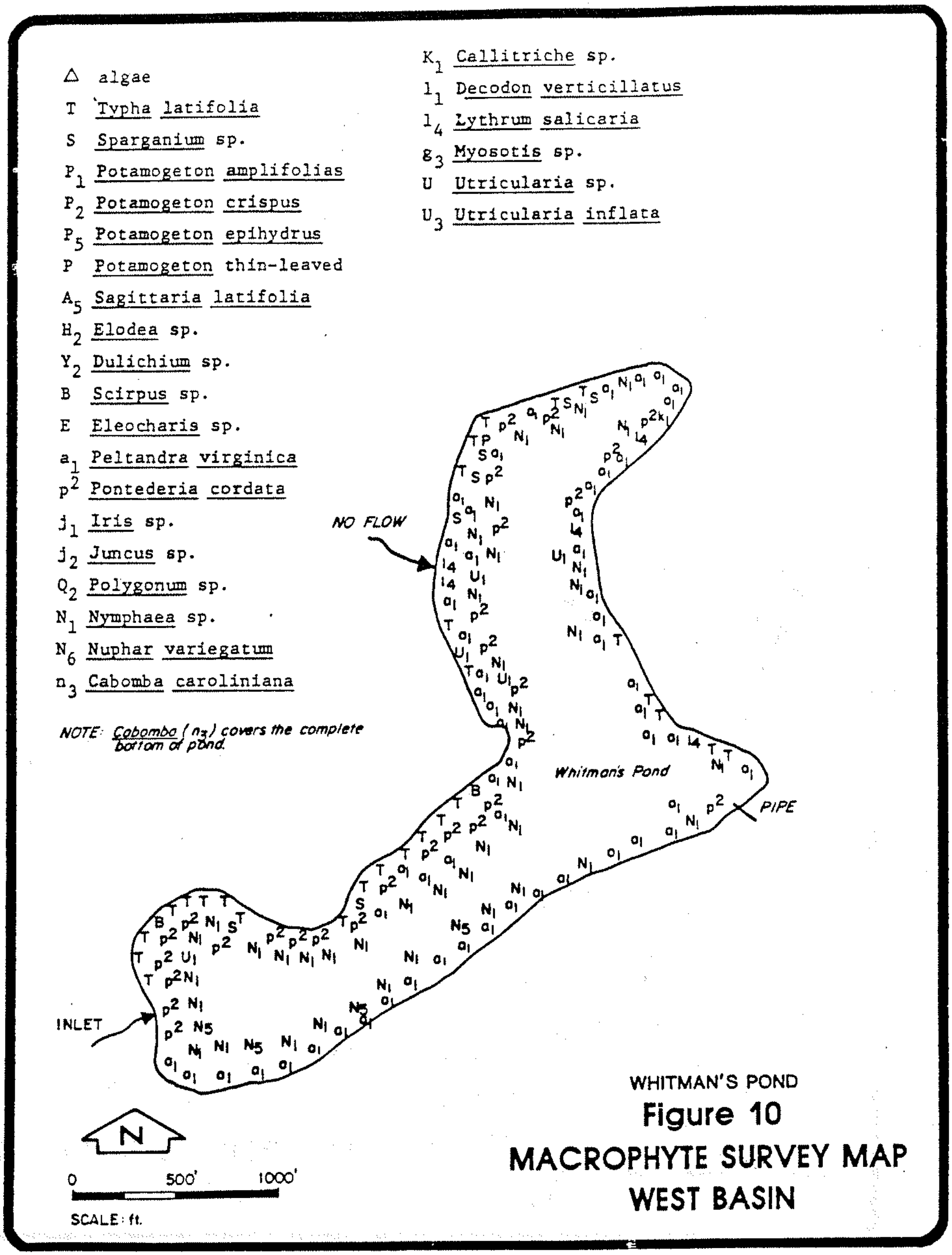
DATES:	1980 5/12	7/21	8/4	8/19	9/2
Diatoms	1293	28	0	0	0
Blue-Green	-	-	-	0	0
Green	0	1265	140	393	168
Flagellates	309	955	84	251	56
Total	[illegible]02	2248	224	674	224

STATION #3

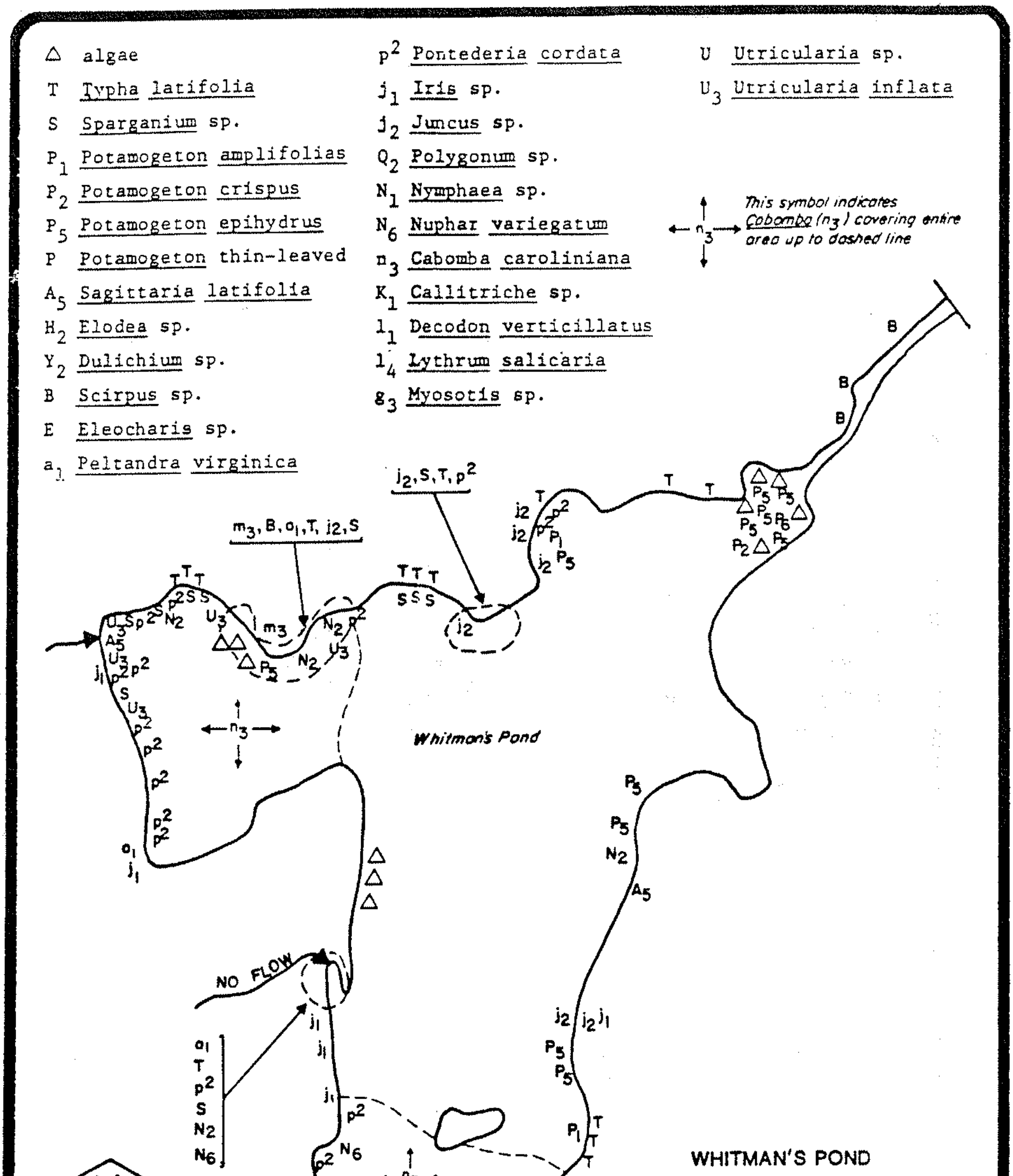
DATES:	1980 5/12	6/11	6/25	7/7	7/21	8/19	1981 3/16	3/30
Diatoms	140	140	899	154	56	140	28	533
Blue-Green	--	--	--	--	--	56	--	--
Green	--	1489	814	42	337	56	--	--
Flagellates	126	674	196	56	28	252	14	140
Total	266	2304	1910	252	421	504	42	673

STATION #5

DATES:	1980 6/25
Diatoms	1995
Blue-Green	646
Green	1264
Flagellates	505
Total	4410



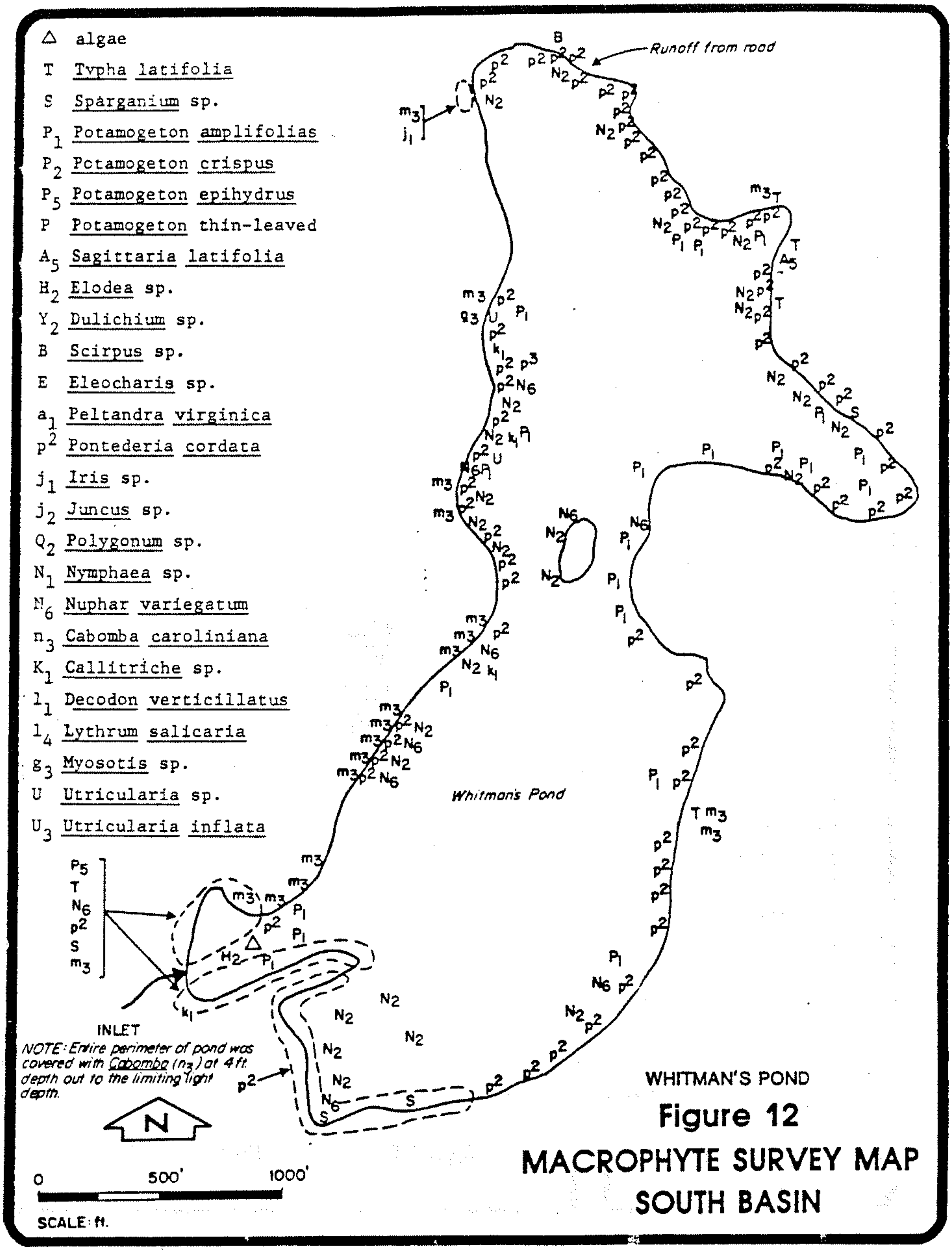
WHITMAN'S POND
Figure 10
MACROPHYTE SURVEY MAP
WEST BASIN



WHITMAN'S POND

Figure 11

MACROPHYTE SURVEY MAP MAIN BASIN

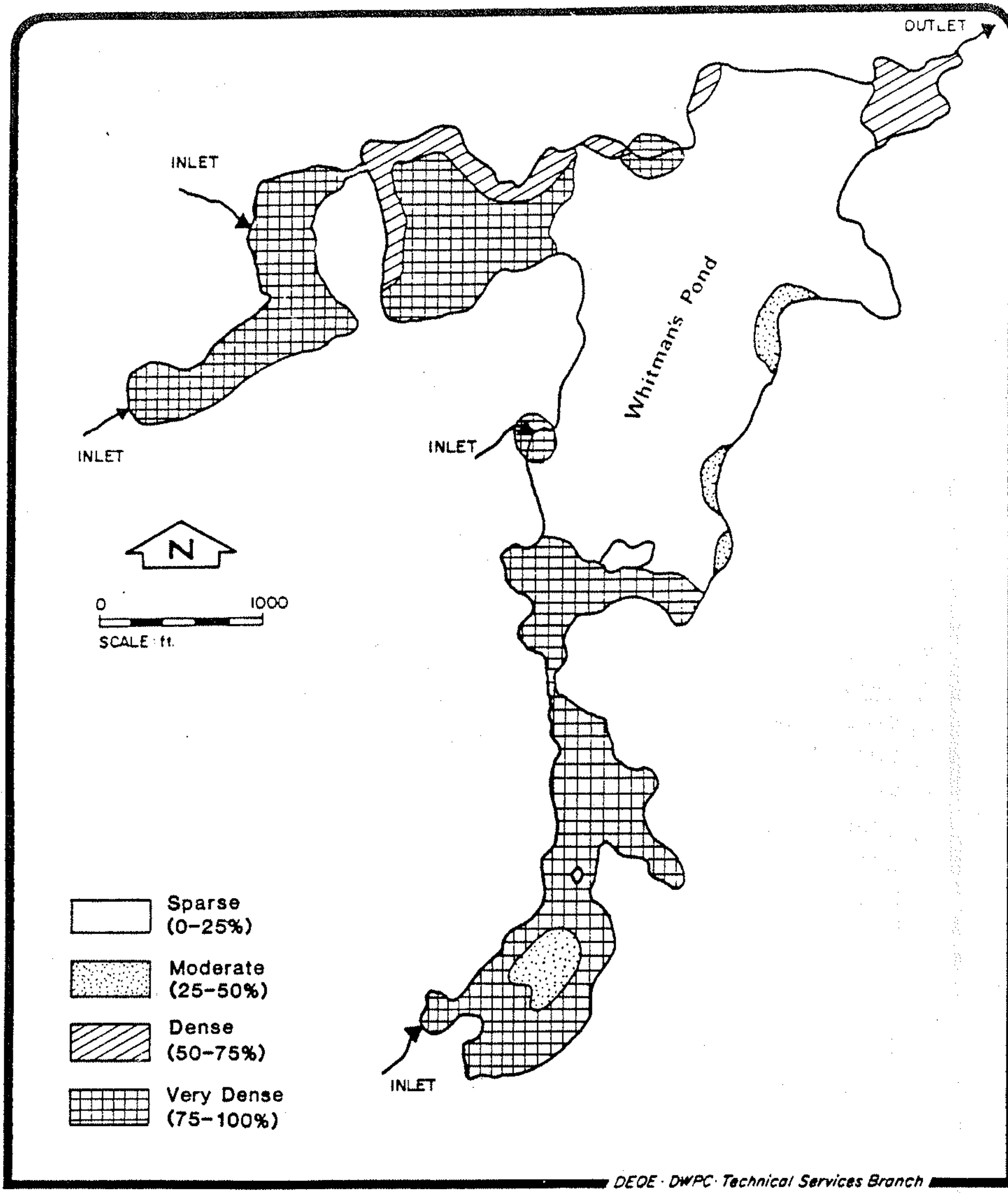


WHITMAN'S POND

Figure 12

MACROPHYTE SURVEY MAP

SOUTH BASIN



WHITMAN'S POND

Figure 13

MACROPHYTE DENSITY MAP

CONCLUSIONS

Watershed

1. The watershed contains 36.3% urban land use that ultimately drains into Whitman's Pond. Pollution sources originating from urbanized areas include stormwater runoff and surface runoff.

2. The perimeter of Whitman's Pond is densely populated with single family dwellings with approximately 70% of them sewered. Unsewered areas adjacent to the pond, particularly the hilly area east of the pond have experienced persistent problems with their subsurface septic systems.

3. The soils adjacent to Whitman's Pond have severe limitations for the construction of leaching fields. Poor drainage and bedrock close to the surface prevent effective nutrient removal. Management techniques to overcome the limitations such as sewering may be too expensive and expansion of the leach field area may not be possible.

4. A total of 45 storm drains ultimately discharge into Whitman's Pond. Effluent includes high levels of bacteria during the summer months that are a public health concern. Phosphorus levels in the storm water were also high in the spring due to wet weather conditions.

Pond

1. Whitman's Pond is a stratified, mesotrophic waterbody based on the Massachusetts Lake Classification Program. This system assigns severity points to lake parameters such as macrophyte density, transparency, hypolimnetic dissolved oxygen concentration, nutrient concentrations, and phytoplankton to determine the trophic status (Appendix D).

2. The pond is a soft water system with a pH range of 5.6-7.8 and a correspondingly low alkalinity range. The Massachusetts Division of Fisheries and Wildlife criteria for alkalinity indicates that the pond is effective in buffering the effects of acid deposition.

3. The pond is a valuable recreational resource in the town of Weymouth. The beach area was closed on one occasion in July, 1979 due to excessive coliform counts; the effluent from a proximate storm drain was a contributing factor.

4. The macrophyte density during the summer months causes clogging problems at the Washington Street pump station. Water is pumped to Great Pond from Whitman's to supplement the water supply source for the town.

RECOMMENDATIONS

The diagnostic study report contained herein represents only part of the complete diagnostic/feasibility study to develop a feasible cost-effective method to restore and preserve the water quality of Whitman's Pond. This report represents data collected from April 1980 - March 1981 and analyses of them. The diagnostic study indicates that the accelerated eutrophication of Whitman's Pond may be abated by the control of incoming nutrients from the watershed via storm drains and septic system leachate as well as the development of a public awareness program. The feasibility study has been completed by the consulting firm of Metcalf and Eddy, Inc. under contract with the Division and in conjunction with Section 314 of the Federal Water Pollution Control Act. The feasibility study will attempt to identify specific nutrient sources and to develop a recommended plan for the restoration of Whitman's Pond. In addition, the following tasks are to be addressed in the feasibility study:

1. Hydraulic budget based on discharges as measured by this Division, precipitation measurements and a survey of existing groundwater wells.

2. Nutrient budget as determined by the sampling program and the developed hydraulic budget.

3. An estimate of the impact of storm events on the existing water quality as determined by the diagnostic study.

4. An identification and discussion of the alternatives considered for pollution control and a justification of the selected alternative.

5. A discussion of the particular benefits expected to result from implementing the project.

In addition, the feasibility study will include a task by task cost breakdown of the recommended solution, a milestone work schedule and a discussion of the public participation. An environmental evaluation of the proposed plan will also be developed. It is necessary that the town of Weymouth support the proposed plan in order for the project to be successful.

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DESCRIPTION OF TERMS

The terms related to limnology and other limnological entities, as used in this report, are defined below to assist the reader in interpreting some of the data presented:

AREA of a lake refers to the size of the surface, exclusive of islands, measured in square units by planimetry.

AQUATIC PLANTS or aquatic macrophyton can be defined as those vascular plants which germinate and grow with at least their base in the water and are large enough to be seen with the naked eye. The following three broad categories are recognized:

1. Emergent types are those plants rooted at the bottom and projecting out of the water for part of their length. Examples: arrowhead (*Sagittaria* spp.), pickerelweed (*Pontederia* spp.)

2. Floating types are those which wholly or in part float on the surface of the water and usually do not project above it. Examples: water shield (*Brasenia* spp.), yellow water lily (*Nuphar* spp.)

3. Submerged types are those which are continuously submerged (except for possible floating or emergent inflorescences). Examples: bladderwort (*Utricularia* spp.), pondweed (*Potamogeton* spp.)

CLINOGRADE is a stratification curve of temperature or of a chemical substance in a lake that exhibits a uniform slope from the surface into deep water.

CULTURAL EUTROPHICATION refers to the enrichment or rapid increase in productivity of a body of water caused by man. It is an accelerated process as opposed to natural, slow aging of a body of water. Visual effects include nuisance algal blooms, low transparency, extensive aquatic plant growth, and loss of cold-water fisheries due to oxygen depletion. It is caused by the rapid increase in nutrient additions to a lake.

DEVELOPMENT OF SHORELINE is the degree of regularity or irregularity of a shoreline expressed as an index figure. It is the ratio of the length of the shoreline to the length of the circumference of a circle of an area equal to that of the lake. It cannot be less than unity. The quantity can be regarded as a measure of the potential effect of littoral processes on the lake.

DEVELOPMENT OF VOLUME is defined as the ratio of the volume of the lake to that of a cone of basal area equal to the lake's area and height equal to the maximum depth.

DIMICTIC LAKE is one with spring and fall turnovers (temperate lakes).

<u>DISSOLVED OXYGEN</u> (D.O.) refers to the uncombined oxygen in water which is available to aquatic life; D.O. is therefore the critical parameter for fish propagation. Numerous factors influence D.O., including organic wastes, bottom deposits, hydrologic characteristics, nutrients, and aquatic organisms. Saturation D.O., or the theoretical maximum value, is primarily a function of temperature. D.O. values in excess of saturation are usually the result of algal blooms and therefore indicate an upset in the ecological balance. Optimum D.O. values range from 6.0 mg/l (minimum allowable for cold water fisheries) to saturation values. The latter range from 14.6 mg/l at $0^{o}C$ ($32^{o}F$) to 6.6 mg/l at $40^{o}C$ ($104^{o}F$).

<u>EPILIMNION</u> refers to the circulating, superficial layer of a lake or pond lying above the metalimnion which does not usually exhibit thermal stratification.

<u>HETEROGRADE</u> is a stratification curve for temperature or a chemical substrate in a lake which exhibits a non-uniform slope from top to bottom. It can be positive (metalimnetic maximum) or negative (metalimnetic minimum).

<u>HYPOLIMNION</u> refers to the deep layer of a lake lying below the metalimnion and removed from surface influences (i.e., not circulating).

<u>LENTIC</u> refers to still or calm water, such as lakes or ponds.

<u>LOTIC</u> refers to moving water, such as rivers or streams.

<u>MAXIMUM DEPTH</u> is the maximum depth known for a lake.

<u>MAXIMUM EFFECTIVE LENGTH</u> is the length of a straight line connecting the most remote extremities of a lake along which wind and wave action occur without any kind of land interruption. It is often identical with maximum length.

<u>MAXIMUM EFFECTIVE WIDTH</u> is similar to maximum effective length but at right angles to it.

<u>MAXIMUM LENGTH</u> is the length of a line connecting the two most remote extremities of a lake. It represents the true open-water length and does not cross any land other than islands.

<u>MAXIMUM WIDTH</u> is the length of a straight line connecting the most remote transverse extremities over the water at right angles to the maximum length axis.

<u>MEAN DEPTH</u> is the volume of a lake divided by its surface area.

<u>MEAN DEPTH - MAXIMUM DEPTH RATIO</u> is the mean depth divided by the maximum depth. It serves as an index figure which indicates in general the character of the approach of basin shape to conical form.

<u>MEAN WIDTH</u> is the area of a lake divided by its maximum length.

METALIMNION is the layer of water in a lake between the epilimnion and the hypolimnion in which the temperature exhibits the greatest difference in a vertical direction.

MILLIGRAMS PER LITER (mg/l) is used to express concentrations in water chemistry because it allows simpler calculations than the English System. The basis of the metric system is the unit weight and volume of water at standard conditions ($20^{o}C$). At these conditions, one milliliter of water equals one cubic centimeter and weighs one gram. One milligram per liter is therefore essentially equal to one part per million by weight or volume.

NON-POINT SOURCE POLLUTION can be defined as any pollutant which reaches a water body by means other than through a pipe. Examples of non-point sources include leachate from dumps and agricultural runoff from dairy farms.

NUTRIENTS are basically organic compounds made up of carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur. Small amounts are vital to the ecological balance of a water body. Larger amounts can lead to an upset of the balance by allowing one type of organism, such as algae, to proliferate. The most significant nutrients in water bodies are those of carbon, nitrogen, and phosphorus. Nutrients of carbon are measured indirectly in the BOD test; separate tests are run to measure nutrients of nitrogen and phosphorus.

ORTHOGRADE is a stratification curve for temperature or a chemical substance in a lake which has a straight, uniform course.

pH is the measure of the hydrogen ion concentration of a solution on an inverse logarithmic scale ranging from 0 to 14. Values from 0 to 6.9 indicate acidic solutions, while values from 7.1 to 14 indicate alkaline solutions. A pH of 7.0 indicates a neutral solution. Natural streams usually show pH values between 6.5 and 7.5, although higher and lower values may be caused by natural conditions. Low pH values may result from the presence of heavy metals from acid mine drainage or metal-finishing waste. High pH values may result from detergents or photosynthetic activities of phytoplankton.

POINT SOURCE OF POLLUTION refers to continuous discharge of pollutants through a pipe or similar conduit. Primarily included are sewage and industrial waste, whether treated or untreated.

SESTON refers to all the particulate matter suspended in the water.

SHORELINE is the length of a lake's perimeter, measured from a map with a rotometer (map measurer).

SILICA (SiO_2) is necessary for diatom growth. The concentration of silica is often closely linked with the diatom population's growth. The limiting concentration is usually considered to be 0.5 mg/l.

THERMOCLINE is coincident with the metalimnion and relates to the lake zone with the greatest temperature change in a vertical direction.

VOLUME is determined by computing the volume of each horizontal stratum as limited by the several submerged contours on the bathymetric (hydrographic) map and taking the sum of the volumes of all such strata.

A NOTE ON LIMNOLOGY AND LAKE RESTORATION PROJECTS

Limnology is the study of inland fresh waters, especially lakes and ponds (lentic water vs. lotic water for streams and rivers). The science encompasses the geological, physical, chemical, and biological events that operate together in a lake basin and are dependent on each other (Hutchinson, 1957). It is the study of both biotic and abiotic features that make up a lake's ecosystem. As pointed out by Dillon (1974) and others before him, in order to understand lake conditions, one must realize that the entire watershed and not just the lake, or the lake and its shoreline, is the basic ecosystem. A very important factor, and one on which the life of the lake depends, is the gravitational movement of minerals from the watershed to the lake. Admittedly, the report contained herein concentrates mainly on the lake itself. Yet the foremost problem affecting the lakes and ponds today is accelerated cultural eutrophication, which originates in the watershed and is translated into various non-point sources of pollution. A great deal of lake restoration projects will have to focus on shoreland and lake watershed management.

Hynes (1974) sums up the science well in stating:

> ...The conclusions...are therefore that any interference with the normal condition of a lake or a stream is almost certain to have some adverse biological effect, even if, from an engineering point of view, the interference results in considerable improvement. At present it would seem that this is little realized and that often much unnecessary damage is done to river and lake communities simply because of ignorance. It is of course manifest that sometimes engineering or water-supply projects have over-riding importance and even if they have not, the question of balancing one interest against the other must often arise. But, regrettably, even the possibility of biological consequences is often ignored. It cannot be emphasized too strongly that when it is proposed to alter an aquatic environment the project should be considered from the biological as well as the engineering viewpoint. Only then can the full implications of the proposed alteration be assessed properly, and a reasonable decision be taken. Obviously this will vary with the circumstances and the relative importance of the various consequences involved, but, at present, unnecessary and sometimes costly mistakes are often made because the importance of biological study is unknown to many administrators. Often, as for instance in drainage operations, it would be possible to work out compromises which would satisfy both engineering and biological interests. [1]

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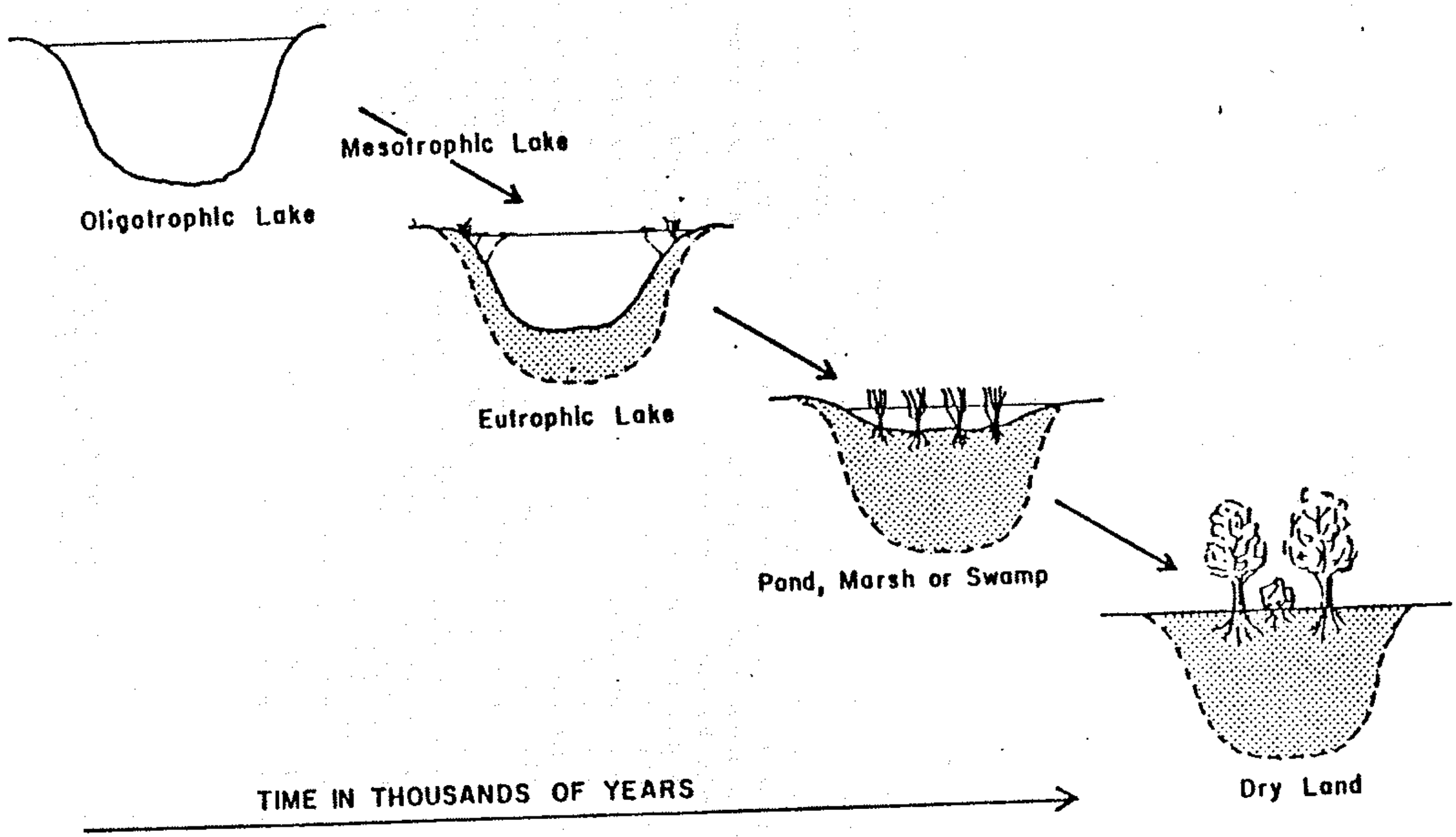
1 Hynes, H.B.N., 1974. The Biology of Polluted Waters. University of Toronto Press, Toronto, Ontario, Canada.



EUTROPHICATION – the process of aging by ecological succession.

Source: <u>Measures for the Restoration and Enhancement of Quality of Freshwater Lakes.</u> Washington, D.C.: United States Environmental Protection Agency, 1973.

FIGURE A

EUTROPHICATION

The term "eutrophic" means well-nourished; thus, "eutrophication" refers to natural or artificial addition of nutrients to bodies of water and to the effects of added nutrients (Eutrophication: Causes, Consequences and Correctives, 1969). The process of eutrophication is nothing new or invented by man. It is the process whereby a lake ages and eventually disappears. An undisturbed lake will slowly undergo a natural succession of stages, the end product usually being a bog and, finally, dry land (see Figure A). These stages can be identified by measuring various physical, chemical, and biological aspects of the lake's ecosystem. Man can and often does affect the rate of eutrophication. From a pollutional point of view, these effects are caused by increased population, industrial growth, agricultural practices, watershed development, recreational use of land and waters, and other forms of watershed exploitation.

It might also be mentioned that some forms of water pollution are natural. Streams and ponds located in densely wooded regions may experience such heavy leaf fall as to cause asphyxiation of some organisms. Discoloration of many waters in Massachusetts is caused by purely natural processes. As pointed out by Hynes (1974), it is extremely difficult to define just what is meant by "natural waters," which is not necessarily synonomous with "clean waters."

For restorative or preservative purposes of a lake and its watershed, it is important to identify both a lake's problem and the cause of the problem. Problems associated with eutrophication include nuisance algal blooms (especially blue-green algae), excessive aquatic plant growth, low dissolved oxygen content, degradation of sport fisheries, low transparency, mucky bottoms, changes in species type and diversity, and others. The pollutional cause is identified as either point or non-point in origin. A point source of pollution may be an inlet to the lake carrying some waste discharge from upstream. Or it may be an industrial, agricultural, or domestic (e.g., washing machine pipe) waste discharge which can be easily identified, quantified, and evaluated.

Non-point sources of pollution, which are the more common type affecting a lake, are more difficult to identify. They include agricultural runoff, urban runoff, fertilizers, septic or cesspool leakage, land clearing, and many more. They are often difficult to quantify, and thus evaluate.

An objective of a lake survey is to measure a lake's trophic state; that is, to describe the point at which the lake is in the aging process. The measure most widely used is a lake's productivity. Technically, this involves finding out the amount of carbon fixed per meter per day by the primary producers. Since it is a rather involved procedure to determine the energy flow through a lake system, the lake survey attempts to indirectly describe the lake's trophic state or level of biological productivity.

During the process of eutrophication, a lake passes through three major broad stages of succession: oligotrophy, mesotrophy, and eutrophy. Each stage has its characteristics (Table I). Data from a lake survey can be analyzed for assessment of the lake's trophic state. Although the level of productivity is

LAKE TROPHIC CHARACTERISTICS

1. Oligotrophic Lakes

   a. Very deep, thermocline high; volume of hypolimnion large; water of hypolimnion cold.

   b. Organic materials on bottom and in suspension very low.

   c. Electrolytes low or variable; calcium, phosphorus, and nitrogen relatively poor; humic materials very low or absent.

   d. Dissolved oxygen content high at all depths and throughout year.

   e. Larger aquatic plants scarce.

   f. Plankton quantitatively restricted; species many; algal blooms rare; Chlorophyceae dominant.

   g. Profundal fauna relatively rich in species and quantity; *Tanytarsus* type; *Corethra* usually absent.

   h. Deep-dwelling, cold-water fishes (salmon, cisco, trout) common to abundant.

   i. Succession into eutrophic type.

2. Eutrophic Lakes

   a. Relatively shallow; deep, cold water minimal or absent.

   b. Organic materials on bottom and in suspension abundant.

   c. Electrolytes variable, often high; calcium, phosphorus, and nitrogen abundant; humic materials slight.

   d. Dissolved oxygen in deep stratified lakes of this type minimal or absent in hypolimnion.

   e. Larger aquatic plants abundant.

   f. Plankton quantitatively abundant; quality variable; water blooms common, Myxophyceae and diatoms predominant.

   g. Profundal fauna, in deeper stratified lakes of this type; poor in species and quantity in hypolimnion; *Chironomus* type; *Corethra* present.

h. Deep-dwelling, cold water-fishes usually absent; suitable for perch, pike, bass, and other warm-water fishes.

i. Succession into pond, swamp, or marsh.

3. Dystrophic Lakes

a. Usually shallow; temperature variable; in bog surroundings or in old mountains.

b. Organic materials in bottom and in suspension abundant.

c. Electrolytes low; calcium, phosphorus, and nitrogen very scanty; humic materials abundant.

d. Dissolved oxygen almost or entirely absent in deeper water.

e. Larger aquatic plants scanty.

f. Plankton variable; commonly low in species and quantity; Myxophyceae may be very rich quantitively.

g. Profundal macrofauna poor to absent; all bottom deposits with very scant fauna; Chironomus sometimes present; Corethra present.

h. Deep-dwelling, cold-water fishes always absent in advanced dystrophic lakes; sometimes devoid of fish fauna; when present, fish production usually poor.

i. Succession into peat bog.

Source: Welch, P.S., Limnology, McGraw Hill Book Co., New York, 1952. (Reprinted with permission of the publisher.)

not quantified, the physical, chemical, and biological parameters measured go a long way in positioning the lake as to its trophic status. The perimeter survey helps locate and identify sources of pollution. It should be noted, however, that at the present time, there is no single determination that is a universal measure of eutrophication.

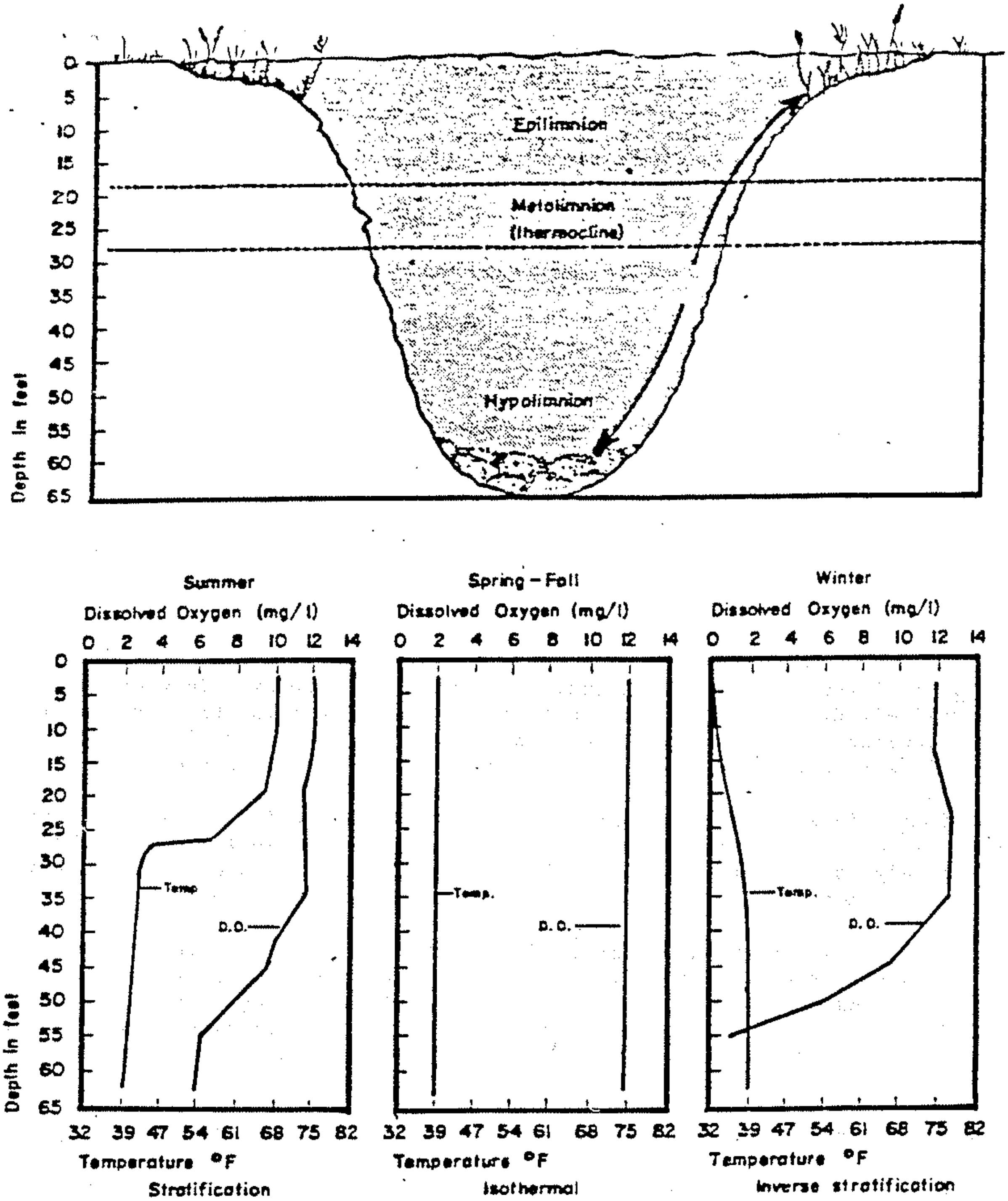
Figure B shows the various zones of a typical stratified lake. In addition to the lake's life history mentioned above, a lake also has characteristic annual cycles. Depending on the season, a lake has a particular temperature and dissolved oxygen profile (Figure B). During the summer season, the epilimnion, or warm surface water, occupies the top zone. Below this is the metalimnion, which is characterized by a thermocline. In a stratified lake, this is the zone of rapid temperature change with depth. The bottom waters, or hypolimnion, contain colder water. The epilimnion is well mixed by wind action, whereas the hypolimnion does not normally circulate. During the spring and fall seasons, these regions break down due to temperature change and the whole lake circulates as one body. In shallow lakes (i.e., 10 to 15 feet maximum depth) affected by wind action, these zones do not exist except for short periods during calm weather.

The summer season (July and August) is the best time to survey a lake in order to measure its trophic status. This is the time when productivity and biomass are at their highest and when their direct or indirect effects can best be measured and observed. The oxygen concentration in the hypolimnion is an important characteristic for a lake. A high level of productivity in the surface waters usually results in low oxygen concentrations in the lake's bottom. Low oxygen in the hypolimnion can adversely affect the life in the lake, especially the cold-water fish which require a certain oxygen concentration. Organic material brought in via an inlet can also cause an oxygen deficit in the hypolimnion. Hutchinson (1957) has amply stressed the importance of dissolved oxygen in a lake.

> A skilled limnologist can probably learn more about the nature of a lake from a series of oxygen determinations than from any other kind of chemical data. If the oxygen determinations are accompanied by observations on secchi disc transparency, lake color, and some morphometric data, a very great deal is known about the lake.

Nitrogen and phosphorus have assumed prominance in nearly every lake investigation in relating nutrients to productivity (eutrophication). Some investigators (Odum, 1959) use the maximum nitrogen and phosphorus concentrations found during the winter as the basis of nutrient productivity correlation due to the biological minimum caused by environmental conditions. Others use data following the spring overturn as a more reliable basis for nutrient productivity correlation. In any event, considerable caution must be used in transporting nutrient concentration limits found in other lakes to the present situation.

Diagrammatic sketch showing thermal characteristics of temperate lakes



Source: Measures for the Restoration and Enhancement of Quality of Freshwater Lakes. Washington, D.C.: United States Environmental Protection Agency, 1973.

FIGURE B

Appendix A

Soil Description

Augres: These soils occur in nearly level to gently sloping, poorly drained areas. It contains some pebbles and occupies the low-lying parts of outwash plains. A seasonal high water table is at or near the surface for 7-9 months each year. There are no sublayers that prevent water from moving rapidly downward but drainage can be improved if outlets are available.

Carver: These soils are excessively drained and occur in nearly level to steep slopes. They are one of the coarsest textured soils and occupy pitted and disected outwash plains. Water moves rapidly downward through the conduits underlying substratum. It does not retain enough moisture for plant growth and is extremely acid.

Deerfield: A moderately well drained soil that occurs on level to gently sloping areas. They occupy small low-lying parts of sandy outwash plains. If the water table is lowered, these soils are likely to be droughty because of their coarse texture and low organic matter content.

Hinkley: These soils are excessively drained and developed in deep deposits of sand and gravel, chiefly from granite and gneiss. They have a gravelly, loamy, sand surface and gravelly subsoil underlain by stratified sand and gravel. They occur on level to very steep slopes.

Hollis: These soils occur on gentle to very steep slopes. They are somewhat excessively drained and formed in thin deposits of glacial till from schistose and granitic materials. Also known as shallow of bedrock soils, the bedrock is usually within 2 feet of the surface but may be deeper in places.

Merrimac: These soils are excessively drained soils which usually possess sandy loam surface soil and subsoil. Both surface and subsoil layers have moderately rapid to rapid permeability. Underlying sand and gravel layers are rapidly permeable. They occur on nearly level to slight slopes.

Muck: These are very poorly drained bog soils formed in accumulation of organic deposits that are underlain by mineral soil characteristics. Surface layers of organic material generally are decomposed to such a degree that plants cannot be identified. This type occurs in depressions and potholes with a depth range at 0.5m to several meters. The water table is at near the surface most of the year.

Paxton: These soils occur in level to very steep slopes. They are well drained soils developed in stony, compact glacial till derived mostly from schist and gneiss. The surface is stony with a substratum of fine sandy loam. Hardpan at a depth of about 0.6m is slowly permeable.

Peat: Similar to muck, these soils are poorly drained bog soils underlain by mineral soil material. Plant remains can be identified by the unaided eye. They are mostly woody peat with some sphagnum peat areas. They also occur in depressions and potholes and depth can range from .03m to several feet of organic material. The water table is at or near the surface most of the year.

Plymouth: These soils consist of deep, excessively drained to moderately well drained soils in areas of wind-deposited sand from nearby coastal beaches. They are located on glacial uplands with a slope range of 3-25 percent. Reaction throughout the soil ranges from strong to extremely acidic.

Scarboro: These are poorly drained soils that have formed in deep deposits of sands and gravel derived mostly from granite, gneiss and quartz. They occupy depressions and lot flat areas that remain wet most of the year by a high water table. They have rapid permeability and are usually free of stones and boulders.

Scituate: On nearly level to gentle slopes, these soils are moderately well drained and formed in compact glacial till derived from granitic material. They occur in lower parts of ground moraines. At depths of 1 1/2 to 2 1/2 feet, a fragipan of compact sandy loam exits. Because of the fragipan, the soils are wet in early spring and remain wet until late spring. Their natural state is very stony.

Sudbury: These soils are well drained with a fine, sandy loam surface soil. The sandy loam subsoil is underlain by layers of sands and gravel at a depth of about 2 feet. A high water table is within 1.5-2.0 feet of the surface for 4-5 months of the year.

Wareham: Similar to Augres soils, they are poorly drained soils that occupy low-lying flat regions. They remain wet most of the year due to a high water table. Drainage can be improved if outlets are available.

Windsor: These soils occur on level to very steep slopes. They are excessively drained that have formed in deep sand deposits. They possess a loamy sand surface and subsoil and are commonly free of gravel to a depth of 1-2m. or more. These soils have rapid permeability and low moisture holding capacity. The water table is generally many feet below the surface.

Woodbridge: These soils occur on level to moderately steep slopes. They are moderately well drained soils that have developed in compact, stony, glacial till. They have a fine sandy loam surface soil and subsoil that have moderate to moderately rapid permeability. Underlaying the subsoil is slowly permeable hardpan. During the spring and fall, seepage water from adjacent land, or by a high water table, causes the soil to remain wet. During prolonged rainy periods, the water table is usually within 0.5-0.6m of the surface.

APPENDIX B

CHLOROPHYLL a

PROCEDURES

I. Reagents and apparatus

A. Flourometer

1. "Blue lamp" Turner No. 110-853
2. Excitation Filter: Corning CS-5-60, #5543, 2 in^2, 4.9 mm polished
3. Emission Filter: Corning CS-2-64, #2408 2 in^2, 3.0 mm polished
4. R-136 photo multiplier tube

B. Tissue grinder and tube

C. Vacuum flask and pump

D. Millipore filter holder

E. Glass fiber filters: Reeve Angel, grade 934AH, 2.1 cm.

F. Centrifuge (Fisher Scientific Safety Centrifuge)

G. 15 ml graduated conical end centrifuge tubes with rubber stoppers

H. 90% acetone

I. 1 N HCl (11.1 dilution of distilled water to conc. HCl)

J. Saturated Magnesium Carbonate solution in distilled H_2O

II. Procedure

A. Filter 50 ml (or less if necessary) of sample through glass fiber filter under vacuum

B. Push the filter to the bottom of tissue grinding tube

C. Add about 3 ml of 90% acetone and 0.2 ml of the $MgCO_3$ solution

D. Grind contents for 3 minutes

E. The contents of the grinding tube are carefully washed into a 15 ml graduated centrifuge tube

F. Q.S. to 10 ml with 90% acetone

G. Tubes are then centrifuged for 20 minutes and the supernatent decanted immediately into stoppered test tubes.

H. Test tubes are wrapped with aluminum foil and stored in the refrigerator for 24 hours.

Chlorophyll a
Page 2

I. The tubes are allowed to come to room temperature, the temperature recorded, the samples poured into cuvettes, and then the samples are read on the fluorometer. (The fluorometer must be warmed up for at least ½ hr. before taking a reading.)

J. 0.2 ml of the 1 N HCl solution is added to the sample in the cuvette, the cuvette stoppered and inverted and righted 4 times to mix thoroughly, and the sample is read again

K. Both values are recorded, along with the window orifice size and whether the high-sensitivity or the regular door was used

APPENDIX C

WHITMAN'S POND FLOW RECORD M^3/SEC (CFS)
APRIL 1980 - MARCH 1981

STATION / DATE	4		7		9		10	
14 April 1980	0.517	(18.46)	0.521	(18.62)	0.052	(1.86)	0.217	(7.77
30 April	0.769	(27.46)	0.424	(15.12)	0.058	(2.07)	0.391	(13.97
12 May	0.214	(7.64)	0.175	(6.24)	Unknown		0.068	(2.42
22 May	0.226	(8.06)	0.165	(5.90)	0.016	(0.58)	0.034	(1.20
11 June	0.117	(4.17)	0.063	(2.26)	No Flow		0.061	(2.17
25 June	0.048	(1.71)	0.014	(0.50)	"	"	No Flow	
7 July	0.050	(1.79)	0.0016	(0.057)	"	"	"	"
21 July	0.014	(0.486)	.00005	(0.002)	"	"	"	"
4 Aug.	0.059	(2.107)	No Flow		"	"	"	"
19 Aug.	0.015	(0.55)	"	"	"	"	"	"
2 Sept.	~ 0.010	(~0.36)	"	"	"	"	"	"
23 Sept.	0.0		"	"	"	"	"	"
6 Oct.	0.0		"	"	"	"	"	"
20 Oct.	0.024	(0.86)	"	"	"	"	"	"
19 Nov.	0.239	(8.54)	"	"	"	"	Slight	
15 Dec.	0.101	(3.61)	"	"	"	"	Slight	
12 Jan. 1981	0.062	(2.21)	"	"	"	"	No Flow	
9 Feb.	0.544	(19.43)	~ 0.004	(~0.14)	0.037	(1.33)	~ 0.010	(~.3
16 March	0.243	(8.68)	0.023	(0.82)	No Flow		0.070	(2.5
30 March	0.197	(7.04)	0.027	(0.98)	0.012	(0.44)	0.055	(2.0

APPENDIX D

LAKE CLASSIFICATION SYSTEM

The Division of Water Pollution Control has developed a lake classification system as an aid to setting priorities for the Lake Restoration Program (Section 314 of PL 95-217) in Massachusetts. This system is generally applied only to those lakes and ponds for which the Division has collected water quality data. Although a host of physical, chemical, and biological parameters are measured during the normal lake survey, only six critical parameters are employed in the lake classification priority system. The six parameters are hypolimnetic dissolved oxygen, secchi disc reading, phytoplankton count, total ammonia- and nitrate-nitrogen, total phosphorus, and aquatic macrophyton. The most recent survey data are used and the priority listing is updated annually. The optimum season for collecting lake data is mid to late summer, or during peak biological production. Unfortunately, this cannot always be achieved, thus spring or autumnal data have to be used in the lake classification system.

The limits used for awarding severity points for the six parameters have been based on several considerations and information sources. These include lake classifications of other states. the natural range of parameters in Massachusetts, limnological texts, and accepted indices of eutrophication reported in the literature. The severity point system has been formulated as follows:

PARAMETER	CONCENTRATION OR DEGREE OF SEVERITY	POINTS
Hypolimnetic dissolved oxygen	≥5.0 mg/l	0
	<5.0-3.0 mg/l	1
	<3.0-1.0 mg/l	2
	<1.0 mg/l	3
Transparency (secchi disc reading)	≥15 feet	0
	<15-10 feet	1
	<10-4 feet	2
	<4 feet*	3
Phytoplankton	0-500 ASU or natural cells/ml	0
	>500-1000 ASU or natural cells/ml	1
	>1000-1500 ASU or natural cells/ml	2
	>1500 ASU or summer "blooms"	3
Epilimnetic $NH_3 + NO_3$-N	0-<0.15 mg/l	0
	≥0.15-0.3 mg/l	1
	>0.3-0.5 mg/l	2
	>0.5 mg/l	3
Epilimnetic total phosphorus	0-0.01 mg/l	0
	>0.01-0.05 mg/l	1
	>0.05-0.10 mg/l	2
	>0.10 mg/l	3

* Four feet is the minimum allowable transparency at bathing beaches, as stated in Article VII of the State Sanitary Code.

PARAMETER	CONCENTRATION OR DEGREE OF SEVERITY	POINTS
Aquatic Vegetation	Sparse	0
	Medium	1
	Dense	2
	Very dense	3

\- It is expected that chlorophyll-a data will soon augment or replace the phytoplankton data as they become part of the routine lake survey. The severity points may be interpreted as follows:

0 = No problem. Considered to be representative of clean water quality.

1 = Slight problem; borderline case considered to be potentially degrading.

2 = Definite problem. Considered unacceptable for lake water quality.

3 = Severe problem, undoubtedly causing degradation of the lake's water quality or some recreational uses.

Lakes, ponds, and reservoirs are first divided into two major categories:

1. Those which stratify during the summer;
2. Those which do not stratify during the summer.

Next, severity points are assigned to each of the above critical parameters. On the basis of the severity point system, a priority listing can be maintained. This listing, in conjunction with other available data, can then be used for a trophic level classification system. On the basis of a possible 18 severity points, the trophic level index would be as follows:

0 - 6	oligotrophic
6 - 12	mesotrophic
12 - 18	eutrophic

The overlap of severity points is intentional and meant to underscore the system's flexibility. The general range of severity points is considered more important than the absolute total for a given lake.

Although the system is not 100% equitable, it does appear to give a fair representation of lake trophic conditions for the vast majority of Massachusetts' lakes. River impoundments below point waste discharges present special cases. Personal knowledge of these situations helps explain anomalies in the data. By its very nature, the system cannot be static but will be under constant reevaluation as new data become available.